Lecture Notes in Electrical Engineering 843

Reji Kumar Pillai
B. P. Singh
N. Murugesan *Editors*

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Contents

Legal Framework for Protection of Critical Information Infrastructure

Tarun Batra, Aamir Hussain Khan, and S. Samanta

Abstract Many utilities have adopted digital technologies to bring the required efficiency in their operations and meet the stakeholder requirements. As part of these digitization initiatives, the organizations have implemented multiple state of the art technologies which have helped them to improve and deliver quality services. Although implementation of latest technologies have brought numerous advantages to the utilities but it has also brought a unique challenge in the form of Cybersecurity. As power distribution utilities host nation's Critical Information Infrastructure, it becomes imperative for utilities to ensure all required measures are in place to protect them from any kind of misadventure from Cyber adversaries. In view of above, many utilities have implemented various controls covering all aspects of People, Process and Technology. But it seems that a gap still exists which is not covered by standard approach. A survey of recent cyber-attacks on CII has revealed that a lot of advance and modern utilities have been a successful target of such malicious campaigns. The reason for utilities to become victim of such campaigns seems to be due to lack of legal framework for protection of Critical Information Infrastructure. It is also required that accountability for protection of CII at multiple stages should be recognized along with stringent review mechanisms. This paper shall focus on approaches adopted by various cyber instruments to curb crimes and what strategy needs to be adopted by nations to protect CII from falling victim to malicious campaigns by cyber adversaries who are based out of different geopolitical location.

Keywords CII · SCADA · OT · IT · Physical security

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Abbreviations

ADMS	Advance Distribution Management system
CII	Critical Information Infrastructure
CPS	Cyber Physical System
CERT-In	Indian Computer Emergency Response Team
FRTU	Field Remote Terminal Unit
ICS	Industrial Control Systems
IT	Information Technology
NBA	Network Behaviour Analysis
NCIIPC	National Critical Information Infrastructure Protection Centre
OT	Operation Technology
OS	Operating System
PLC	Programmable Logic Controller
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
US-CERT	United States Computer Emergency Readiness
SPOC	Special Point of Contact
ERP	Enterprise Resource Planning
BCM	Business Communication Manager
CRM	Customer Relationship Manager
PI	Process Integration
GIS	Geographic Information System
SCADA	Supervisory Control and Data Acquisition
FFA	Field Force Automation
ESB	Enterprise Service Bus

1 Introduction

Power utilities have always played a major role in development of national economy. Over the years the utilities have followed a traditional model of supplying power to its consumers and have not shown interest in upgrading its infrastructure especially the digital one. Since the demand of power has increased multi-folds due to various technological advancements like mobile phones, electric vehicles etc. Also at the same time, consumers have also become more aware of power consumption details owing various energy efficiency initiatives, it has now become important for utilities to adopt a modern approach to upgrade its infrastructure to state of the art level. Due to this approach power utilities have implemented various technological solutions like:

- SAP-ERP
- SAP-BCM

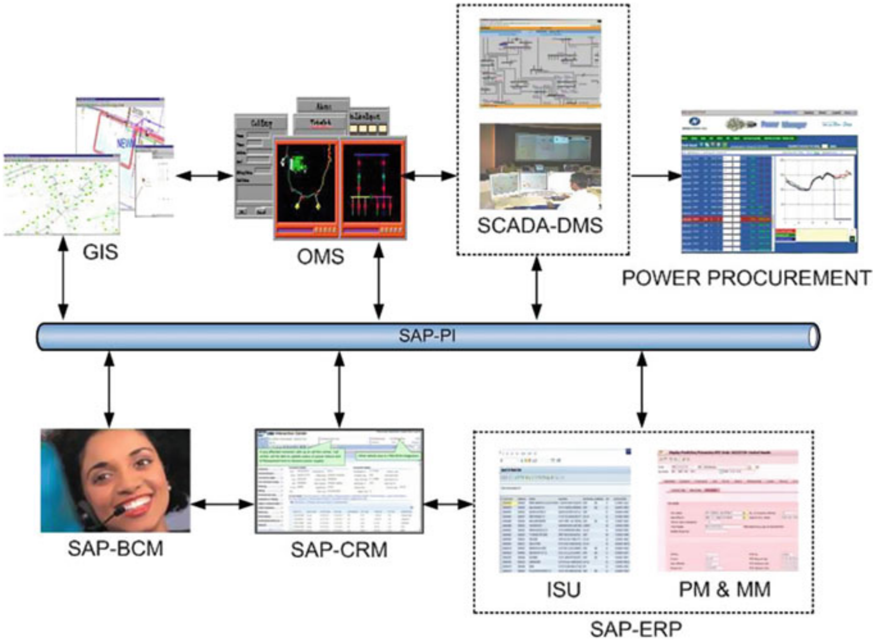

Fig. 1 Block level diagram of various systems in a CII

- SAP-CRM
- SAP-PI
- SCADA/ADMS
- AMI
- MDM
- FFA
- ESB
- Power Procurement Application.

These systems have enabled utilities to track consumption of power on near real time basis and also to meet the demands of its consumers. These systems work in an integrated fashion with the help of enterprise service bus and Common Information Model concept as shown in the architecture below (Fig. 1).

2 Challenges

Some of the challenges that operators of Critical Information Infrastructure face today are as mentioned below:

Table 1 Details of cyber attacks

Year of attack	Name of organization	Attack type
2013	New York City Dam	Google dorking technique
2014	European ICS Manufacturers	HAVEX malware
2015/2016/2017	Ukraine Power Grid	Black energy, industroyer and NotPetya malware
2018	Saudi Petrochemical Company	Triton malware
2018	US Power Grid	Grizzly steppe
May 20	UK Grid Balance Authority	Ransomware
Oct'20	Dr. Reddy Labs	Ransomware (phishing technique)
Nov'20	Lupin Pharmaceutical	Ransomware (phishing technique)
Dec'20	Solar Wind	Data compromised

- Power utilities are supplying electricity to various other critical infrastructure, hence incapacitation of its key systems may have debilitating impact on national economy, public health and security.
- Cyber physical components of IT and OT networks are now being exposed to public network which poses a major risk to critical infrastructure.
- Any failure to address cyber vulnerability in any of the component of critical infrastructure may create havoc in the entire network resulting in unavailability of system and services.
- Lack of understanding on applicable (sector-specific) Cyber Risks to Critical Information Infrastructure.
- Lack of cooperation and accountability among stakeholders involved in operation of Critical Information Infrastructure.

3 Analysis of Cyber Attacks

In order to further understand the magnitude of challenge and complexity faced by operators of CII, we tried to create a table of cyber-attacks which has happened over the last few years (Table 1).

4 Possible Cause of Such Attacks

See Table 2.

State Sponsored:

See Fig. 2.

Table 2 Possible causes of cyber attacks

S. No	Possible cause	How was it checked	What is the finding?
1	State sponsored attacks	Cause and effect	Limited information on unknown adversaries
2	Hacktivism	Pareto analysis	Organization is vulnerable to such attacks
3	Insider threats	Pareto analysis	Employee is the weakest link

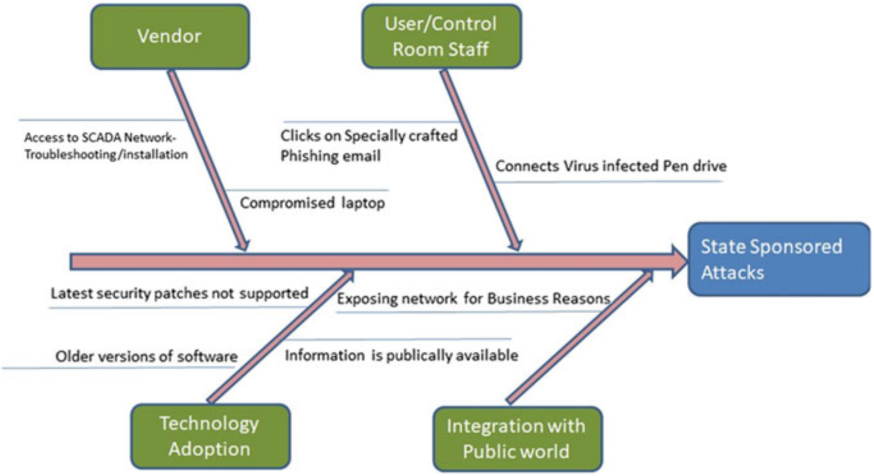

Fig. 2 Analysis of state sponsored attacks

Hacktivism:

See Fig. 3.

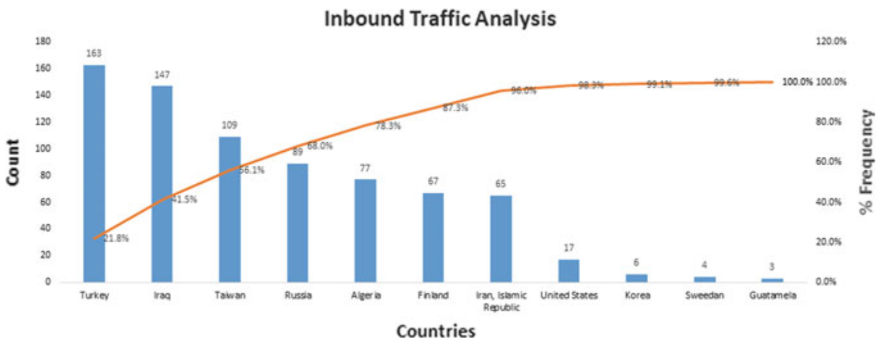

Fig. 3 Analysis of traffic generated from countries

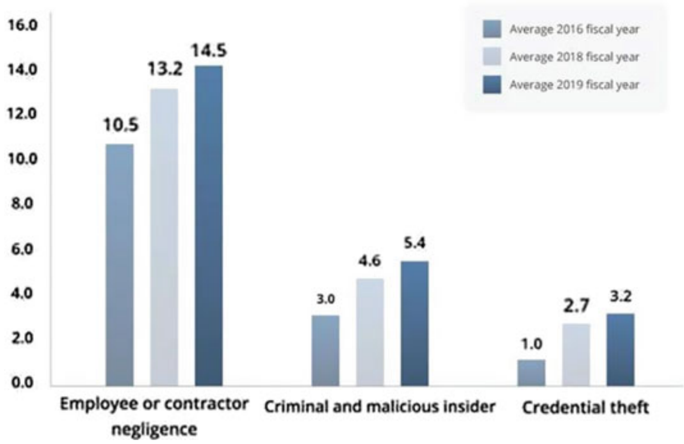

Fig. 4 Details of insider threats

Insider Threats:

See Fig. 4.

One of the important points which is coming out of the analysis is that there is a rise in nation state attacks which is usually carried out from a different land. Also it becomes challenging for the security agencies to catch hold of adversaries due to lack of formal agreement.

5 Review of Cyber Crime Instruments

In view of challenges faced by various Critical Information Infrastructure, it is understood that adopting a legal framework based approach is best suited to address this issue. Since there are multiple stakeholders in the entire value chain, hence it becomes important to ensure accountability at each of the partner's end to bring in the necessary responsibility. Also since due to the rise in adoption of digital technologies, adversaries based out of other geo location are able to carry out cyber-attacks without getting caught. Moreover due to unavailability of any legal arrangement, most of such cases remain unresolved leaving critical infrastructure to merely depend on technology to defend themselves. Failure to meet the necessary requirements should be covered as part of legal framework which should include provisions for penalty, black listing, etc.

Further below we have analyzed few of the international instruments available to deal with the challenge of Cybercrime and how a future course of action can be developed on the basis of the same.

i. European Convention on Cyber Crimes:

It is the first international treaty on crimes committed via the Internet and other computer networks. However, the main focus of the Convention is to deal with infringements of copyright, computer-related fraud, child pornography and violations of network security.

The Convention contains four chapters. First chapter dealing with definitions whereas second chapter specifies the measures that are to be taken by the signing nations. The third chapter makes it mandatory for the nations to cooperate with each other to deal effectively with the cyber-crime. The fourth chapter provides for signature by the parties to the Convention.

ii. Additional protocol to the convention on cybercrime:

On 1 March 2006, the Additional Protocol to the Convention on Cybercrime came into force which is concerning the criminalization of acts of a racist and xenophobic nature committed through computer systems. The ratifying States of the additional protocol are required to criminalize the dissemination of racist and xenophobic material through computer systems, as well as threats and insults motivated by racism or xenophobia.

The protocol states that it has taken into account the relevant international legal instruments in this field, and in particular the Convention for the Protection of Human Rights and Fundamental Freedoms.

iii. Recognition of Foreign Judgments

The "recognition" of a foreign judgment occurs when the court of one state accepts a judicial decision made by the courts of another state as in rem and so precludes the relitigation of a claim on the same facts on the ground of res judicata and/or collateral estoppel. Once the judgment is recognized, the party who was successful in the original case can then seek its "enforcement."

There are many international instruments, which govern the reciprocity on this aspect such as Hague Convention on Foreign Judgments in Civil and Commercial matters.

6 Conclusion

After carefully examining various conventions or treaties available to address cyber-crimes, it is concluded that a separate or a new international level convention or treaty is required to be formed addressing the unique challenges of Critical Information Infrastructure. The treaty should involve all the stakeholders of CII with provision for strict penalty in case of non-adherence. Stakeholders could be operators, suppliers, member countries, etc.

The proposed convention on protection of CII should include following clauses:

- Member states of convention shall cooperate in tracking adversaries responsible for carrying out cyber-attacks
- Member states shall share information of adversaries present in their land with each other
- Accountability of Vendors or suppliers who are supplying service to CII needs to be defined
- Identification of SPOC for vendors and suppliers
- Review of source code must be a standard practice
- Setting up of cybersecurity labs to test equipment's prior to being supplied to CII
- Suppliers of CII needs to be empanelled with nodal agency like national CERT's
- Formation of national vulnerability database applicable to Critical Information Infrastructure
- Option for allowing only those suppliers registered with a nodal agency like CERT to provide service to CII
- Practice of conducting Cybersecurity audit of Suppliers or vendors needs to be included
- 3rd party agencies who provide services on behalf of vendors or suppliers should be made equally liable
- Products supplied must be labelled with a certificate for their adoption in CII
- Option of blacklisting suppliers or vendors from providing services to other CII in case of performance issues needs to be considered as well.

7 Way Forward

The future work shall involve working on development of draft international level instrument which can be adopted by the member states who are party to it. The instrument shall consider all possible aspects of protecting a Critical Information Infrastructure including Supply Chain Attacks which have also seen a steep rise in the recent times. The paper shall also discuss provisions related to penalty that should be levied in-case of cyber-attacks. The paper shall also discuss various ways how majority of the nations can be brought under this arrangement.

Reference

1. https://www.techrepublic.com/ https://www.ekransystem.com/ https://digitalguardian.com/ https://www.techrepublic.com/ http://ili.ac.in

Real Time Monitoring of OT Devices Through INMS

Aamir Hussain Khan, Tarun Batra, and Kundan Kumar

Abstract Tata Power-DDL is a front-runner utility in implementing new technologies in order to improve quality of service to its consumers and enhance consumer delight from time to time. Tata Power-DDL has been successfully managing its power grids remotely. As we are aware that technology plays an important role in increasing the efficiency of our electrical network system, hence to increase the reliability and efficiency of our electrical network system we have automate our network along with real time control on OT devices. In view of this we need a system by which can enable us to monitor the real time availability of the Operational devices like RTUs, FRTUs IEDs etc. which are used to operate the electrical network remotely. To achieve this we propose to implement an integrated system called INMS (Integrated Network Management System) which will enable the utilities to monitor the real time availability and performance of all OT devices. In this paper we are focusing on mainly two issues that is (A.) How we will monitor OT devices on real time basis (B.) What would be the benefits of implementing INMS in a Power Utility? With the help of INMS we are able to monitor the availability and performance of our large electrical network devices on real time basis. It automatically detects faults of electrical network devices through periodic polling of each devices and generate alerts if it is unable to communicate with that device. INMS gives us a complete monitoring solution with following capabilities: (a) Fault monitoring, (b) Alerting, (c) Topology discovery, (d) Performance monitoring.

Keywords INMS · RTU · FRTU · IED · SNMP · MIB · ICMP · SAIDI · SAIFI · OT · NPS · ITIL · OT

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Abbreviations

FRTU	Field Remote Terminal Unit
ICMP	Internet Control Message Protocol
IED	Integliance Electronics Device
INMS	Network Node Manager
ITIL	Information Technology Infrastructure Library
MIB	Management Information Base
NPS	Network Performance System
OT	Operational Technology
RCA	Root Cause Analysis
RTU	Remote Terminal Unit
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption frequency Index
SNMP	Simple Network Management Protocol
TPDDL	Tata Power Delhi Distribution Limited

1 Introduction

Tata Power Delhi Distribution Limited is a Power Distribution Utility which supply electricity in area of 510 sq. km in North and North-West parts of National Capital. Tata Power DDL serving a populace of 7 million and having a customer base of 1.7 million with peak load of approximately 2100 MW. Quality of Service, Reliability and AT&C (Aggregate Technical and Commercial Loss) are the key parameters for any regulators for measuring the performance of discoms. Tata Power-DDL has a great history to reduce the AT&C losses to below 8% from 53% when it took over Delhi Vidyut Board. We have implemented various technology to improve reliability and customer delight.

As Power utilities are approaching towards integration of Information Technology (IT) and Operational Technology (OT), we need a single window platform to monitor all our IT and OT devices on real-time basis.

Integrated Network Management System (INMS) helps us to monitor large number of OT network devices by providing us with a unified environment to view network fault, availability, and performance and proactively address problems of our network infrastructure. INMS uses a central server-based monitoring framework. We have to install and configure INMS on a dedicated server, called INMS management server, and it begins to discover the network by gathering information about the devices connected to the network and the network topology.

After completing discovery of network, INMS uses a polling mechanism to periodically collect data from the discovered network devices. INMS largely relies on Simple Network Management Protocol (SNMP) agents on network devices while collecting health status of each device. The SNMP agents configured on each OT device provides INMS with a rich set of details on the health and availability of the devices. By running periodic polls, INMS proactively and continuously collects the data that indicates the health of the OT devices. For communication between field devices to Management Server an SNMP (Simple Network Management Protocol) agents is configured on the field devices like RTUs, FRTUs, and IEDs which acts on behalf of the devices to perform network management operations requested by INMS server.

Figure 1 shows the broad architecture of monitoring the OT devices installed in our grids on real time basis. All OT devices of grid are connected to a switch whose uplink is connected to the router to carry information's of devices to the INMS server. INMS server running periodic polls on each devices and collects SNMP traps to check the status of devices. If the agents configured on devices which is used for communication with server went unresponsive to the management server then an alert in INMS of that particular device is generated.

The alerts are categorize in five category 1. (Normal) 2. (Warning) 3. (Minor) 4. (Major) 5. (Critical) as shown in Fig. 2 INMS server uses ICMP (Internet Control Message Protocol) protocol to pings all remote devices at a fixed periodic interval. When the server doesn't get ping response from the remote device then it generate an alert of node down in INMS. At the same time INMS server collects the performance data of devices using syslog. These syslog data are manipulated by server to display the performance of the devices.

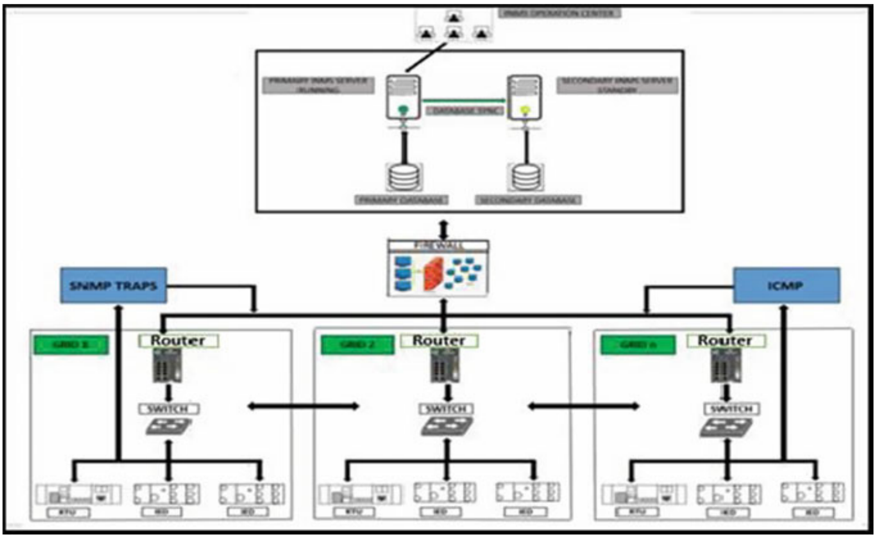


Fig. 1 .

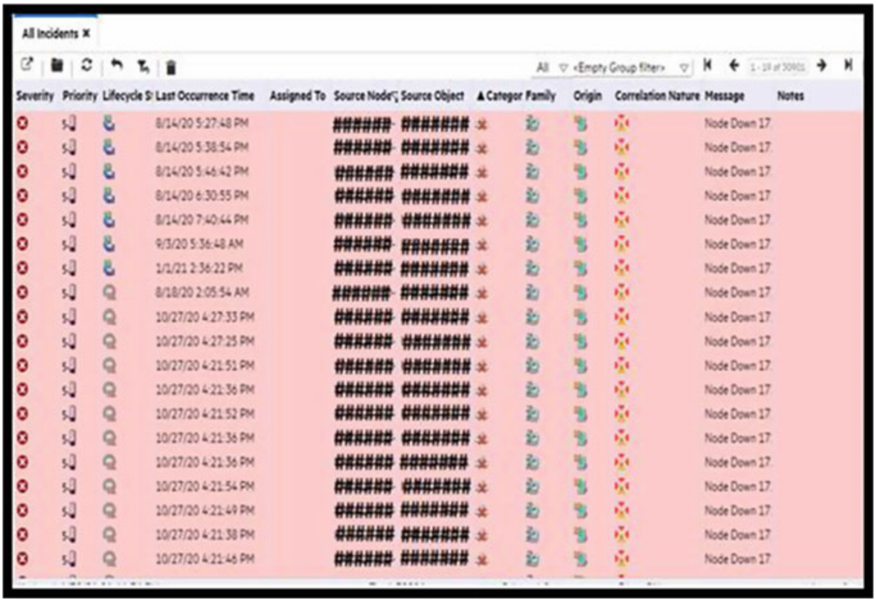


Fig. 2 .

2 Tata Power-DDL Challenge

In today's scenario in TPDDL, our main challenge it that we are monitoring few devices (only RTU) on real time basis. The number of devices monitored is very less as we have large number of IEDs, FRTUs, Switches etc. in grids which are used to operate grids remotely whose status is not known on real time basis as shown in Table 1. For devices which are not monitored on real-time basis, we are using reactive approach i.e. when it goes down and we get complaint of breakdown of device; then we started to find out the possible reasons of breakdown and it takes a lot of time to identify the issue. The main challenges are listed below:

- Difficult to trace the main reason of device failure.
- Not able to monitor all devices of operation technology on real time basis.

Table 1 .

Devices monitored before INMS	Devices monitored after INMS
RTU-133	RTU-133
IED-0	IED-2238
Switch-0	Switch-141
Gateway-0	Gateway-85
Total devices-133	Total devices-2597

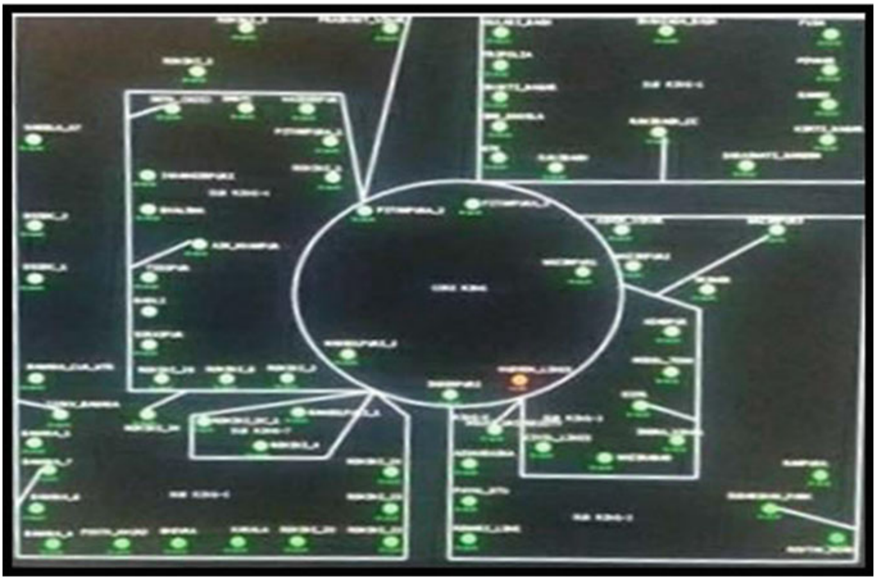


Fig. 3 .

- Restoration time is devices are high.
- Not able to check the performance of devices.

Before INMS we were only able to monitor the availability RTU i.e. it is up or down as shown in Fig. 3. We have no mechanism to address the issue why devices are down.

The unavailability of devices like RTU, IEDs FRTUs etc. are due to reason like communication failure, due to port hanged on router or it may be due to power failure. Today, we are not able to analyze the root cause of unavailability of OT devices quickly. To identify the issue maintenance team has to follow up with different teams and it takes a lot of time to acknowledge the real issue and it increased our MTTR (Mean time to restore). This impact our operation services and increase SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption frequency Index).

3 Methodology

In order to address the challenges of monitoring of all our OT devices on real-time basis we have suggested to implement INMS system as follow:

1. Mapping of devices as per our geographical area.
2. Discovery of Devices by INMS system.

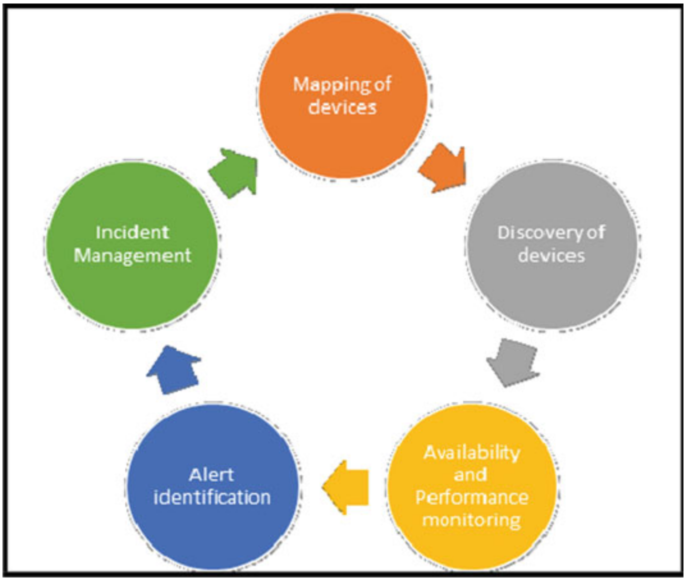


Fig. 4 .

3. Availability and Performance monitoring of devices.
4. Alert identification.
5. Incident Management.

Process flow diagram is shown in Fig.4.

4 Mapping of Devices as Per Our Geographical Area

To identify the location of devices easily in case of any breakdown we have mapped the devices as per their geographical location of our distribution area as shown in Fig. 5.

In our large network it helps to troubleshoot the problem with layered approach i.e. when we get an alert of device down we check that at which layer problem occurs as shown in Fig. 6. This will helps us to reduce the total outage time of device.

5 Discovery of Devices

We have mapped all the field devices in INMS topology map as per the physical connectivity of devices. INMS network topology monitoring capability helps us to diagnose network connectivity problems. A topology map indicates the status of

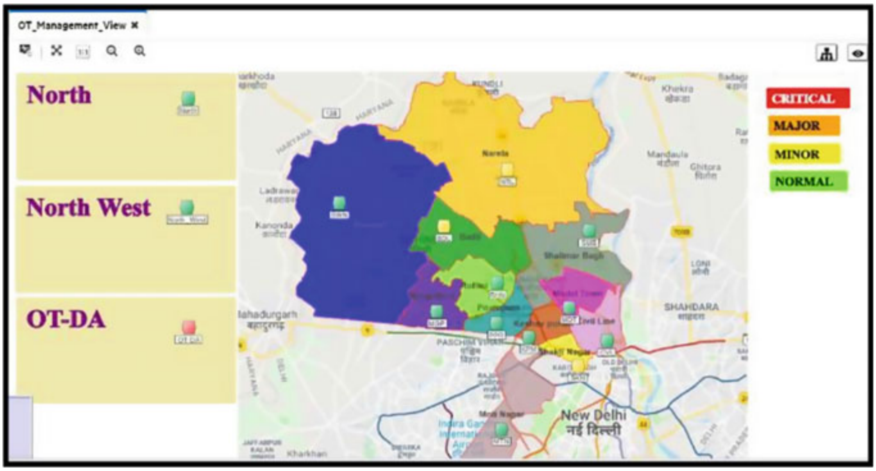
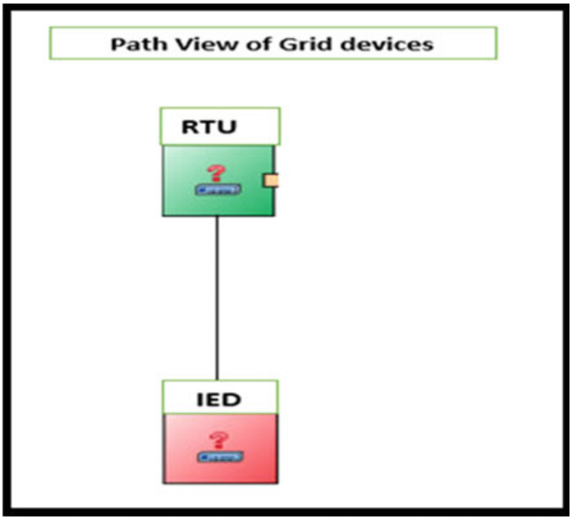


Fig. 5 .

Fig. 6 .



a network node, interface, or network connection with colors (for example, green indicates the node is up, yellow indicates that there is some minor issue and red indicates that link is down) and is useful in performing the following tasks:

Finding the cause of a connectivity problem (the device status is not Normal).
Understanding the RTU connectivity in the network.
Understanding the IED connectivity in the network.
Understanding the Ethernet Switches connectivity in the network.

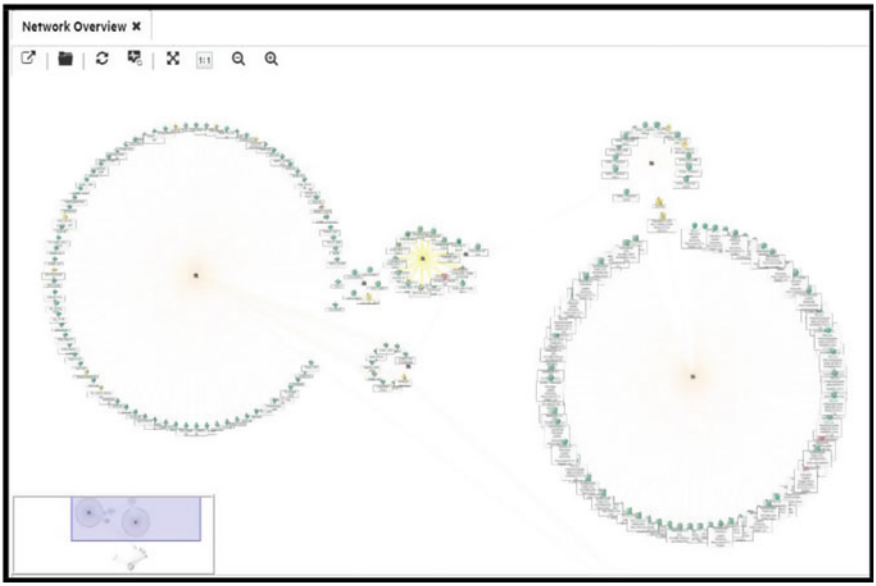


Fig. 7 .

6 Availability and Performance Monitoring of Devices

INMS assists us in figuring out how to fine-tune our network's performance by collecting a rich set of performance metrics from devices and interfaces and presenting the metrics on easy-to-understand graphs, charts, and reports. Delivered with the INMS ISPI Performance for Metrics, INMS performance management capability continuously collects, stores, and manages performance-related metrics from across our network, store the data into a scalable database on the Network Performance Server (NPS)—the central component for building and viewing network reports, and provides you with seamless transitions from fault data to performance reports and back as per Fig. 8 (Fig. 7).

7 Alert Identification

INMS is specifically built for the exception-based management paradigm, which enables you to focus on priority tasks quickly. INMS actively notifies you when an important event or incident occurs on the network. An incident can be triggered by a change in the status of a RTU or IED, a disruption in connectivity, or a non-responsive SNMP agents. Incidents are monitored by INMS and reported through INMS incident views (Fig. 9).

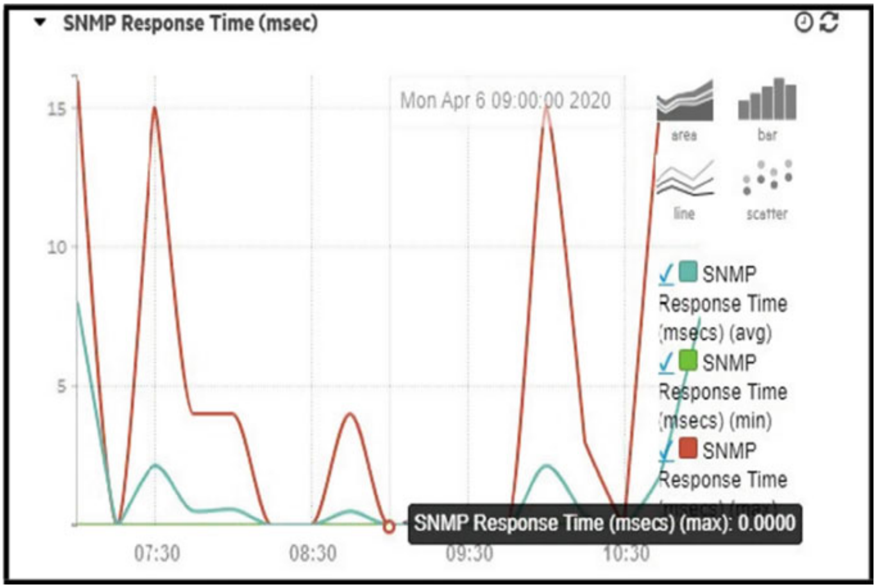

SNMP Response Time (msec)
Mon Apr 6 09:00:00 2020
15
10
5
07:30
08:30
09:30
10:30
area
bar
line
scatter
SNMP Response Time (msecs) (avg)
SNMP Response Time (msecs) (min)
SNMP Response Time
SNMP Response Time (msecs) (max): 0.0000

Fig. 8 .

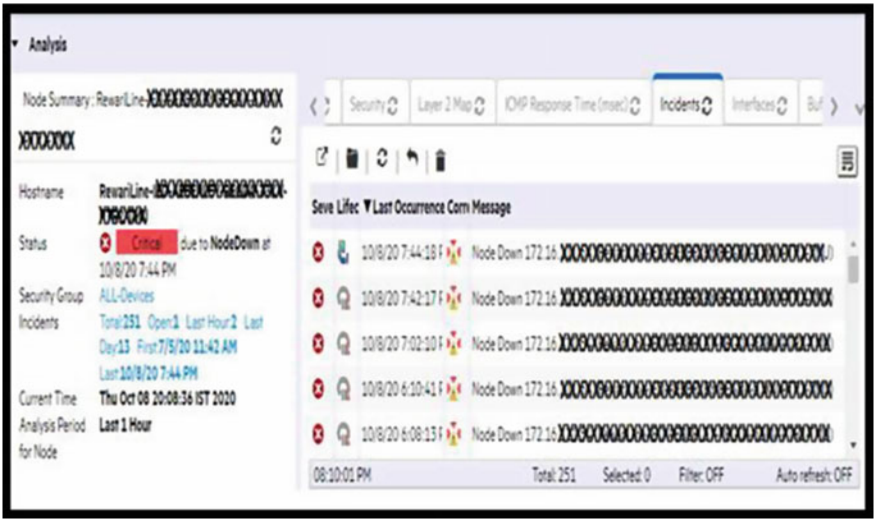

Analysis
Node Summary: RewariLine-[redacted]
Hostname RewariLine-[redacted]
Status Critical due to NodeDown at 10/8/20 7:44 PM
Security Group ALL-Devices
Incidents Total 251 Open 1 Last Hour 2 Last Day 13 First 7/5/20 11:41 AM Last 10/8/20 7:44 PM
Current Time Thu Oct 08 20:08:36 IST 2020
Analysis Period for Node Last 1 Hour
Security
Layer 2 Map
ICMP Response Time (msec)
Incidents
Interfaces
Seve Lifec ▼Last Occurrence Corr Message
10/8/20 7:44:18 Node Down 172.16 [redacted]
10/8/20 7:42:17 Node Down 172.16 [redacted]
10/8/20 7:02:10 Node Down 172.16 [redacted]
10/8/20 6:10:41 Node Down 172.16 [redacted]
10/8/20 6:08:13 Node Down 172.16 [redacted]
08:10:01 PM
Total: 251
Selected: 0
Filter: OFF
Auto refresh: OFF

Fig. 9 .

We can browse through incidents to diagnose network problems. We can view incidents by specific node or other sort criteria to solve problems quickly. Every incident appears in the incident views with a default message, which can be customized, and can include helpful tips for resolving a particular network fault. Incident views offer a quick way to diagnose the problems detected by INMS and finding a resolution to the problems.

8 Incident Management

Incident Management is usually the first IT Infrastructure Library (ITIL) process targeted for implementation or improvement among organizations seeking to adopt ITIL best practices. The reasons for this are simple: Improved Consumerization and Service Value Realization. Incident Management is the day-to-day process utilized by the organization through engagement with the service desk or self-help technology for rapid service restoration. We do various analysis like Pareto Analysis of the incidents generated in the INMS for finding the most vulnerable OT Devices as shown in Figs. 10 and 11.

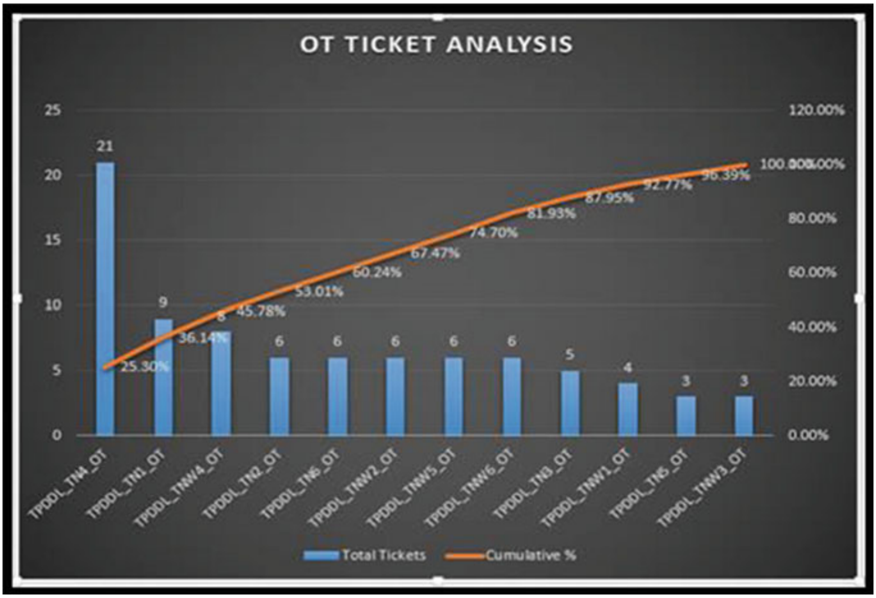


Fig. 10 .

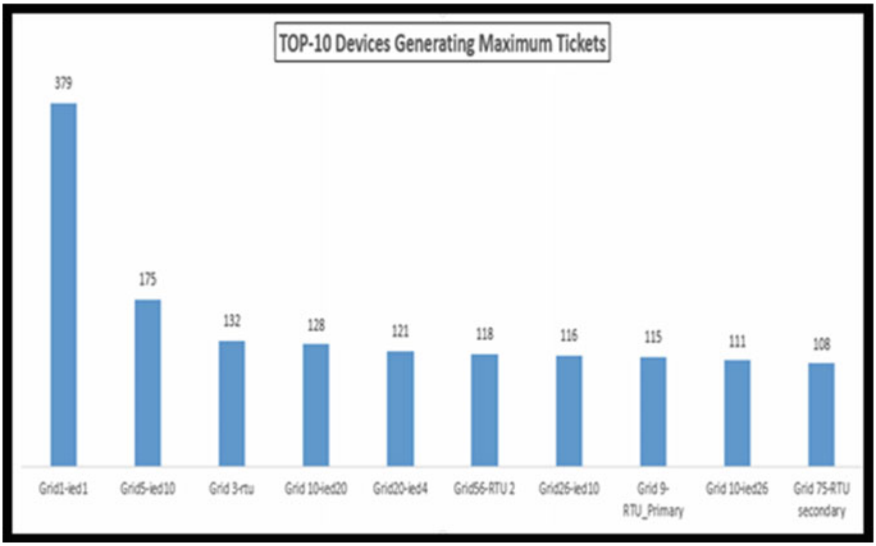


Fig. 11 .

9 Benefits

- Reduce the cost of delivering improved network availability with decreasing SAIDI and SAIFI.
- Integrated our OT network with IT network infrastructure (for example, reduce the number of management servers).
- Achieve low total cost of ownership with features such as single windows monitoring for all the IT and OT Devices.
- Achieve greater staff productivity and efficiency with Automated Ticketing Method i.e. in case of any breakdown, alerts of that device is sent to concern team for restoration.
- Reduce mean-time-to-response (MTTR) with a deterministic and adaptive RCA and other intelligent automation features.

10 Observation

Tata Power-DDL has adopted smart grid technologies in moving forward to become a smart utility. INMS is a part of smart grid technology where we can monitor our OT devices and analyze its performance. INMS can give a boost in ensuring the availability to our OT network. It detects fault automatically and generate alerts through continuous polling and collecting performance data of devices. We can update the inventory of devices as per our geographical location area i.e. devices of a particular location can be added in a separate group. This will help us in troubleshooting to check how many devices of that particular location was down or unavailable. Overall with the adaption of INMS, TATA Power-DDL is moving toward integration of IT and OT network.

11 Conclusion

To achieve vision of IT and OT Integration on a single platform, INMS tool is a landmark step to improving OT network reliability. Hence INMS tool help TATA POWER-DDL to gain unique experience of integrating various smart grid technology with INMS which can be liberate by other by other organization to enhance their OT network reliability.

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Combined Billing and Customer Care Systems for All Utilities in a Smart City

Amit Jindal

Abstract Smart city is a structural, predominantly composed of Information and Communication Technologies (ICT) and several physical devices, to optimize the system efficiency and improvement in various services including utilities (Electricity, Water, Gas, etc.). ICT assist to enhance service quality, system performance and collaboration between numerous departments to deliver services in a time bound manner. Utilities supply electricity, gas, water, sewer etc. to consumer's premise and charge fee against the services provided as per regulatory guidelines. These services might be provided by a single entity or multiple entities as per structure of urban local body. In major cases, utility services are provided by distinct entities and charges from the consumers are collected independently. In such a scenario, each entity must visit consumer premises and generate reports for billing, payments, collections, customer notices and customer base, which consume a lot of time, effort and impose huge costs. Consumers pay all utilities bills separately, which billing cycle, cash collection counter and customer care systems are working independently. Combined billing and customer care systems will help utilities to overcome aforementioned problems and visiting of consumer premises is required only once a month to collect consumption data and bill distribution for all utility services. In such scenarios all utilities will work in an efficient manner with a smaller number of employees, which leads to cost savings to them. The combined CC&B enables utilities to manage payments, deposits, consumer accounts, tax and meters through a single interface. Consumers will be empowered to make payment for all utility services at the same counter in one go and their service problem will be resolved in an efficient manner.

Keywords Billing · Customer care · Utilities · Revenue · Information and Communication Technologies (ICT)

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1 Introduction

A utility bill is a detailed invoice, issued from utilities, including electric, water, gas and sewer as per defined billing cycle in accordance with utilities business process. Utility bills for consumers are majorly categorized in residential, commercial and industrial segment. The billing structure of these categories are basically the same. However, charges for industrial and commercial categories are more than the residential category. The billing calculation of water, gas and sewer consumption is somewhat straight forward; however, electrical energy and power billing can be more complex.

A utilities infrastructure should be designed in such a way to meet its consumer's demand. Basically, the utility must predict the demand-supply scenario in its service area. The over-sizing of the equipment is expensive and the utility recaptures such investment through various components of the bill. On the aspect with the utilities is that the system's demand tends be worse during certain seasons and times of the day. For example, during summers, electricity load of air conditioning will be highest in the afternoon and evening. Secondly, consumption of the water also increased multi fold. In the winters, the electrical and gas systems may experience increased loads in the early morning and afternoon. However, demand of water sharply declines due to less consumption. These peak demand/loads vary largely depending on what types of heating and cooling systems (gas or electric) make up in the utilities' service area.

In many cases, the utility systems are working on their full capacity. That is, any significant additional load (demand) will stretch the existing infrastructure such as lines, equipment and system's capacity. Utilities use different pricing methods for different time zone, or signals, to encourage consumers to reduce usage during periods when the utility system is nearing its peak capacity. These signals are often printed into the consumer's tariff structure. Understanding the tariff structure often leads to the ability to save energy costs.

In the "metered" service arena, we can accurately measure energy consumption for electricity, water and gas. Based on consumption, utility generates bill with applicable tariff structure and tax regime. Within just those confines, we obviously need a method to measure consumption, a technique to get that measurement back into billing system, and a way to create, store and apply the correct rate to that measurement. Additional complexities arise in the multiple way's consumption can be measured with the most complex being electricity with kWh, kW, kVAR, TOU, MD, PF, Fuel surcharge etc.

Utilities capture and maintain consumer centric information covering name, address, sanctioned demand, billing and payment history along-with other key parameters. Based on consumption, utilities generate the bills to the consumers and send them to pay for the services availed. i.e. it is the entire Meter-to-Cash process. In utilities, this is a structured and complicated process requiring a sophisticated software.

Every created bill has unique number to record in their general ledger. Therefore, a billing system to have a way to flexibly code their rent, tariff charges, consumption, demand, taxes etc. to link them to an appropriate set of general ledger account numbers, and then appropriately roll up and transmit totals to those general ledger account numbers. All financial transaction, such as payments or adjustments or write-offs are recorded in a debit/credit pair. Ultimately a billing system is the AR (Account-Register) sub-ledger and must be fully integrated into the financial system.

Combined billing system is the collective bill of different utilities covering electricity, water, gas and sewer and only single entity will responsible for the meter to cash process. The combined bill sent by the responsible entity to the consumer is actually separate invoices on one piece of paper, including all necessary information to fulfil regulatory requirements of the invoice. The entity is responsible for the receivables from the consumer, including debt collection in situations where the consumer is late with payments or does not pay at all. The consumer's payment is settled on a single account owned by the respective entity, which is responsible for settlement of payment with all utilities.

a. The billing entity is responsible for printing and distributing the combined invoice to the consumer. The consumer will receive one piece of paper with data that fulfils regulatory requirements.
b. The billing entity is responsible for the monetary settlement with the consumer and for accurately passing forward the respective utility's claim against the consumer.
c. The billing entity shall responsible for due date monitoring and collection for the total claim against the consumer.

The entity shall be responsible for meter to cash related issues covering meter fault, billing issues, including debt collection. However, issue related to service quality, outage and leakage shall mainly be handled directly by respective utility.

2 Background

Nowadays consumer receive utility bills all the time for their services namely electricity, water, gas and sewer. These bills are received monthly or bimonthly and sometime on ad hoc basis as per their billing cycle in respective utility supply/service area. Many consumers have more than one connection at different periphery (Suppose different electricity connection in same city for different properties), so they receive multiple bills every month, whose billing cycles are different and it is very difficult to keep track of all the bills. Even consumer receive more than one bill from different utilities in the same territory in different bills and consumer need to pay them separately. Such bills are provided in hard copy or via e-mailto the consumer. The consumer reviews/validates the bills and pay to the utilities. Different bills have different payment deadlines and late payments usually result in substantial penalties. Needless to Say, receiving, reviewing, tracking, and paying each bill is and inconvenient and time consuming task (Fig. 1).

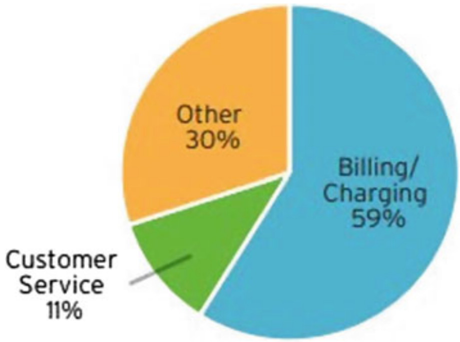

Fig. 1 Most cause of utility customer complaints. *Source* UK Energy Ombudsman

Additionally, if there is some discrepancy/dispute in the utility bills for different services or for same service under different territory then consumer needs to follow up with the separate consumer care service centers for resolution of the issues, which leads for the time, cost and dissatisfaction from the utility services. In such cases, creditability of the utility services will also be severely damaged.

In the 2016, Government of India has launched concept of Smart City would include:

- Adequate water supply
- Assured electricity supply
- Sanitation, including solid waste management
- Efficient urban mobility and public transport
- Affordable housing, especially for the poor
- Robust IT connectivity and digitalization
- Good governance, especially e-Governance and citizen participation
- Sustainable environment
- Safety and security of citizens, particularly women, children and the elderly and
- Health and education.

Smart city is a structural, predominantly composed of Information and Communication Technologies (ICT) to optimize the system efficiency and improvement in various services including utilities (Electricity, Water, Gas, etc.). ICT assist to enhance service quality, system performance and collaboration between numerous departments to deliver services in a time bound manner. Also, ICT can enable various services under one roof for improvement in consumer services, saving of time and fuel and gain consumer faith.

With deliberation of utilities backdrop in their billing and service methods and availability of smart city ICT infrastructure, notion of combined billing and customer care systems for all Utilities is conceptualized. Combined billing system is an individual-based System which collect billing information for a consumer premises and sends bills through the e-mail or a hardcopy, as per regulatory guidelines, for payment. The consumer receives a single bill with all desired information and make combined payment in a Single account.

Combined billing system will overcome mass mailing system, multiple bills in different billing cycle, different payment timelines and provide improved billing and payment Systems. Apart from this, customer bill dispute can be rectified from the one place only.

3 Recent Utilities Trends

In recent years, the utilities are moving towards transformation of their business in digital era. Digitalization and new technologies are driving demands for advanced strategies and integrated data-driven business solutions, providing higher operational efficiency, better financial management and advanced customer services in cost effective manner.

Nowadays, the customers are demanding for more accurate and transparent billing along-with real time monitoring for control, billing review and timely payment. So, utilities are concentrating on customer demand and listening more carefully their voice to respond for more involvement and control over energy usage. The new generation become more conscious and comfortable with mobile apps, social media, and always-on connectivity, which all adds up to a "new normal" in the customer experience. In this new normal, customer is desiring, specifically in electricity energy, in tariff structure, source of electricity, time of day mechanism, micro grid, RE and net metering. Commercial and industrial customers are looking to combine more cost and utilization control with opportunities to self-generate, while setting themselves and their utilities ambitious targets to reduce emissions from their energy use.

On the other hand, Involvement of multiple stakeholders, more access of data and open access, cybersecurity anxiety is increasing from technology to management that can disrupt service on multiple levels, from data security to infrastructure. Unfortunately, cyber security and associated threats are underestimated and unimplemented by the utilities due to lack of knowledge, expertise, cost, resource, and time constraints.

According to the UK government's latest survey on cybersecurity breaches, almost half of businesses experienced a breach or attack in the last year, making the cybersecurity the 2nd most addressed topic for the UK's utilities.

Cyber security technology by itself, however, can only partially address the issue of cyber threats. Utilities also need to deploy the proper organization and processes in order to supplement the impact of cyber security protection technologies. One potential solution is for utilities and suppliers to develop standardized processes together, so that concepts such as device configuration will be effective in a multi-suppliers environment.

In the technology changing environment, the regulators are promoting for evolve and adapt to recognize and incentivize new technology options such as energy storage, EV charging infrastructure, Rooftop solar, two-way power flows, cloud-based solutions, demand side management, smart metering and customer centric solutions throughout the business. Traditional cost-of-service regulatory structure often does not encourage innovation nor impels the investments necessary to satisfy customers' evolving needs.

It will be of utmost importance that regulations in the energy and utility sectors are timely aligned with the customer expectations, market evolvement and adoption of new technologies such as digital capabilities or storage, taking their relationship with customers on an entirely new level, for the overall disruptive transformation of the industry.

4 Distinctive Features of Purposed Solution

We propose combined billing and customer care systems (CB&CCS) for all utilities in a smart city. Combined billing system will extract all utilities bills of single customer and combined them into one bill. The customer can pay for the consolidated bill once per billing cycle and all the bills are settled by the combined billing system. The customer can call to combined customer care center to rectify of bill dispute related to any utility service.

- **Multiservice** bill for utilities of different standards (electricity, gas, water, sewage, garbage collection, etc.)
- **Multi-regional** supports for multiple jurisdictions, with different business rules for each jurisdiction, including different utilities, prices and tariffs, taxes, billing and payment options etc.
- **Multi-payment mechanism** provision of the multiple payment mechanism like cash counter, card swiping, online, account auto-debit and payment gateway.
- **Multi-utility customer care** support to handle multiple utilities billing and service-related complaints.
- **Multi-language** bill as per customer requirement.

The combined billing and customer care systems (CB&CCS) should be able to connect to all utilities billing, payment and customer care interfaces so that system can get the billing information such as user account, bill amount, bill date, payment deadline, bill breakdown details and minimum payment amount, and payment details such as payment history, and store them into database. The billing deadline for all utility bills for one customer shall be same (Fig. 2).

Utility Billing: We recommend that combined billing agency collect the billing data from customer premises for all utility services in one visit. Collected billing data to be sent to the respective utility for calculation of the bill amount and send back to the combined billing agency for distribution. Combined billing agency collect the billing parameters from respective utilities, validate data and compute combined bill with a suitable payment deadline. Further, they send the combined bill to customer on email or hardcopy as per regulatory guidelines. Each customer has unique account number for combined billing system as well. Consumer receive a single combined

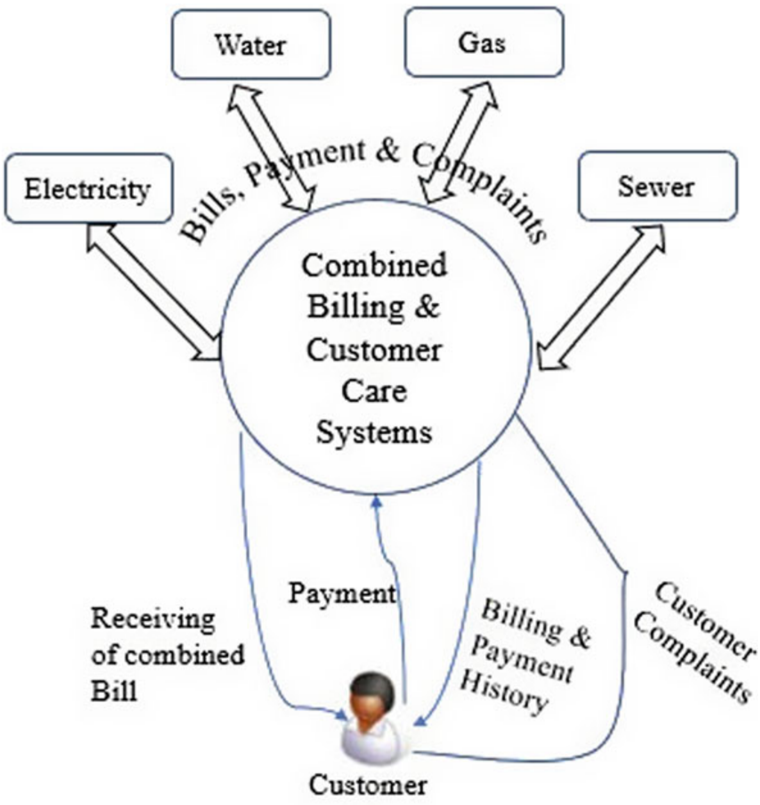

Fig. 2 Depicted of combined billing and customer care

bill for all utility's services availed by them and deadline of the payment to be same for all services.

Payment Collection: Financial health of any utility solely depends upon collection of bill amounts from the consumers. To ensure prompt payments by consumers proper facilities to be provided. Combined billing agency collect the payment from consumers against the bill and handover to the respective utility as per their agreement. Consumer can receive their bill and payment history from single portal/app (Fig. 3).

Customer Care: Consumer can connect to the central customer care for the bill, payment and supply related concerns. Central customer care system can resolve the billing and payment related disputes at 1st level, else take the consumer complaint and forward to the respective utility department for resolution of the matter. In case of consumer's complaint related to supply quality and outages, customer care can connect with respective utility team and maintain the complaint history for record. Further, consumer can check the complaint status from the central portal only.

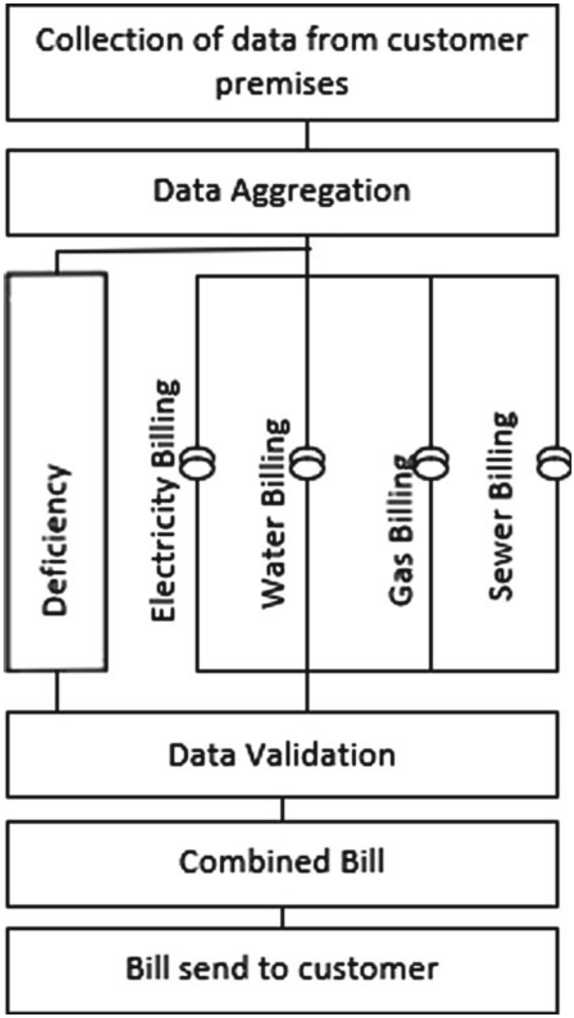

Fig. 3 Indicative process flow

5 Implementation Strategy

The combined billing and customer care systems can be implemented successfully with necessary strategy to address technical, commercial and regulatory aspects.

- Simplify utilities tariff structure and billing format to make easier for understanding to consumers.
- A standardized data exchange with all utilities to promote well-functioning processes.
- Minimum essential data requirements include the point of delivery data, accurate and timely measurement of data, and utility's tariff data.

- Long-term commercial tie up of service provider with all utilities and relevant stakeholders.
- Solid payment reconciliation process along-with frequency to be defined clearly.

The customer's payment is settled on cash counter and online bank account owned by the service provider and the service provider is responsible for passing forward to the utilities part of the payment on regular frequency. In other way, consumer's payment can be settled in the escrow account for transparency.

System should be allowed to accept partial payment with the due approval of concern authority. However, at the time of payment, consumer needs to define particulars of utility to make partial payment.

Software as a service (SaaS):

The development of new technology and widespread availability of an access facility, the combined billing system on SaaS software complex with cloud-based solution is more flexible and productive. The system is maintained by the service provider with guarantee of 100% uptime and the access to the users (utilities and consumers) are provided through online services. The service provider shall collect the metering data from consumer premises and facilitate to the utilities through data exchange interface for billing calculation (Service provider can also calculate billing depends on the utility's requirement). The system combines billing data, receives payment data, as well as issues receipts and maintain customer complaints history. System provider shall have following key responsibilities as SaaS:

- Maintain and update system to achieve 100% uptime
- Development of new featured as per future requirements and regulatory guidelines
- Data exchange interface for seamless data transfer
- Both utilities and consumers can access system on the same platform.

6 Benefits

The combined billing and customer care systems are beneficial for all stakeholders including customer, utilities and combined billing agency in the new billing and payment mechanism.

Customers:

- Don't have to keep track of their individual bills and less risk of late payment fines.
- Online accessibility to check all utility bills along-with details from anywhere at one place in more organized way.
- Track multiple utilities bills and make payment without logging into individual utility portal/app separately.
- Easy to analyze various expenses at one place and generate reports without any expenses tracking tool.

- Rectification of utility's billing and service-related issue at one place.
- The user also doesn't have to receive multiple physical mails or emails from different organizations.
- Saving time for the customer as well as saving resources for the environment.

Utilities:

- The process of billing system is simplified by the combined billing system.
- No need to visit customer premises for collection of billing data and bill distribution.
- Saving time, manpower and fuel costs especially for the visiting consumer premises for data collection, bill distribution and payment collection.
- Improvement in billing and collection efficiency more reliably and more promptly.
- Less manpower is required for reconciliation of billing and payment collection data.
- Minimal capacity of customer care center is required to handle customer complaints.
- Improve customer satisfaction and reduce the workload on customer service.

Combined Billing and Customer Care Agency:

- Collection of all utilities metering data in one visit in place of repetitive visit at customer premises
- Combined billing system can make a profit by providing services to both utilities and the customers.
- Increase brand value and customer base for other billing services such as telecom, insurance, tax, banking etc.
- The billing system also earn some profit by holding collection money for some time.

7 Conclusion

Nowadays consumers are getting separate bill for each of the utility service, whose billing, and payment cycles are different so tracking of bills become huge task. In case of dispute in the billing or payment then consumer needs to connect with different utility offices, which is completely wastage of time, fuel, cost and other resources. The proposed combined billing system provides a more convenient way of organizing and tracking utility bills. Consumers will receive a combined bill of different utility's services instead of many bills separately. This makes consumer less likely to forget to pay the bills, saving both time and cost in convenient manner. Consumers can track and check different utility bills in one combined system, which help for more understanding about usage. Consumer can download billing and payment history from one place. Utilities don't require to visit at the consumer premises for collection of billing data and bill distribution. On the other hand, the combined billing agency will get all the payments in time as billing cycle of all utility's service will same for individual consumer.

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Effective OT Cyber Security for Modern Grid Operations and Asset Management

Anil Kumar Ojha, Yogesh Gupta, Amit Mazumdar, and Aakash Verma

Abstract Historically, Substation automation system were based on local connections and proprietary applications. Systems were designed for safety, reliability and ease of use, and security was not traditionally a concern of power system managers or implementers. But this approach is no longer valid. As power system grid has evolved significantly over the past decade in terms of technological advancement and breakthroughs. At the heart of these intelligent advancements are specialized IT systems—various control and automation solutions such as SCADA/AMI/substation automation systems etc. The new generation of automation systems uses open standards such as IEC 60870-5-104, DNP 3.0, Modbus and IEC 61850 and commercial technologies, in particular Ethernet- and TCP/IP-based communication protocols. They also enable connectivity to external networks, such as office intranet systems and the Internet. These changes in technology, including the adoption of open IT standards, have brought huge benefits from an operational perspective, but they have also introduced cyber security concerns previously known only to office or enterprise IT systems. Cyber security is often used to describe protection against online attacks, but a more holistic view of cyber security involves a collection of measures adopted to prevent unauthorized use, malicious use, denial of use, or modification of information, facts, data or resources. Cyber security not only refers to intentional attacks from outside the network, but also internal issues and unintentional modifications of information. Many automation and modernization programs are now employing intranet/internet technologies in industrial control strategies. The ensuring systems

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are a mixture of state-of-the-art and legacy installations and create challenges in the implementation and enforcement of security measures. Control system intrusions can cause environmental damage, safety risks, poor quality and lost operations. This paper give glimpses of the methodologies involved for IT-OT convergence along with the Cyber security, asset management, information security implementation on the OT (Power system) networks and components. This will presents methods to determine and reduce the vulnerability of networked control systems to unintended and malicious intrusions. The procedure for conducting a thorough assessment of the process control networks to evaluate these risks is presented. Security issues are identified, as are technical and procedural countermeasures to mitigate these risks. It also includes hindrance/obstacle occur during the implementation approach where OT system run far behind from the IT systems in any organization.

Keywords Operational technology · Cyber security · Firewall · SCADA · OT monitoring tool · Grid substation · Control centre · Vulnerabilities

Abbreviations

TPDDL	TATA power Delhi distribution limited
OT	Operation technology
SCADA	Supervisory control and DATA acquisition system
RTU	Remote terminal unit
OT	Operations technology
IT	Information technology
NCIIPC	National critical information infrastructure protection centre
SNMP	Simple network management protocol
SSL	Secure socket layer
ICS	Industrial control system
OEM	Original equipment manufacturer
IED	Intelligent electronic device
IP/MPLS	Intelli protection/multi packet label switching
Syslog	System logs
DPI	Deep packet inspection
IIoT	Industrial Internet of Things

1 Introduction

Tata Power Delhi Distribution Limited (TPDDL) is power Distribution Utility, distributes electricity in North and North-West part of Delhi, serving about 1.7 million consumers. TATA Power-DDL has always been an early implementer of latest technologies and procedures in India and has perhaps most number of standalone and integrated platforms in use. These procedures have also been instrumental in improving the overall performance of the company and also been able to deliver business benefits in terms of return on capitalization of assets and improving reliability. TPDDL's competence in adaptation of latest technologies makes it very appropriate to achieve high standards in optimization of resources in maintenance and management of Grid networks.

The technological shift took place with the introduction of "Intelligent Electronic Devices". IEDs revolutionizes the conventional Grid substations monitoring and control These IEDs performs various complex functions like:

- Advanced numerical, differential, distance Protection of Grid Electrical equipment's and reporting of the same to master SCADA.
- Digitization of Electrical Processes.
- Centralized remote Monitoring and Controlling of Grid equipment's and networks.
- Enhanced Transformers Monitoring and remote OLTC operations for voltage optimization.

The integration of cyber and physical systems is making major improvements in the capability to Monitor and operate the grid, as well as offering improved protection. But at the same time, it is also introducing new weaknesses. To reduce existing vulnerabilities and minimize the introduction of new ones, cyber and physical expertise must be integrated into all stages of the research develop-build-operate continuum. Additional integration is needed when existing systems are upgraded or repaired, not just when new technology is introduced. This is because such changes can introduce unrecognized vulnerabilities if both overall systems and components are not evaluated before changes are made.

Here we discusses methodologies involved to enhance cyber security for OT network i.e. Substation networks which consists of RTU, data concentrator, numerical relays and IED's.

2 Approach

Historically, industrial networks were kept separate from corporate networks, but significant efficiency gains and a broad trend for digital interconnectivity have driven a convergence between Operational Technology (OT) and Information Technology (IT) systems. Adoption of new control technologies, and the introduction of the Industrial Internet of Things (IIoT) are also increasing the complexity and interconnectedness of traditional OT environments.

Digitalization means that systems and equipment are interconnected, so these connections must be secured by authentication and encryption. With the increasing digitalization of OT/ICS environments, conventional malware attacks in the OT/ICS area cannot be ignored. Although more and more targeted attacks on companies are being observed, the danger from classic malware attacks is still present.

Following are the few cases in the past where the business were affected by the cyber-attacks on the OT system:

i. Stuxnet Worm 2010 on Iranian Nuclear Plant
ii. HAVEX 2013
iii. German Steel Plant attack 2014
iv. DEC, 2015 Ukraine's Power Grid Attack
v. DEC, 2016 Russian Operation Hacks a Vermont Utility
vi. AUG, 2017 Irish Power Grid Compromised By Foreign Actor
vii. Wanna Cry Ransom ware Attack 2017.

Ensuring the cyber security of information systems and associated networks has always been challenging. Serious vulnerabilities are identified on a regular basis and new threats continue to emerge to exploit those vulnerabilities. Industrial systems share many of the same vulnerabilities and are subject to the same threats. However, the consequences may be very different and, in some cases, more severe. This makes cyber security an imperative for the asset owner, who ultimately must bear the consequences of an adverse event. The threat is ongoing and evolves constantly, so cyber-security should not be viewed as a one-time "project" with a defined beginning and end. Since there is no such thing as being fully secure, the preferred approach should be ongoing, similar to the approach used for safety, quality, and other performance-based programs. Similarly, it is not sufficient to focus on specific elements. Instead, asset identification and management, patch management, threat assessment, and so on are all parts of a broader response that must address all phases of the life cycle.

An **OT asset** is a digital device that is part of an OT infrastructure. Devices can either be physical or virtualized. One can argue that there are other types of OT assets besides digital devices, such as software assets. From a theoretical perspective, that argument has its merits. From a practical perspective, experience has shown that it is most efficient to identify OT assets with devices, while software, networks etc. are conceived as their configuration attributes. Assets covered under OT system are as follows;

a. RTU's
b. IED's
c. Network Switches
d. Routers
e. SCADA servers
f. SCADA Software
g. RTU Software
h. IED Software
i. Database

3 Implementation

Any Power Utility shall have grid locations for distribution of services to end customers. Each Grid locations have multiple IED panels that connect to the RTU (data concentrator) at site. The underlying protocols on grid might vary e.g. IEC 61850, Modbus etc. However once it is forwarded to RTU, the RTU converts the communication protocol to IEC 104 standard and forwards it to the SCADA servers in Master Locations via the Utility own MPLS Infrastructure. Figure 1 depicts the architecture of SCADA system without OT firewall in place.

3.1 Installation of Firewall at Substation

The firewall is deployed in bridge (L2 transparent) mode at all grid substations. The connectivity from Ethernet switch for SCADA services towards router is bridged through the firewall. This implies, that a pair of port is configured in bridge mode on the firewall for each SCADA service and cables from switches connects one end of the bridge pair while other cable connects the second interface of bridge pair towards the router. This will only require the physical cable connectivity change where as there is no logical changes w.r.t IP address, routing etc. in the network for this connectivity.

The OT Network monitoring tool fetches the Grid's OT data from the respective grid firewall itself. As the Grid firewall has the OT switch data using the Mirror port (along with feeds) from the local OT switch.

A Mirror/SPAN port is configured on the existing substation switch. The port is configured such that it captures the data from specific ports related to OT assets like RTU/IED Panels etc. This mirror port is connected to a dedicate port on the substation firewall; thereon the OT network monitoring tool System fetch the copy of traffic from the firewall. Architecture after installation of OT firewall at control center and grid substation is depicted in Fig. 2.

3.2 Installation of Firewall at Control Centre

Similar to grid substations, the firewall is deployed in bridge (L2 transparent) mode at control centres. The connectivity from Ethernet switch for SCADA services towards router is bridged through the firewall. This implies, that a pair of port is configured in bridge mode on the firewall for each SCADA service and cables from switches connects one end of the bridge pair while other cable connects the second interface of bridge pair towards the router. This will only require the physical cable connectivity change where as there is no logical changes w.r.t IP address, routing etc. in the network for this connectivity.

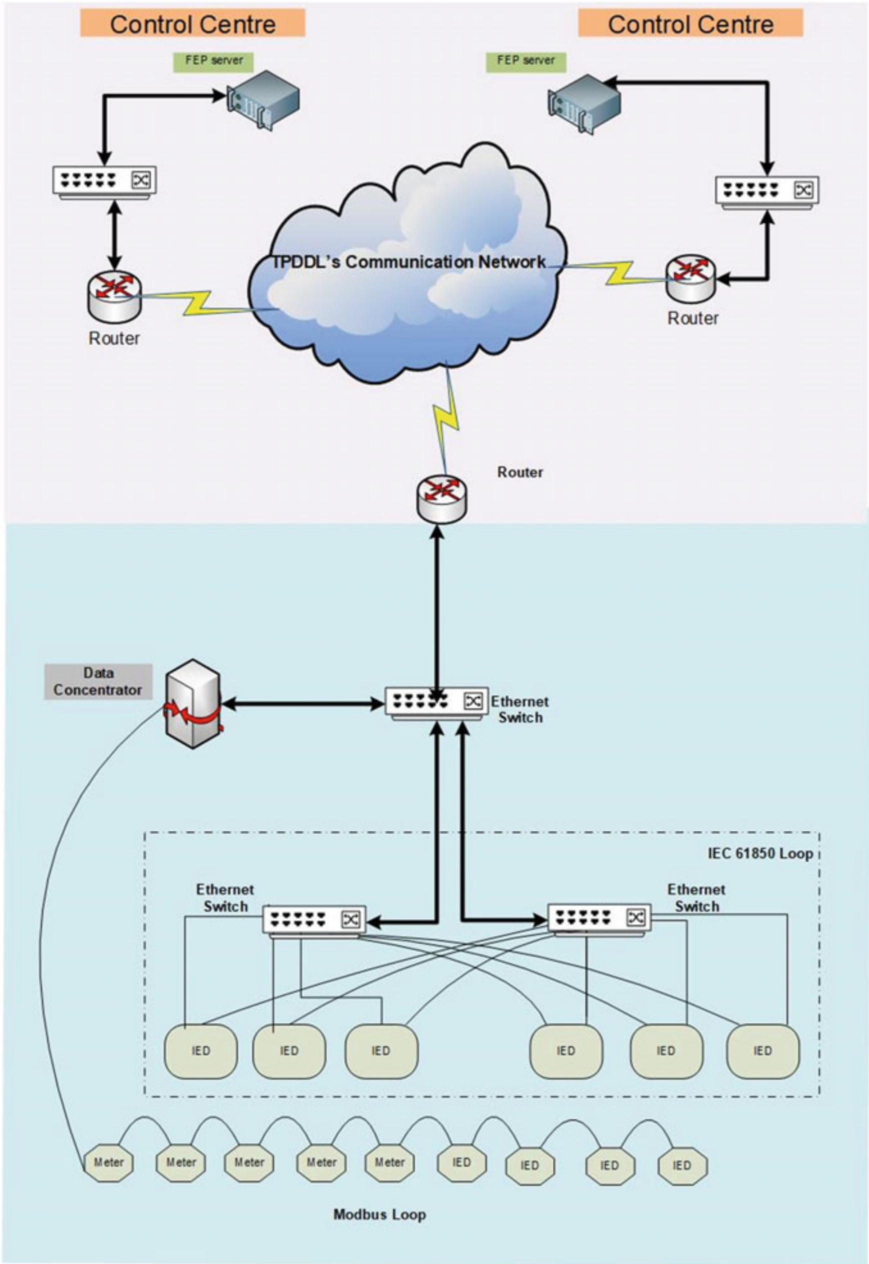

Fig. 1 SCADA architecture without OT firewall

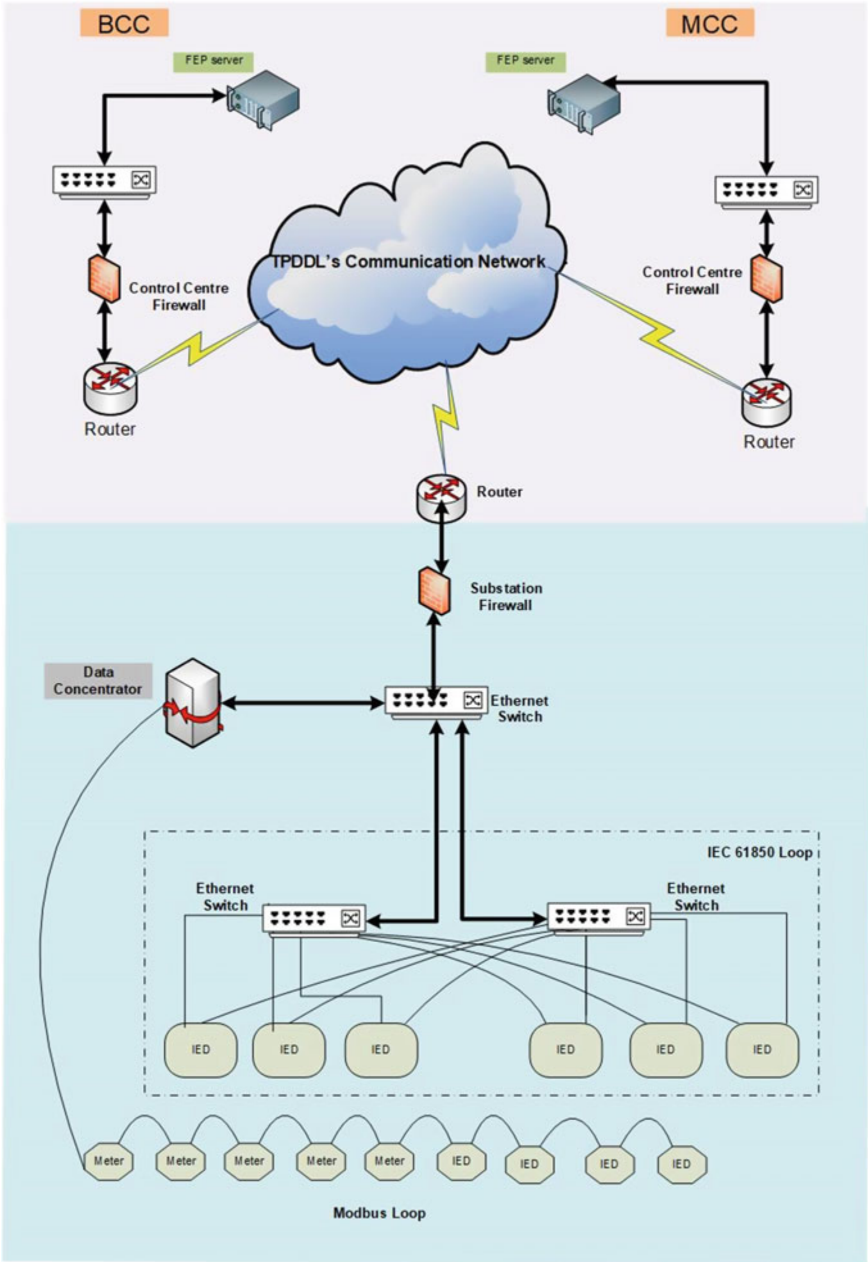

Fig. 2 SCADA architecture with firewall

Security Features enabled on Next Generation Gateways:

a. **Firewall**—Software Blade incorporates all of the power and capability of the revolutionary Firewall solution while adding user identity awareness to provide granular event awareness and policy enforcement
b. **Anti-Bot**—The Anti-Bot Software Blade detects bot-infected machines, prevents bot damages by blocking bot C&C communications.
c. **Anti-Virus**—Antivirus uses real-time virus signatures and anomaly-based protections, extensive threat intelligence to proactively stop threats and manage security services to monitor your network for rapid incident response and fast attack resolution.
d. **Intrusion Prevention (IPS) System**—The IPS Software Blade delivers complete and proactive intrusion prevention, all with the deployment and management advantages of a unified and extensible next-generation firewall solution.
e. **Application Control**—Application Control enables IT/OT teams to easily create granular policies based on users or groups—to identify, block or limit usage of applications and widgets. Applications are classified into categories, based on diverse criteria such as applications' type, security risk level, resource usage, productivity implications and more.

All the firewalls (Substation and Control Centre) is managed by a Centralised Firewall Management System. The same Firewall Management system also act as the central Log servers, event and reporting server for all integrated firewalls. This implies all the deployed firewalls are forwarding the traffic logs to the central management server.

Prime functions of the Centralised Firewall Management System:

a. Network Policy Management
b. Logging and Status
c. Monitoring and Reporting
d. Events and Logs Correlation
e. Reporting Software Blade.

3.3 OT Monitoring Tool

OT monitoring tool automatically discovers assets, learns network topology, models the networks unique communication patterns and creates a fine-grain behavioural baseline that characterizes legitimate traffic. The system provides important insights about network hygiene, configuration issues, and vulnerable assets. This tool is deployed centrally at control center for the continuous monitoring of OT network assets and communication across control center and respective grid locations.

It constantly monitors the SCADA network traffic and generates alerts for anomalous network behaviour that indicates a malicious presence and for changes that have the potential to disrupt the industrial processes.

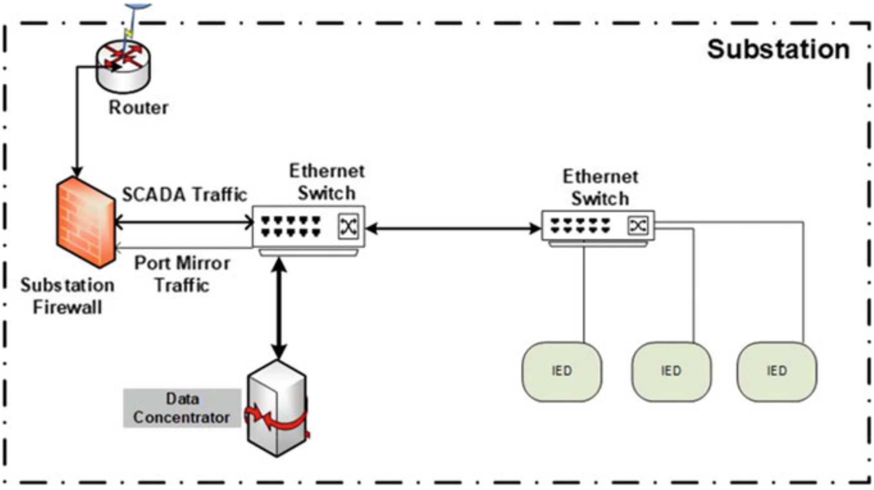

Fig. 3 Firewall architecture with port mirror configuration at grid

This system collects the data from respective location via the firewalls, where the firewall collects the data from respective locations local OT/SCADA switches through a mirror port (span port). Figures 3 and 4 shows the port mirror connectivity for Control centre firewall and substation firewall with OT monitoring tool.

A Mirror/SPAN port is configured on the existing switch. The port has to be configured such that it captures the data from specific ports related to OT assets like SCADA Servers and IEDs. Since the few servers are also connected on other switch, we have extend the require the data copy of required ports on the configured mirror port on switch 1 via methods like RSPAN since both the switches are configured on stack. This mirror port is connected to a dedicate port on the master Control center firewall monitored interface; thereon the OT Monitoring tool fetches the copy of traffic from the firewall. Benefits are

- SIEM systems
- Log management systems
- Asset management system
- Ticketing system.

Few Features of OT monitoring tool:

1. The system identifies alerts on devices that stop communicating, allowing the user to set the threshold for inactivity duration, per asset or group of assets. Alert on devices that are non-communicating not configured.
2. The system presents the following details on devices that respond to SNMP queries (e.g. networking equipment/ICS assets): system description, up-time, contact name.
3. It identifies dormant assets, ones that are not communicating over the network.
4. It allows the user to configure it to monitor specific IP range/IP ranges.

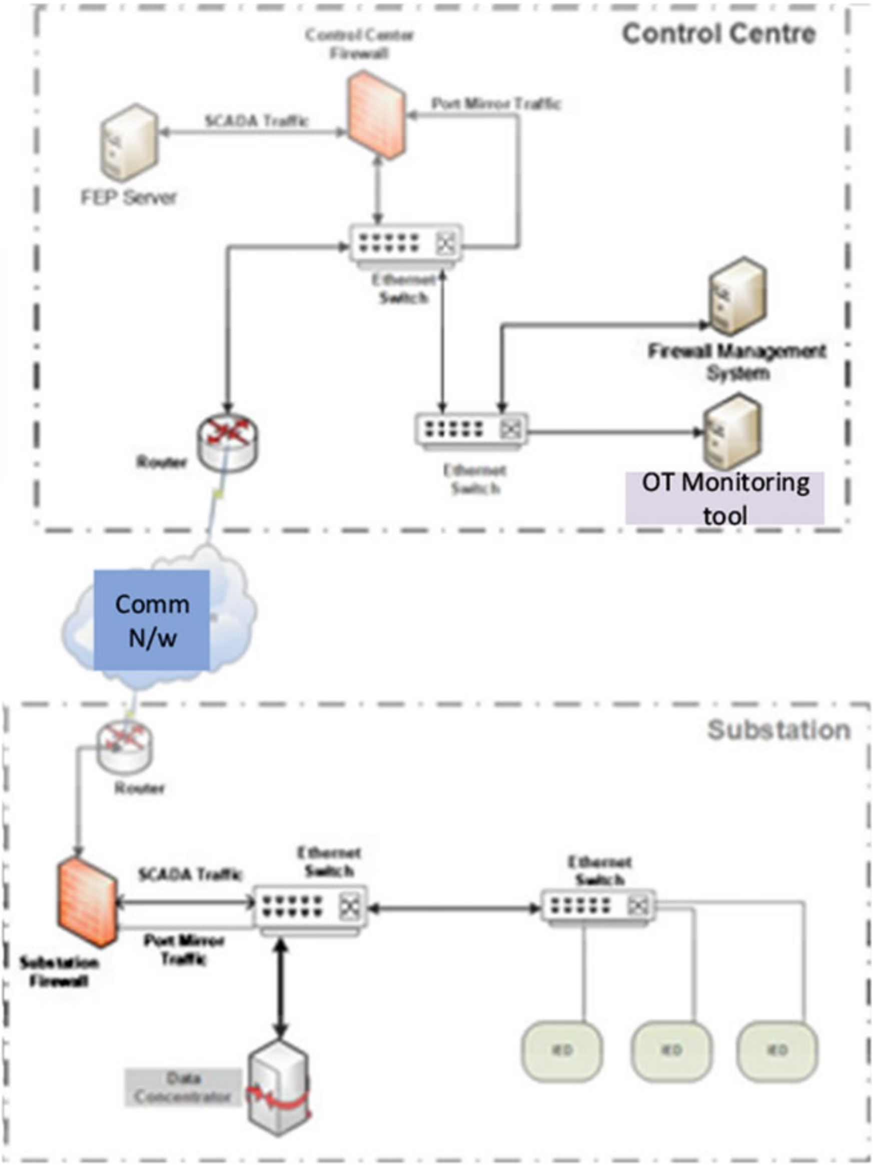

Fig. 4 System deployment architecture with SCADA and port mirror connectivity

5. It discovers: (1) level 2 control devices: operator stations, engineering workstations, and servers (Windows/Linux-based). (2) Level 1 control devices: RTUs, BCPU's, IED's. (3) Level 0 devices (I/Os).
6. It identifies and alerts on code changes that are done on RTU/IED locally as well as over the network.

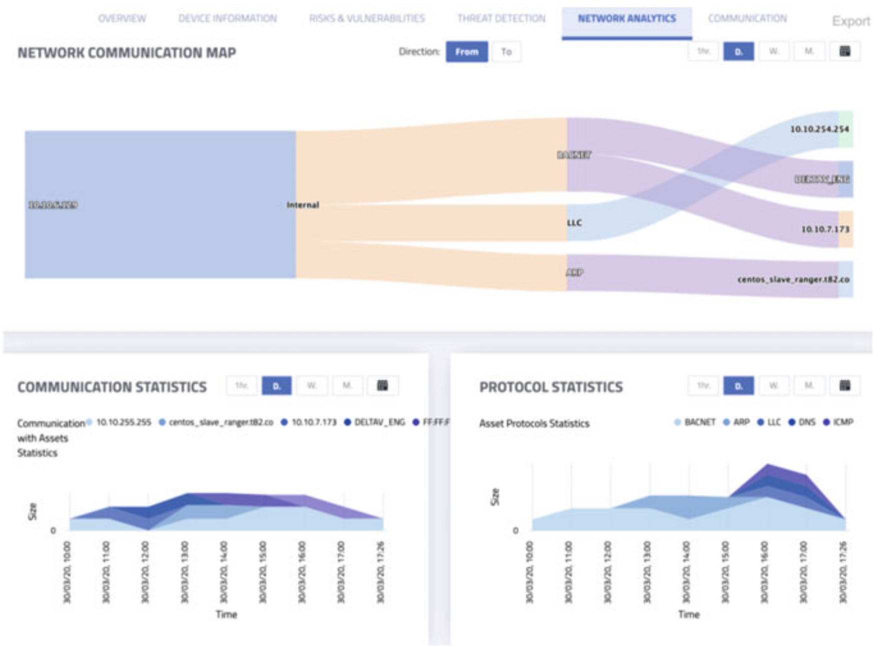

Fig. 5 Detailed asset page—network analytics

7. Baseline normal network traffic volume and protocols, then alert when network traffic is outside of that norm.
8. The system identifies alerts on any traffic sent to industrial assets that uses un-allowed network port/protocol, by vendor.

Figure 5 shows the network analytics functionality of the OT monitoring tool.

4 Challenges/Learnings During Implementation

OT Cyber Security is still a new and emerging technology in Power Distribution and not many power system/industries has used it as a combination of IPS and IDS system.

During the initial phase of the project, main challenge faced was the configuration of firewall such that it passes on the SCADA traffic as well as the port mirror traffic which is necessary for OT monitoring tool system. At present very few solution are available in market which are designed commonly for firewall and sensors feed in single box in OT environment.

The traffic flow in the grid network with all IEDs and RTU was known however the data rate and throughput was still unknown for different make of IED’s. The network switch configuration need to be done as per the requirement of firewall wherein a port was to be used for flow of SCADA traffic and other was to be used for port Mirror data accordingly.

Switch configuration such as port limiting, spanning tree protocol enablement, ingress settings were also explored and implemented to avoid the bulk broadcast traffic. These were generally not used in conventional grid networks for SCADA communication.

5 Conclusion/Benefits

The deployed system is not only responsible for detection and prevention of the threats but also alarming the operator for the identified threat.

OT cyber security solution quickly detect industrial operations risk, enhance cyber resiliency, and minimize unplanned downtime. It provides:

- extreme visibility
- continuous threat and vulnerability monitoring
- deep insights into ICS networks.
- extracts precise details about each asset on the industrial network
- profiles all communications and protocols
- generates a behavioral baseline of legitimate traffic.
- it alerts you to network changes, vulnerabilities and threats.

It also offers Deep Packet Inspection (DPI) which identifies:

a. The specific assets on the network
b. The lines of asset communication
c. Communication timing
d. Protocols between assets.

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IIOT in Utility Operations Paper

Varun Thakur and Abhinav Mogha

Abstract In this paper, we have explicitly described about the needs, implementation methodologies, and challenges being faced in Internet of Things (IOT) solutions adoption in Tata Power-DDL operations. Utilities have been trying hard to optimize Operational and Capital expenditures to achieve higher operational efficiencies and improved performance indices. A Smart grid roadmap was adopted by TPDDL and technologies like Substation and Distribution Automation, SCADA/ADMS, GIS, AMI, DSM, Smart Meters, Communication Infrastructure and RF Canopy have been successfully implemented. Early technologies in TPDDL different verticals have dedicated centralized smart systems with field devices are often appeared to be locked into purpose built, non-interoperable solutions. As uses and requirements multiplied, the complexities and obstacles to integrate these SILOS of technologies are becoming more and more challenging. The Internet of Things (**IoT**) is creating huge opportunities in Power Utilities, adding value to both the **Utility** and the **Consumer**. IOT or Cloud based solutions which utilizes all three technology verticals i.e. IT, OT and Communication infrastructure break open the new era of "Digitalization and Data Analytics" in Power Industry. In TPDDL, we have implemented IOT innovations which are helping us to drive down the cost in Operations and Maintenance and Project Execution. **Case I**—IOT based communication system to conduct an Integrated-Factory Acceptance Test. I-FAT plays an important role to ensure timely completion and quality execution of a project. However, OEMs are still reluctant to conduct the IFAT because most of their equipment's are being manufactured at different geographical locations. An IOT/Cloud based wireless communication was established between two OEMs locations and complete integration and protection testing was carried out using a pair of 4G enabled Modems. Site commissioning of project carried out effortlessly with record time. **Case II**—Remote secure access of SCADA network for Work from Home. During the tested times of Covid-19, an

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IOT based cyber secure wireless connectivity was established by which Automation and Protection maintenance teams could able to connect with Grid Automation devices to perform critical activities like Fault Data recorders downloading during faults, IED breakdowns rectification, RTU and relays configurations. **Case III**—IOT cloud based Power Transformer Residual Life Assessment system. This system is being used to fetch critical performance parameters of transformer like DGA, Oil and winding temperatures, Moisture content and further data analytics. Smart Grid may be viewed as IoT for electric power 1.0. Critical processes and Assets health can now be monitored more accurately using IOT enabled digital data collection and analytics. Connected technologies and operations can reshape the way **Utilities** operate, allowing them to make smarter and more informed decisions.

Keywords Advanced distribution management system · Integrated network management system · Simple network management system · Operations technology · Grid substation automation system · System average interruption duration index · Mean time to restore · Internet message control protocol · Remote terminal unit · Intelligent device

Abbreviations

TPDDL	TATA Power Delhi Distribution Limited
IIOT	Industrial Internet of Things
SCADA	Supervisory Control and DATA Acquisition System
ADMS	Advanced Distribution Management System
RTU	Remote Terminal Unit
INMS	Integrated Network Management System
OT	Operations Technology
IT	Information Technology
SNMP	Simple Network Management Protocol
SSL	Secure Socket Layer
MU	Millions Unit
CAPEX	Capital Expenditure
OPEX	Operational Expenditure
LAN	Local area Network
WAN	Wide area Network
IP	Internet Protocol
SL	Service Level
OEM	Original Equipment Manufacturer
AT&C	Aggregate Technical and Commercial
AMI	Automated Metering Infrastructure
GIS	Geographical Information System
DSM	Demand Side Management
RF	Radio Frequency

FFA	Field Force Automation
IED	Intelligent Electronic Device
DER	Distributed Energy Resource
TCP/IP	Transmission Control Protocol/Internet Protocol
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
TMU	Transformer Monitoring Unit
IIOT	Industrial Internet of Things
HES	High End System
MDM	Meter Data Management
IP/MPLS	Intelli Protection/Multi Packet Label Switching
ICMP	Internet Message Control Protocol
Syslog	System Logs
DTL	Delhi Transco Limited
CPU	Central Processing Unit
GSAS	Grid Substation Automation System
MTTR	Mean Time to Restore

1 Introduction

Tata Power Delhi Distribution Limited (TPDDL) is a Power Distribution Utility, distributes electricity in North and North-West part of Delhi, serving about 1.7 million consumers. TATA Power-DDL has always been an early implementer of latest technologies and procedures in India and has perhaps most number of standalone and integrated platforms in use. These procedures have also been instrumental in improving the overall operational efficiency and performance of the company and also been able to deliver business benefits in terms of return on capitalization of assets and improving reliability. TPDDL's competence in adaptation of latest technologies makes it very appropriate to achieve high standards in optimization of resources in Project Execution, maintenance and management of Grid networks.

Automation of Distribution Grid at TPDDL was started in 2006. Major technology up gradation carried out where in:

- Grid Substation Automation Systems deployed and end to end connectivity communication solutions like Fiber Optical back bone development carried out.
- Distribution Automation carried out with 2G GPRS/Cellular communication.
- RTUs and IEDs were introduced at mass scale.
- Gas Insulated Switchgears compact Substations were installed.
- Digital Substation process bus integration.

All this technological shift took place with the introduction of Operations and Communications technologies. These Communication technologies revolutionizes the conventional Utility Grid operations. Below are the few communication solutions built for different verticals of Utility:

- Grid Substations SCADA connectivity solutions for e.g. Substation to Control Center, Substation to Substation, MCC to BCC.
- Tele protection connectivity for Differential and Distance main protection schemes.
- Integrated Security and Surveillance connectivity solutions.
- GIS, IT-SAP, ERP, FFA and other mobility applications connectivity
- AMI and Energy metering communication Infrastructure.

A distribution grid has become a complex ecosystem of Intelligent Electronic Devices which communicates with each other or dedicated centralized platforms and most of the above communication solutions are purpose built and are non-portable/extensible in nature. This create different standalone verticals of technology platforms which are critical to drive Utility operations but seldom communicate with each other.

2 Approach to Way Forward

Problem Statement/Understanding the need/purpose and Objective

As per the Vision of TPDDL 2.0, ambitious targets have been set for AT&C loss reductions, Capital Expenditures optimization and O&M expense reduction. Up till now major focus was to provide real time information exchange and conventional SCADA operations of distribution network but less focus was given to advance methodologies which further improve the performance of different verticals of Utility operations. Still conventional maintenance and operational methodologies are being used which results in under-utilized Utility assets. Going forward, Distributed Energy Resources integration will make our networks more complicated and unstable. This is the high time to shift our focus from "Digitization to Digitalization" which would help in building a future ready distribution utility. Below are few Major challenges ahead for Utilities.

2.1 Digitization to Digitalization

Utilities experience technical and commercial challenges on a daily basis. In utility operations, main focus was given to mitigate the technical challenges and subsequent technology advancements were made to automate a Grid Substation and distribution network. Major developments were carried out in secondary section i.e. Substation Control Room or control and protection equipment's like Relays, BCUs, Transformer Monitoring Units, Energy Meters. "Real time" and "Near-Real-Time" process data exchange was established up to centralized monitoring systems for operational purposes. But during the course of time, it has been felt that less efforts were made towards system health or performance data analysis. Now, this is the time to change approach towards Grid substations maintenance and operations methodologies.

2.2 Distributed Energy Resources Integration and Realizing Economic Benefits

Energy demand is rising approx. 8–10% every year and Utilities are more dependent on conventional generation of power procured through PPM. The advent of distributed energy resources (DERs) is changing the way power is generated and transmitted to the electric grid. DERs, the smaller power sources that can be used individually or aggregated to serve the grid, have paved the way for a two-way flow of energy and allowed the incorporation of new, connected technologies for power generation.

DER technologies—such as solar arrays, micro grids, and battery energy storage systems or EVs bring with them a host of challenges which include, a threat to utilities from grid instability, reductions in revenue. With volatile nature of DERs, it is not just the electrical integration but the digital/data integration which will play a critical role to effectively utilize DERs to their full potential with economic benefits to utility. An umbrella of plug and play IIOT communication devices will be required to integrate these huge numbers of DER sites.

2.3 Advance Utility Assets Health Monitoring, Analysis and Condition Based or Predictive Maintenance

Substation equipment's like transformer, CT, PT, Relays, RTU, Breakers, Isolator and Earthing Devices requires proper maintenance on regular basis for their proper functioning. Any abnormality in their condition may lead to faults, non-compliance hereby impacting our SAIDI, SAIFI and AT&C figures. Hence, practice of Asset health monitoring and analysis is required, which is directed towards predictive maintenance rather than preventive or corrective maintenance practices currently followed in most of the utilities.

For developing these practices, IIOT analytics platform should be made which take the real time data of these equipment's, Name-plate data, specifications, maintenance schedule history and by using advanced AI & ML algorithm predicting the fault/abnormalities. Currently we have been putting significant efforts in getting real time process data like V, I, P, Q, PF, OTI, WTI, Temperature, earth resistance, DC voltage condition and various other parameters.

2.4 Utility Technologies Integration

TPDDL implemented many technologies under smart grid road map for e.g. Grid Substation and Distribution Automation, SCADA/ADMS, GIS, AMI, DSM, Smart Meters, Communication Infrastructure and RF Canopy in a phase wise or multi period manner. All this was done to achieve operational efficiencies but off late it has been realized that there is utmost need to interface or integrate these technologies for seamless data availability under a common platform in order to optimize our processes and acquire high level of operational efficiencies otherwise there is threat that these implementations will become liabilities. IIOT Cloud based servers are ideal for similar interfacing of technology platforms and seamless data exchange.

2.5 Conventional Project Execution and Maintenance Practices

We have been continuously facing challenges related to excessive time taken for automation activities in new grid commissioning and expansion projects of 66/33 kV Bay or 11 kV Bus. Initiatives were also taken like Integrated-FAT and was conducted successfully at one OEM factory however other OEMs are still unable to conduct I-FAT due to unavailability of a communication link between their major facilities in India where different IEDs are being manufactured. Sometimes automation I-FAT could not be done at BA factory and bulk of the integration testing is done at Site which results in excessive commissioning time and compromise on certain quality parameters as well because you never get the high competency BA workforce at Sites.

An IIOT based solution can be used to establish plug and play communication between any two geographical locations to perform seamless integration testing.

2.6 Advance Maintenance Systems to Deal with Contingency Scenarios like Covid-19

In addition, with recent smart grid initiatives, more numbers of OT devices are being deployed across all verticals of Grid Networks for real time information exchange and advanced big data analysis.

A future Power Grid will be a huge complex system with two way flow of Electricity and information with multi-dimensional deployment of IEDs for e.g.

- Multi layers sensors, Analog to Digital converters, High end transducers
- Advanced Telemetry and Communication solutions like Optical, RF, Cellular, IIOT based

Fig. 1 IOT components

- High end computing processors, algorithms, servers.

It is clearly indicative that, performance of Grid Networks is directly linked to the performance of these OT IEDs network. Maintenance and Management of these IED's has been a challenge for any Utility due to absence of a smart interoperable solution which is capable to be interfaced with different verticals of Operations and can fetch critical system asset health data which will be analyzed to detect any anomaly to predict the failure of any device, equipment or process. This would ensure the performance, availability and reliability of these IEDs which subsequently increase the efficiency and productivity of Power grids.

3 TATA Power DDL Steps Towards Implementation of IIOT

An IoT system consists of sensors/devices which "talk" to the cloud through some kind of connectivity. Once the data gets to the cloud, software processes it and then might decide to perform an action, such as sending an alert or automatically adjusting the sensors/devices without the need for the user (Fig. 1).

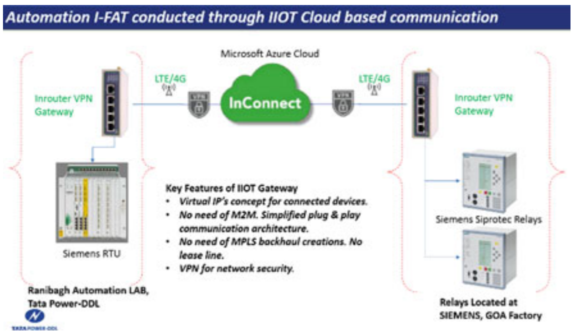
IIOT major components:

1. ***Sensors***
2. ***Communications***
3. ***Data Analysis***

4 Case I

We have faced challenges related to excessive timelines in completing the new grid commissioning. Initiatives were also taken like Integrated-FAT but many OEMs still unable to conduct I-FAT due to unavailability of communication links between their major facilities where different IEDs are manufactured. Due to absence of I-FAT bulk of the integration testing is done at Site which results in excessive commissioning time and compromise on certain quality parameters as well because you never get the high competency BA workforce at Sites.

An IOT based communication platform has been devised which is used to establish quick (plug and use) communication between two geographical nodes through which remotely located IEDs (OEMs factory) can be integrated with the RTU installed in local Substation or LAB or at any other location (Tata Power-DDL) to perform automation integration testing and a series of successful Integrated-FATs were carried out.



In this platform, we have used a set of portable modems installed at both locations which provide the wireless communication links between two or more LAN connections. Modems use available network 4G technology to ensure real time connectivity of two stations without any delay or latency.

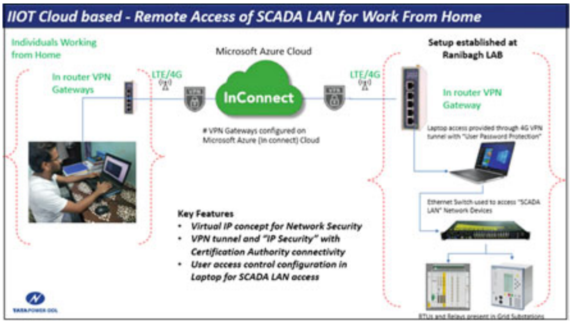
Remote Integrated Factory Inspections were conducted through Internet of thing (IOT) based FAT for turn grid and bay extension activities wherein IEDs/Relays were located at SIEMENS, GOA factory and RTU was at Tata Power-DDL, Ranibagh Lab, Delhi location. Real time automation integration testing was performed with no latency observed. For pairing of IPs between RTU and IED devices (situated at two different locations) an application was hosted in cloud to assign virtual static IPs as SIM cards used for this purpose are normal one with dynamic IPs.

This IOT based Integrated FAT testing not only beneficial during normal conditions which significantly save the new grid commissioning time, no requirement of expert OEM engineers at site, which generally results in massive delays and high cost, but it also proved super valuable during Covid-19 pandemic where keeping the projects activities kept moving itself was a challenge. Through IOT based communication, many factory testings were conducted seamlessly to achieve Business Continuity in these testing times.

5 Case II

Tata Power-DDL has set the new benchmarks in Distribution Grid operational efficiencies with better SAIDI, SAIFI and reduced AT&C losses. Major contribution is from Grid Substation Automation Systems with introduction of RTUs and Intelligent Relays/IEDs for centralized monitoring and control of Substations. During the tested times of Covid-19, due to imposed lockdown conditions, it was a bit challenging to mobilize workforce but Automation had assured Power system Control (PSC) THAT it stands committed in providing reliable-communication and availability of GSAS. The objective was to provide prompt support with optimal utilization of resources for ON Site and OFF Site and re-establishment of working mechanism without affecting the performance.

An IIOT cloud based Wireless connectivity solution has been devised which securely connects to SCADA LAN network remotely to access the IEDs and RTUs to attend emergency breakdowns and to carry out critical maintenance or project activities. An IIOT Cloud based Modem/Gateway is installed at Ranibagh Engineering LAB which is connected to a centralized Laptop/PC system which subsequently connects to SCADA LAN network.



Individual sitting at home is able to access the centralized Laptop/PC first and then, they can connect with Grid RTUs/IEDs. Necessary Cyber Security measures have been adopted like:

1. Virtual IPs have been assigned to each node which makes it a protected network OVER undesirable Global IP addresses which are prone to network attacks.
2. VPN tunnel Cloud connectivity with IP Security. Also modems have inbuilt Certification Authority for gateway connection.
3. User access control for Ranibagh Laptop access. Multi users have been created with different login credentials. System access logs being captured to check any kind of intrusion. Password change policy also adopted.

It greatly helps us in minimizing site mobilization of team members during Covid-19 lockdown to ensure the safety of Employees but simultaneously it was also ensured that emergency breakdowns are timely restored. Critical maintenance and project activities are also carried out. Automation Persons sitting at home able to perform below important activities.

1. RTU/Relays Configurations and diagnostic analysis during breakdowns and resolution of any operational variance (OV) reported by PSC.
2. FDR (Fault data recorder) remotely fetched from relays in tripping and restoration analysis,

Full availability and reliability of GSAS was maintained for seamless centralized monitoring and network operations during these challenging times. All the efforts mentioned above has ensured 24*7 support to PSC for the reliable operation and hence ensuring quality and reliable Power to our customers.

With the use of this solution, the automation and protection team can connect with Grid RTUs/IEDs while Working From Home. The system has all the necessary Cyber Security systems in-place. The complete setup helped the organisation in minimizing site mobilization of team members during Covid-19 lockdown to ensure the safety of Employees while simultaneously ensuring the completion of the following important activities:

- Timely restoration of RTU/IED related issues in case of emergency breakdowns.
- RTU/Relays Configurations and diagnostic analysis during breakdowns and resolution of any operational variance (OV) reported by PSC.
- FDR (Fault Data Recorder) remotely fetched from relays in tripping and restoration analysis.
- Integrated factory acceptance test (I-FAT) for automation and protection device
- Point-to-point testing for project related activity.

The complete system was tested successfully during the Lockdown phase and is being adopted presently for day to day work as well.

6 Case III

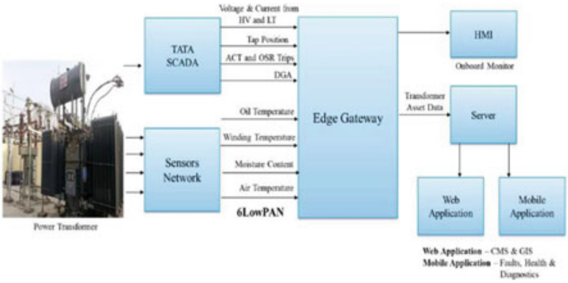
IIOT based Transformer Asset Health Monitoring system POC has been carried out to measure—Transformer Efficiency or Residual Life Assessment or Real time PTRs performance measurement.

Four Power Transformers have been identified on the basis of TAN Delta results, DG results and Ageing of the transformers.

Critical parameters of the transformer have been monitored on the cloud based platform through an IOT based controller installed in Grid Substation. Sensors have been installed in Power Transformer and existing SCADA data interfaced with IOT controller which eventually transmit data on cloud system. Below are the parameters considered:

1. ***Temperature of oil and windings***

2. ***Electrical load levels (Voltage, Current and Active Power values on both sides of windings)***
3. ***Moisture level***
4. ***Operation Status of cooling fans***
5. ***Gas sensors***
6. ***Hot Spot winding temp***
7. ***Ambient Temp***
8. ***Top oil temp***
9. ***Fault current monitoring.***



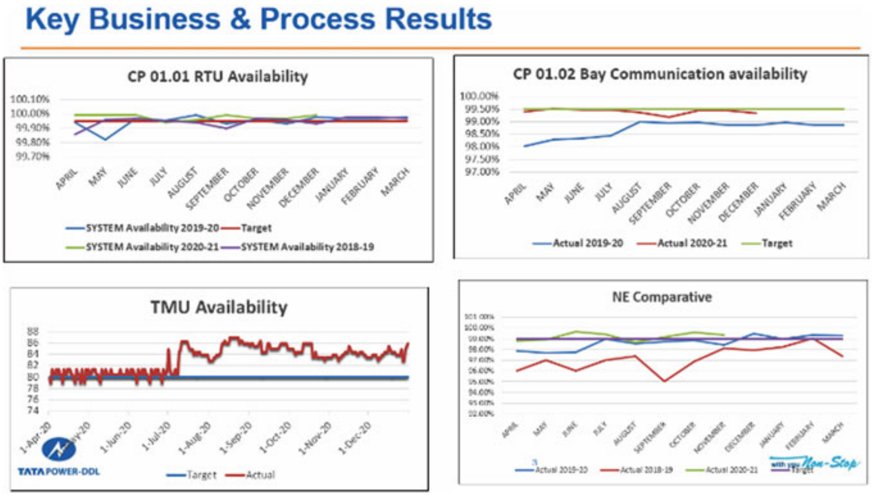
Critical processes and Assets health can now be monitored more accurately using IIOT enabled digital data collection. These digital transformations takes the guesswork out of processing and allow utilities to achieve high Operational Efficiencies and Profitability with optimized resources while maintaining high safety standards thus saving time, life, money and empowering operators to make fewer mistakes.

Cloud-based predictive analysis applications easily connects to Power Transformers and Distribution Transformers and helps Utilities avoid costly and inconvenient failures, allowing engineers to schedule controlled maintenance rather than reactive maintenance. IOT Connected technologies and operations are reshaping the way these utilities operate, allowing them to make smarter and more informed decisions.

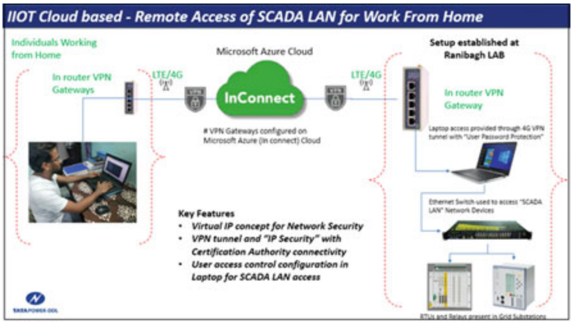
A transformation promising to change how companies work—improving connectivity, efficiency, reliability and safety.

7 Analysis and Impact

1. Significant increase in Automation Availability Index and subsequent increase in numbers of Successful breaker operations due to increased reliability and availability of GSAS OT devices.



2. 24 × 7 Remote configuration and trouble shouting of automation System (IED, RTU, FRTU etc.)
3. Integrated Factory acceptance test (I-FAT) for new IED and Equipment.
4. Ensure business continuity in Sub-transmission and Distribution network during COVID-19 pandemic.



5. Reduce the carbon footprint due to less mobilisation of Protection and automation team.
6. Culture Development of Work from Home and flexible timing in power Distribution.
7. Enhance productivity due to elimination of traveling time to site location.

8 Business Impact

1. **Cost saving:** 5000 km*4Rs./KM = 20,000*10 months = 200,000 Rs., Cost saving in Online FAT = 40,000 (per person Cost) * 2 (no. of person) * 5 (No. of FAT) = Rs. 400,000, MU loss reduction of 0.0835 MU = 0.0835 * 10^6 * 5.10 = 425,850. Overall at a prudence level Rs. 1,025,850 Saving observed from a period of March to December 2020.
2. **Carbon reduction:** Due to Less mobility huge saving in fuel in turn reducing the carbon footprint significantly.
3. **Man-hour-saving:** Saving of the travelling time to a significant level.
4. **High Reliability:** Reduction in SAIDI, SAIFI and AT&C losses as IED failure.
5. **Employee Satisfaction:** Automation Engineer were able to resolve the cases from the comfort if their home.
6. **Customer Satisfaction:** As most people doing wfh, we were ensuring 24*7 supply to them.

9 Return on Investment

Each module cost is around 10,000 * 2

Installation accessories 1000

Total cost = Rs. 21,000

Total saving estimated = Rs. 1,025,850

Total ROI = 4885%

10 Scalability

Highly Scalable and Tata Power DDL is utilizing this technology for IED asset health monitoring, breakdown maintenance, Predictive maintenance, Power quality improvement, Distribution automation, and establish redundant communication infrastructure for emergency.

11 Uniqueness of Project

This IIoT platform promises empowerment and opportunity enabling our utility to oversee communications that reach across and into the homes and workplaces of their customers. With a unified, global solution approach in the execution of Project and maintenance acitvities combined with the lessons learned about security, privacy and engagement with consumers—utility should embrace the uncertainty ahead and lead in the IIoT era.

12 Challenges Faced During Implementation

Early technologies in TPDDL different verticals have dedicated centralized smart systems with field devices are often appeared to be locked into purpose built, non-interoperable solutions. As uses and requirements multiplied, the complexities and obstacles to integrate these SILOS of technologies are becoming more and more challenging.

Key risks likely to face moving forward:

- OT environment is getting exposed to outer levels: We are already in process of implementing Cyber Security in our all grid substations.

13 Conclusion

TPDDL works under regulatory business where CAPITALIZATION and OPERATIONAL expenses are closely monitored by DERC. Our company always strive to control our overall CAPEX/OPEX expenses, these initiatives will definitely improve the performance of RTUs/IEDs as measures will be taken before actual fault scenario. Power system reliability will get improved and MUs loss will reduce. Also, usage of IOT and Cloud based communication platforms will improve the performance of

Project executions and maintenance methodologies. Subsequently, this will improve operational efficiencies. Remote access of large numbers of OT devices network will also decrease carbon footprints on account of team mobilization for on-site accessing of devices and will further increase resource utilization.

Reference

1. IOT in Utility Operations paper has been selected for ISUW2021

Demystifying Digitally Empowered Prosumer—Transformation Opportunities for Utilities in Energy Value Ecosystem

Anindya Pradhan and Sudipta Saha

Abstract Utilities business is getting more and more attractive and interesting, thanks to consumer empowerment, blurring of industry boundaries, fusion of energy and exponentially emerging technologies and transition towards the new business models. Consumers, who are already donning the hats of 'prosumers' are opinionated when it comes to exercising their choices, control, and comfort from the utilities. The two-fold democratization of consumers and energy are empowering the prosumers to partner with the utilities in grid management. Paradoxically, consumer perception about the utility is still evolving and according to IDC Utilities Consumer Survey 2020; the Net Promoter Score (NPS) for Utilities Customers are still negative. That propels the Utilities to pay heed to the digitally empowered prosumer voices and cater accordingly. The paper will start with understanding the need of digitally empowered customers across the value chain starting from Aware, Join, Use, Analyze, Pay, Served etc. A design thinking led approach will be taken to understand the consumer empathy in the journey. Then the paper look how COVID is playing the role of an accelerator for utilities to understand and getting more closure of the customer through new roles like 'partner in crisis'. Next, we will see how global utilities today are leveraging the 'energy value ecosystem' to collaborate and co-create value around the lifestyle of the empowered consumer through fusion of commodity and services. In conclusion, the paper will emphasize the importance of technology and ecosystem to make the voice of customer an integral part of the utility's DNA.

Keywords Digital utility · Customer experience · Utility of future · COVID and utility · Energy value ecosystem

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1 Introduction-Managing Customer Experience is a Must for Utiltites

Consumer and Energy democratization, convergence of industry boundaries, rapid adoption of energy and exponential developments in technologies are creating significant opportunities for Utilities with Prosumer at the center. Utilities today are part of larger 'Energy Value Ecosystem' where they are discovering and creating value in collaboration with prosumer and partners.

Paradoxically, consumer's perception about the utility is still negative to neutral in most of the geographies. In the UK, according to The Institute of Customer Service—'UK Customer Satisfaction Index Report'—Utility Industry is still amongst one of the bottom industries in the table while Leisure and Retail leading the table [1].

In the US, according to the American Customer Satisfaction Index—Energy and Utility Report—for the second straight year customer satisfaction with electric utilities took a hit sliding 1.5% to 72.1 on the American Customer Satisfaction Index's 100-point scale [2]. In Europe, according to IDC utilities Consumer survey, Net Promoter Score of European Customers is still an issue among many of the European countries.

In Australia, according to the Energy Consumer Australia—Energy Consumer Sentiment Survey—57% of household consumers now say they are satisfied with the value for money of electricity, up 22% since the same point in 2017 [3] (Fig. 1).

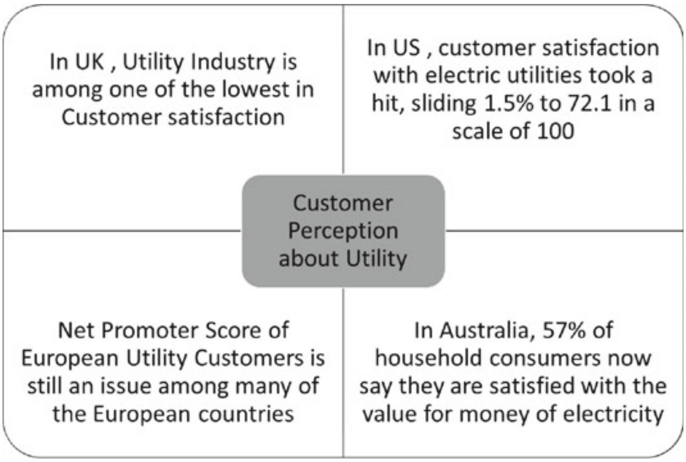

Fig. 1 Customer perception about utilities

2 Utilities Focus on Customer Journey for Managing Customer Experience

Utilities can manage the customer experience either through a journey-based approach or through a touch-point based approach [4] (Fig. 2).

The key advantage of journey-based approach over the touch point based approach is that journey-based approach encompasses the holistic view of the customer experience while touch point based approach primarily focuses on individual transactional experience.

In general, a journey consists of many customer touch points. However, excellence in one touch point doesn't always lead to the overall satisfaction of the entire journey. For example—customer billing complaint journey has multiple touch points such as customer calls the call center, call center agent interacts with customer, call center agent raises a service request for back office resolution, back office team resolves the problem and finally call center agent responds back to customer with the confirmation on the resolution. It may happen that initial interaction of customer with the call center agent went well, however, the resolution provided by the back-office team to this problem does not meet customer requirement and resulting in overall dissatisfaction of the journey.

The above diagram highlights the 6 key important customer journeys for a typical electricity retailer.

It is very important for a utility to understand how to create a positive impact on each of these customer journeys. For example, in case of use energy journey, getting a real time proactive alerts from the utility if consumption exceeds the threshold value is a key differentiating factor. Similarly, various payment options available for the customer to pay energy bill are also beneficial and provide enhanced customer experience.

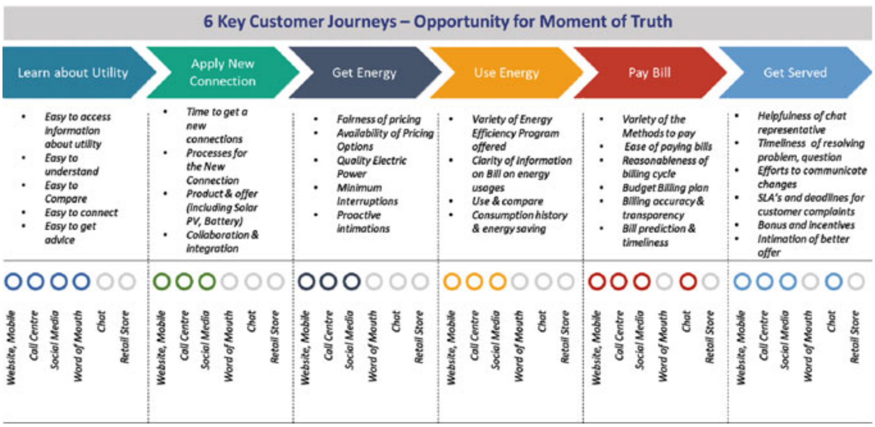

Fig. 2 Key customer journey with utilities

3 Empathy Map for Customer Journey

Understanding the customer voice in terms of say, do, think, feel, pains and gains are very important for the customer journey design. We are seeing that utilities are adopting a design thinking led approach to understand the customer empathy.

Please find below 2 sample empathy maps capturing the voice of the utility customer (Fig. 3).

We see today's customers are looking for personalized attention and to be treated as privileged customer, want to get end to end service beyond energy and to interact with utility anytime-anywhere (Fig. 4).

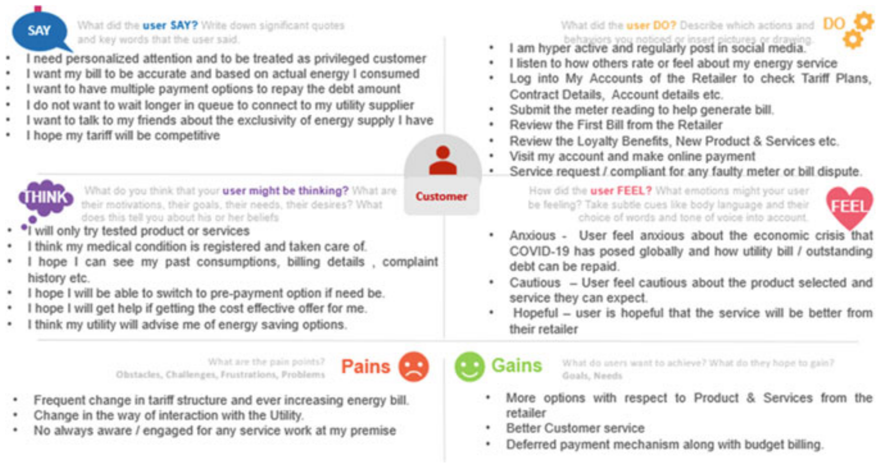

Fig. 3 Customer empathy map

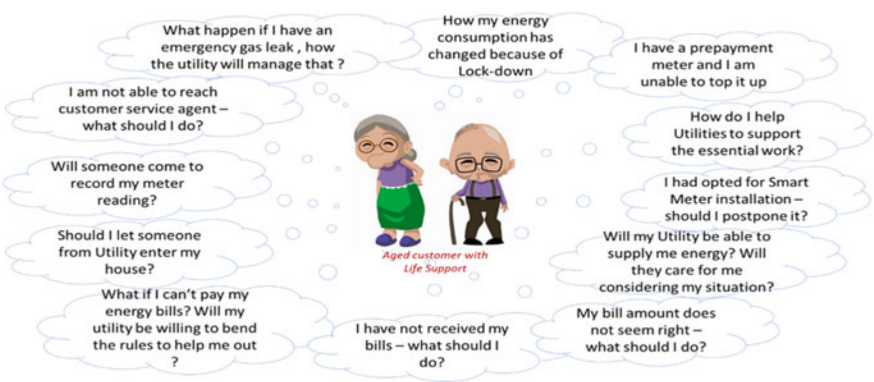

Fig. 4 Customer empathy map during COVID

Due to COVID, many customers are in financial crisis and want to get payment waiver from utility for their bills. Customers today also prefer remote services, wherever possible, rather than physical presence of utility crews at their premises following COVID related norms and social distancing.

4 COVID as an Opportunity for Utilities to Be Closer to Customer

Utilities are among the 16 industries that has been categorized by U.S. Department of Homeland Security (DHS) as critical infrastructure sectors and must be able to operate during a pandemic [5]. While the core purpose of serving the nation and put the lights on continue to remain strong, the pandemic unfolds a new purpose—'Partner in Crisis 'for the Utility.

The pandemic prepares utilities to build an operation that is resilient in managing the increasing call volumes, decreasing/new demand patterns and deferred revenues.

Managing the customer energy demand may not be a key challenge for the utilities in this scenario as demand from commercial and residential sector will decrease whereas residential sector will grow as people will stay in home and may follow a weekend pattern.

However, utilities may expect an increase demand of the call volumes from customers with new issues such as what should customer do if customer is unwell or self-isolating and they have power cut, gas leak or energy meter problems or if a utility company need to access the customer premise.

Prepayment customers may also have the queries like how they can top up their prepayment meters if customer is self-isolating.

Customer and Utility field workers interaction will also change significantly during this scenario. For any non-urgent energy issues, focus will be on self-resolution using mostly online platform, utility App or on call advice. Utilities are also helping customers with their bills by suspending service disconnection due to nonpayment and waiving late fees.

Last but not the least, it is an opportunity for the Utilities to become more adaptable to the changes by leveraging digital to provide safe, secure, simple, and self-driven services to end consumers and bring utilities at the forefront of customer mind.

5 Energy Value Ecosystem

As utilities are moving from energy seller to energy service provider, utilities need to create an ecosystem in collaborations with prosumers, partners and cross-industries. This partnership helps utilities to discover new values such as energy efficiency program, demand side management, bring your own battery, EV charging, DERMS orchestration, home insurance, etc.

We are already observing utilities are merging with telecom service operator to offer bundled product to customer (Fig. 5).

For example, in case of new customer connection utility can leverage the ecosystem of multiple stakeholders such as builder, contractor, architect, electrician, plumber, field engineer, etc (Fig. 6).

The following is an example of how utilities are levering the energy value ecosystem in collaboration with prosumer and partner for defining the value around customer own solar journey. The orchestration of virtual power plant (VPP) along with the demand side management (DSM) will enable prosumer to contribute to grid stabilization and peak load management for utility (Fig. 7).

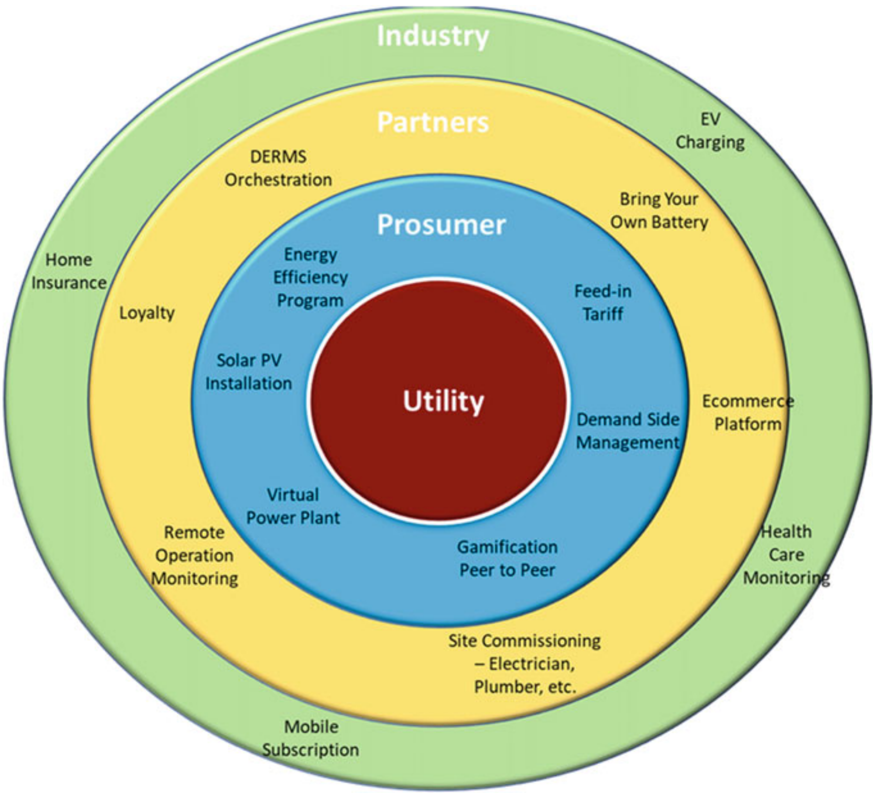

Fig. 5 Energy value ecosystem

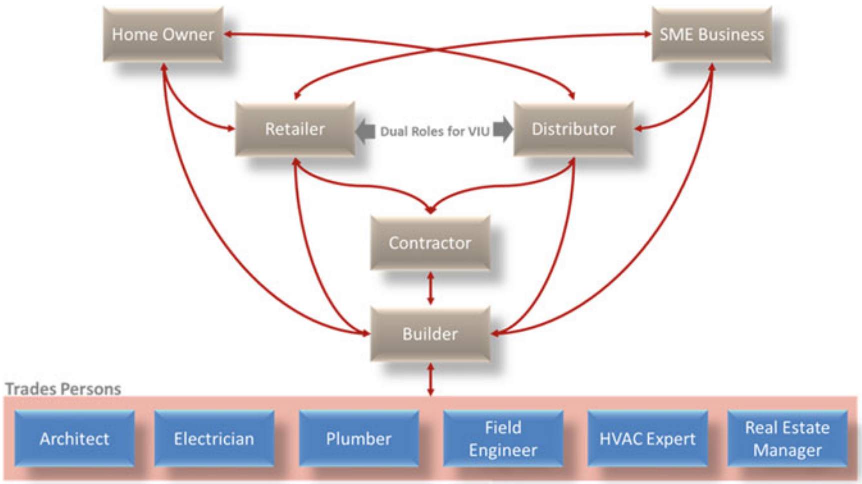

Fig. 6 Partners in new connection ecosystem

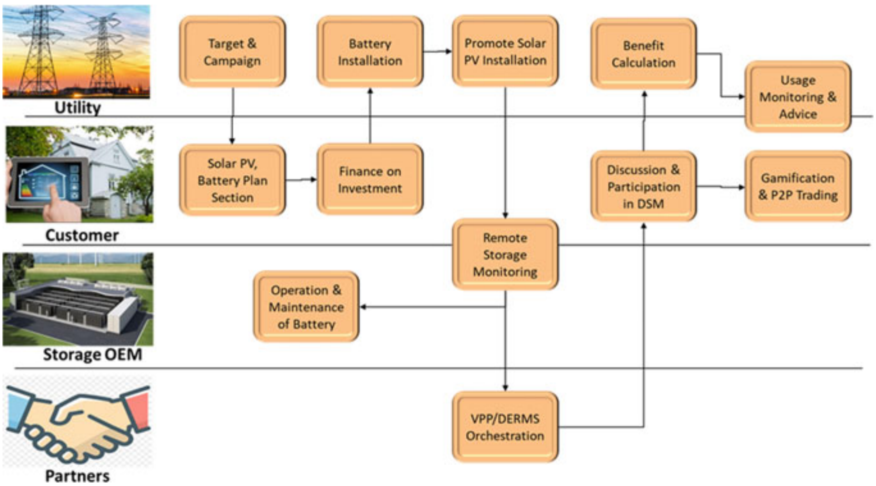

Fig. 7 Customer centric distributed energy ecosystem

6 Customer Management Framework for Utilities

We are seeing utilities are adopting a very structured approach in managing the customer experience across 6 key dimensions—Anytime Anywhere, Hyper Personalization, Trust and Transparency, Communication and Collaborate, Quick and Simple and Customer Empowerment and Engagement.

Anytime Anywhere focuses on 24 $\times$ 7 presence in customer preferred channel along with providing seamless uniform experience to customer across channels.

Hyper Personalization focuses on the contextualized proactive offerings/alerts to customer like advice on appliance on/off, recommended deal for the Electric Vehicle charging station near to customer location, and so on.

Trust and Transparency focuses on building trust with customers across multiple transaction points like billing, meter reading, pricing, complaint management and so on.

Communication and collaboration emphasis on keeping the customer informed about the new offerings, latest changes and so on.

Quick and simple is all about having an experience that focuses on the first time right.

Customer Empowerment is all about providing the right tools and platforms to the customer for better decision making like when to use the battery to the grid or how to optimize the energy consumption (Fig. 8).

In order to support the architectural framework digital technology has a pivotal role to play. Overall stakeholder communications are expected to be both-ways and to be backed by new edge robust technical foundation. There are 3 layers via which entities will be serviced—interaction layer, experience layer and digital fulfilment layer.

While prosumer or partner or utility agents can collaborate using common platform across channels i.e. portal, mobile, telephone, e-mail, social media, etc. the information and knowledge is generated, processed and furnished for consumption with the help of digital technologies like analytics, robotic process automation (RPA), cloud computing, etc.

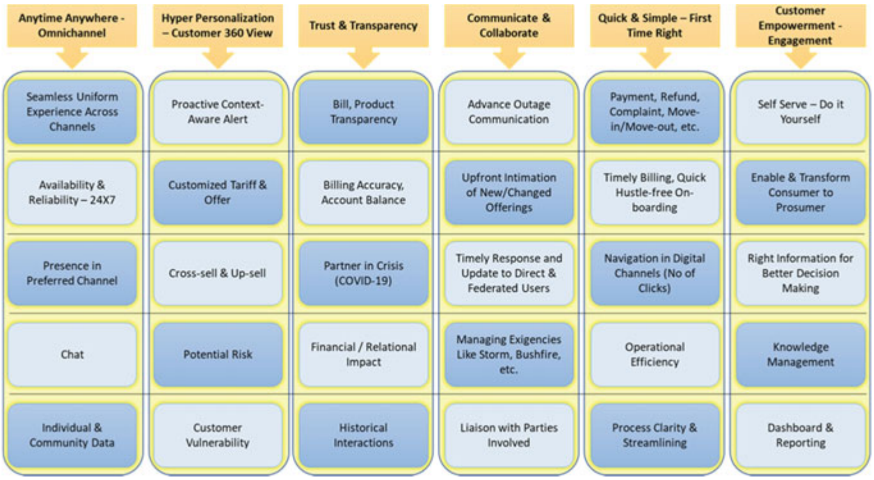

Fig. 8 The framework for managing customer experience

Insights about the required information will be at the fingertips to assist in making the right decision at the right point. The siloed approach with scattered sources of information will be replaced by common platform, onboarding all the stakeholders under a single umbrella and thus increasing the cumulative efficiency of the integrated processes (Fig. 9).

The digital technology platform has 4 underlying levers—agile, automation, intelligence and cloud (Fig. 10).

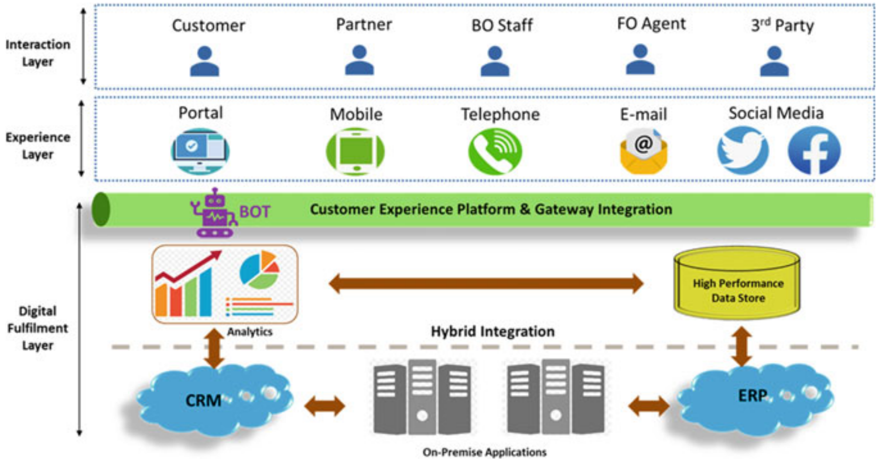

Fig. 9 Digital technology platform as an enabler

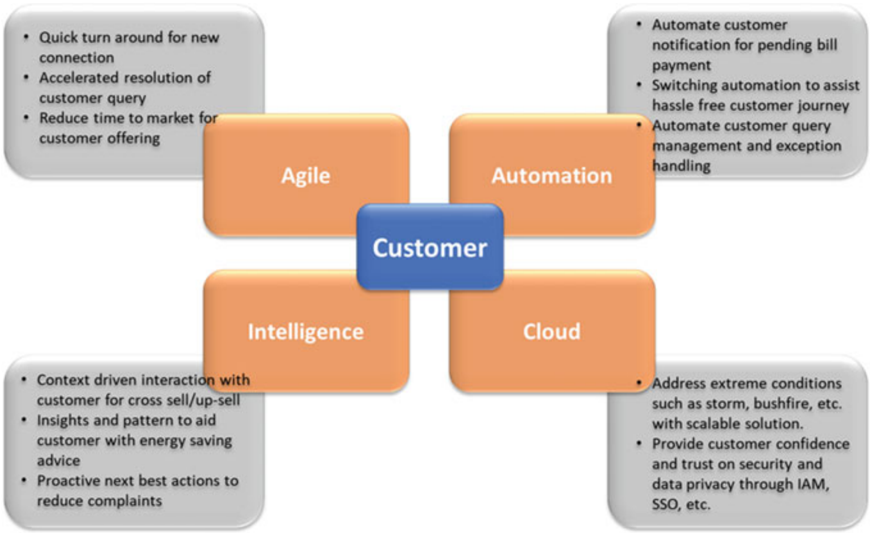

Fig. 10 Levers of digital technology platform

Agile—with the growing adoption of agile methodology, utilities are aiming to provide better services to customer. The lead time of key business processes such as new connection, meter to cash, etc. is being reduced. Customer queries are resolved quicker than what it used to happen earlier. Owing to agile driven reduced time to market, product offerings to the customer are made simple, fast and apt.

Automation—the reduction/removal of manual interventions in the utility processes are of high importance to bring more operational efficiency. It is being observed that automation in customer query management, bill and collection, exception handling are few critical areas where utilities are panning their focus to improve customer satisfaction.

Intelligence—for example the smart home systems use intelligent energy-saving technology to cut costs, reduce wastage and improve convenience. From rooftop solar cells to wirelessly controlled washing machines and heating that adapts to users' needs, intelligence touches on many aspects of domestic life. By adding artificial intelligence into the mix, systems can learn to optimize energy usage based on preferences (e.g. when householders like the heating to be on), and by exploiting real-time electricity prices (e.g. buying-in extra power at times of lower market prices).

Suspicious metering points such as unstable or unexpectedly large consumption, gives an early warning into unusual behavior. However, detecting these metering points requires contextual knowledge.

Insights from data clearly helps solve this situation. Machine Learning and data analysis facilitate customer clustering based on consumption patterns. Utility receives automatic detection of suspicious consumption data to proactively help the customer in finding the cause of the unexpectedly high bills.

Also, some utilities are developing a channel-agnostic, AI-powered chatbot to resolve customer complaints on issues such as outages and bills. Utilities are now able to reduce customer churn and develop deeper insights into their consumer needs.

Cloud—during the extreme scenarios such as storm, bushfire, etc. the scalability benefit of cloud infrastructure is being widely used by the utilities to address high volume customer interactions. Also, the data encryption, identity and access management (IAM), single sign-on (SSO) are some of the unique features of cloud computing that help utilities manage the security and privacy of customer information effectively.

7 Selected Examples from Global Utilities in Managing Customer Experience

Across the globe, we are observing that utilities are taking 4 key approaches in improving the customer experience leveraging the digital.

New Product and Services—we are seeing utilities are coming up with offerings such as subscription model for electric car with home charging facilities, online only brand for tech savvy cost-conscious customers or dynamic tariff for price conscious consumers.

New Sources of Revenue for Prosumers—Utilities are bringing new sources of the revenue for their prosumers by rewarding or incentivizing them if the prosumer enrolls their solar or storage in the VPP program of utilities for managing the peak load.

Platform for Energy Management/Convenience—Utilities are coming with various new platforms for energy management by the customers such as demand side management where customers can change or shift the load against the instruction of the utility. We are also seeing customer convenience platforms for end-to-end customer journey management starting from enrollment to Empowerment.

Joint journey with Customers—In their journey to renewable, utilities are working very closely with the customers to design and develop the renewable roadmap. The joint journey is a win–win situation to both as it helps the customer to have renewable energy and helps the utility to meet its sustainability agenda [6, 7] (Fig. 11).

Fig. 11 Examples of customer engagement

8 Conclusion

Utilities today are in search for new roles and responsibilities around the empowered prosumers. While most of these new roles are focused towards providing an affinity services around the lifestyle of the empowered consumer such as smart home, green energy and beyond the energy, the core of the customer service such as trust and transparency and keeping the power on still play an equal important role in improving the customer experience. The success of the customer improvement lies how utilities can provide affinity services without affecting the core of the customer services.

Last but not the least, involving the customer from the beginning in defining all of these customer journeys; not only to obtain the customer buy-in and their empathy captured, but also include a feedback loop from the customer to correct the course of journey at the all the way through.

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Smart Solutions Based on Smart Metering Data to Improve Distribution Network Operations and Customer Management in France

Antoine Trobois, Sébastien Brun, Victoria Tan, and Laurent Karsenti

Abstract Energy transition, with the integration of distributed energy resources, and digitalization are new challenges that transform distribution networks management in depth. Those challenges lead to a new role for the Smart Distribution System Operator in a growing digital environment: the DSO as a Data Manager. The Smart Metering infrastructure, with all the data it generates, is the game changer for Grid Operations and Customer Management that allows the DSO to embody this new role. In France, the DSO Enedis has developed Smart Solutions for Grid Operations and Client Satisfaction based on its homemade Smart Metering System Linky:

- Solutions for Grid Operations
  - MV Network Dispatching
  - LV Network Operations
  - Quality of Supply Monitoring
  - Network Model Improvement
  - Big Data for Predictive Maintenance
- Solutions for Client Satisfaction
  - Collective Self-Consumption
  - Open Data
  - Public Lighting Management
  - Customers Emergency Management.

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Those solutions are also proposed worldwide by EDF International Networks—the subsidiary that promotes Enedis expertise abroad. In this paper, we will detail those Smart Solutions and emphasize their benefits from a DSO's point of view. Moreover, we will focus on the main milestones of the process for a DSO from customized solutions development towards industrial rollout.

Keywords Smart metering · AMI · Smart grid · SAIDI · G3-PLC · Big data · Open data

1 Introduction

The energy transition transforms in depth the distribution network management. The integration of new uses of electricity are transforming the distribution network from a vertical and unidirectional network to a much more complex system. This context change consists of the development of distributed renewable energy resources and microgrids, the integration of electric mobility and storage and the trend towards prosumers and local consumption and generation of energy (self-consumption, local energy systems, …). In parallel, digital has become mainstream and all the distribution network's stakeholders are waiting for services for a national or regional development of their activities. Even the business scope and core business of the distribution system operators (DSO) are increasingly questioned by more and more intrusive requirements. To face those challenges and to continue to manage the distribution network efficiently, the Smart DSO is becoming a data manager able to manage, share and protect the distribution system data with all the stakeholders committed to energy transition.

2 Smart Metering Data as a Game Changer

Advanced Metering Infrastructure (AMI) enables the development of new technical applications to improve network operations' efficiency and customer's satisfaction. It is obviously the first brick, with all the data it generates, that allows the DSO to embody his new role as a data manager.

The Enedis Linky Advanced Metering Infrastructure constitutes a unique set of sensors on the French distribution network. By the end of 2021, 35 million Linky smart meters are already installed, as well as 750,000 data concentrators, located in secondary MV/LV substations. Hence, the French Linky program is completed and many lessons have been learned by Enedis from this large-scale industrial program, deployed on time and within budget [1] (Fig. 1).

The first function of the AMI is a new communication system to collect data from smart meters and data concentrators. Then, those measurements and events are qualified and processed by the information system that converts them into alarms or

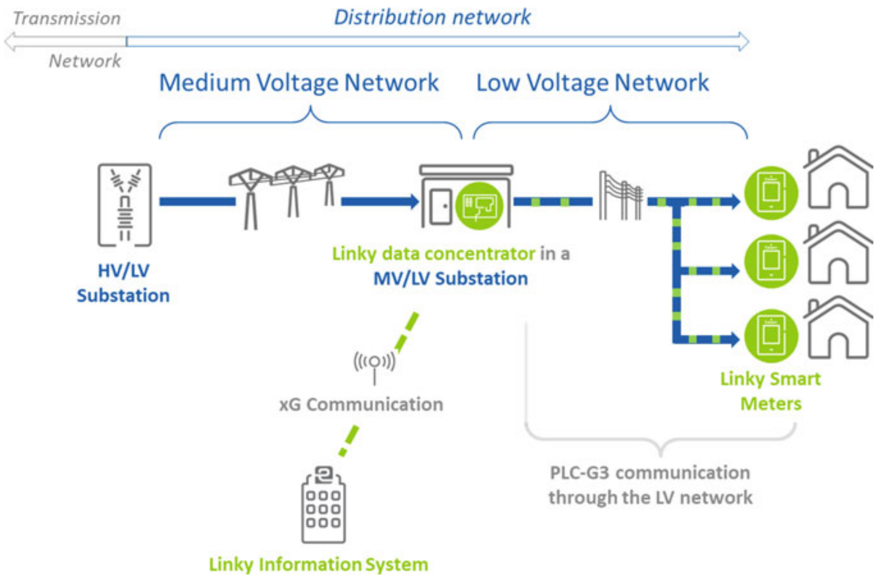

Fig. 1 Enedis Linky advanced metering infrastructure

enriched data. Finally, those alarms, measurements and reports are exploited with a business perspective to enhance distribution network management.

3 Solutions for Grid Operations

In addition to the traditional remote meter readings, Enedis develops applications thanks to its Linky-Réseau program [2] and infrastructure, which implements observation logics of indicators like equipment status, flows and communications of the Linky system through G3-PLC, in order to:

- Further improve the quality of its control,
- Further improve accuracy and responsiveness in the handling of outages,
- Carry out preventive maintenance and prevent incidents on the network.

This Linky-Réseau program is part of the Enedis Smart Grid roadmap [3] that aims on the hand at modernizing network management processes and infrastructure and on the other hand at supporting electric power system stakeholders and regional territories in French energy transition.

3.1 MV Network Dispatching

This first solution aims at strengthening MV faults diagnosis and location as well as confirming in real time switchgear permutation at secondary MV/LV substations.

Linky data concentrators have a key role in the transmission of key indicators that greatly contribute to the operation of MV networks. For example, fault indicators located in MV/LV secondary substations can be connected to the concentrator, which will send the fault alarms in real time through the AMI infrastructure to the MV Dispatching operators. The MV Dispatching Centre uses the information to locate precisely the network fault and send an operator directly to the right location (Fig. 2).

Data concentrators provide as well useful information to identify specific MV resistive faults, not detected by primary substation protection relay, such as MV conductor breakage and phase misbalance, through the analysis of LV negative sequence voltage.

Finally, remote enquiry of the power supply status of the concentrator helps confirm the well switchover of switchgears automatic permutation for urban networks with multiple energy feeders.

Benefits:

- SAIDI (System Average Interruption Duration Index) improvement through the reduction of fault location time, avoiding visual check on secondary substations,
- Quality of supply improvement through voltage unbalance correction,
- OPEX reduction by reducing fault location working hours,
- Safety and security improvement for equipment and persons.

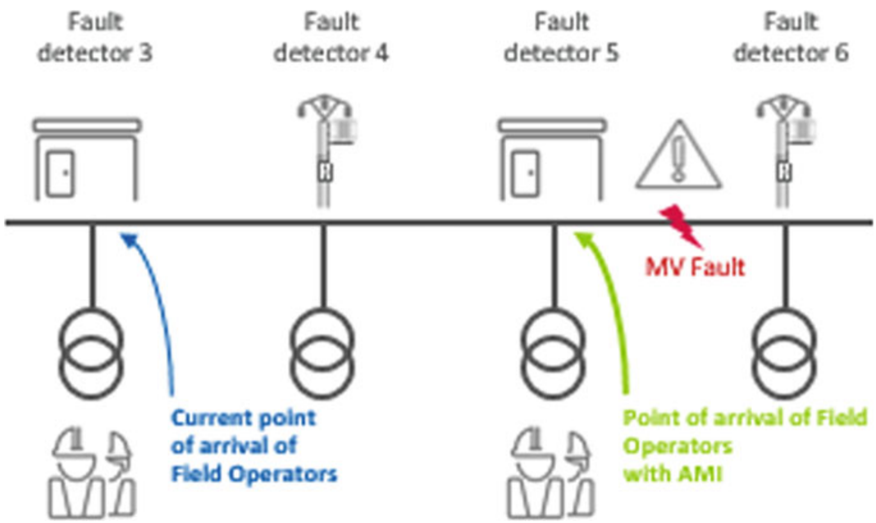

Fig. 2 Illustration of AMI MV fault location

Fig. 3 Illustration of neutral break detected by AMI system

3.2 LV Network Operations

LV network supervision is one of the most relevant solutions that have been added to Enedis operations by the Linky AMI and Linky-Réseau program. It aims at improving customer satisfaction through immediate diagnosis and location of MV grid faults.

Overvoltage alarms (270 V > 5 s), grouped remote ping to several meters, concentrator power loss and phase loss alarms (for 3-phase meters) bring valuable data to the Linky System, which uses it to supervise LV networks, and to identify and locate incidents remotely. Those incidents could be LV network weaknesses such as neutral breaks or circuit breaker tripping in the case of aerial LV networks (Fig. 3).

Benefits:

- SAIDI improvement through reduction of fault location time,
- Quality of supply improvement through quicker diagnosis to fix the affected LV network,
- OPEX reduction by reducing fault location working hours, vain and low value added technician interventions
- Customer satisfaction improvement by reducing the risk of harming customer electrical installation and launching LV technical intervention even before client call emergency desk.

3.3 Quality of Supply Monitoring

This solution aims on the one hand at improving client satisfaction and reducing claims, and on the other hand at deferring LV network CAPEX through an optimal electrical phases' balancing.

Thanks to meter recordings of outages and voltage quality, the 'Quality of Supply Office' has all necessary information to process customer's claim on the right timing.

Computing meter voltage recordings with G3-PLC meter phase and grid topology, the 'Network Planning Office' is able to propose optimal meter phase switching to avoid heavy work on LV networks.

Benefits:

- No more long and complicated investigations to retrace the historic of network quality of supply,
- No need to install recorder at customer premises and analyse their data,
- CAPEX—grid strengthening works—deferring,
- Customer satisfaction and better quality of supply through voltage quality improvement.

3.4 Network Model Improvement

Through G3-PLC routes and interaction between Linky Smart Meters and data concentrators installed in MV/LV secondary substations, the AMI contributes to an improved reliability and transparency of LV and MV connections of each client. This data helps the 'Network Studies Offices' to have a clearer view of the networks they work on. G3-PLC contributes as well to the enrichment of the Geographic Information System (GIS) thanks to phase detection algorithms. Enedis can then know which phase each user is connected to. This network model improvement provides key information and reliable data to all DSO business processes (Fig. 4).

Benefits:

- Optimisation of DSO assets database (GIS),
- Network planning tools precision improvement,
- Enabler to Smart Grid features such as self-healing automation,
- Crisis management and customer information improvement.

3.5 Big Data for Predictive Maintenance

This solution aims at shifting from curative to preventive and even predictive maintenance.

Supervised Machine Learning predictive algorithms, including grid incidents characterization by business experts, have recently been developed by Linky-Réseau Data Scientists. They bring the opportunity to carry out LV predictive maintenance field operations. The principle used by these machine-learning systems is to use the inventory of previous fault on the LV grid, so called signatures, and to identify intermittent events through Smart Metering data in order to prevent faults, as shown in the "Fault signature" in Fig. 5.

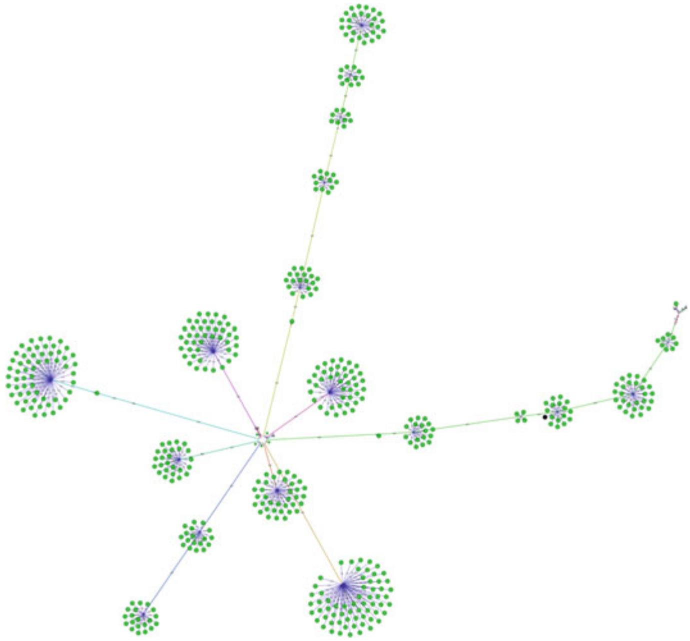

Fig. 4 LV grid topology provided by G3-PLC routing

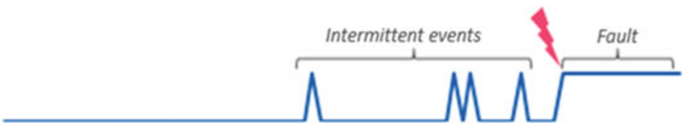

Fig. 5 LV grid topology provided by G3-PLC routing

In this case, preventive treatments, such as material replacement or strengthening, are planned and realized on the LV networks.

Benefits:

- SAIDI improvement through avoided incidents,
- Customer satisfaction and better quality of supply through voltage quality improvement,
- OPEX reduction thanks to an increased share of planned maintenance activity.

4 Solutions for Client Satisfaction

In addition to the traditional customer services delivered by the AMI system (remote meter readings, commissioning, consumption visualization on a web portal or a mobile app), Enedis develops smart applications based on the smart metering data for different actors of the energy transition.

4.1 Collective Self-consumption

The EU Clean Energy Package introduces the notion of Local Energy Communities (LECs).

The French law already enables the sharing of generation among customers connected to the same LV feeder. These projects are called collective self-consumption projects and constitute an example of local energy communities in France. These projects are developed through the signature of a collective self-consumption contract between the legal entity and the French DSO Enedis.

In collective self-consumption projects, consumers and producers are legally bonded by a legal person (association, enterprise, local authority, etc.), share a local production and are all connected to the distribution grid. Photovoltaic is the main source of local generation in these projects and they are often not connected to storage.

Collective self-consumption is a good illustration of how more accurate data (for instance the load curve at a time step of 30 min) is useful for consumers and producers in the development of their local communities' projects.

Benefits:

- Customer satisfaction improvement in terms of electricity supply:
  - The operator supplies electricity even in the absence of local production,
  - The customers are guaranteed of the quality of the power supply (voltage and frequency).
- Customer satisfaction improvement in terms of data services quality:
  - Customers, producers, suppliers and balancing entities involved in the project receive reliable and certified data that are useful to monitor and evaluate the project,
  - The DSO also facilitates changes in the project configuration.
- Finally, these projects constitute an opportunity to make durable the role of public distribution network and DSO data management in the development of local energy communities (Fig. 6).

4.2 Open Data

Open data and its related services platform developed by Enedis are another example of how the DSO positions itself as an actor of data management, in particular as

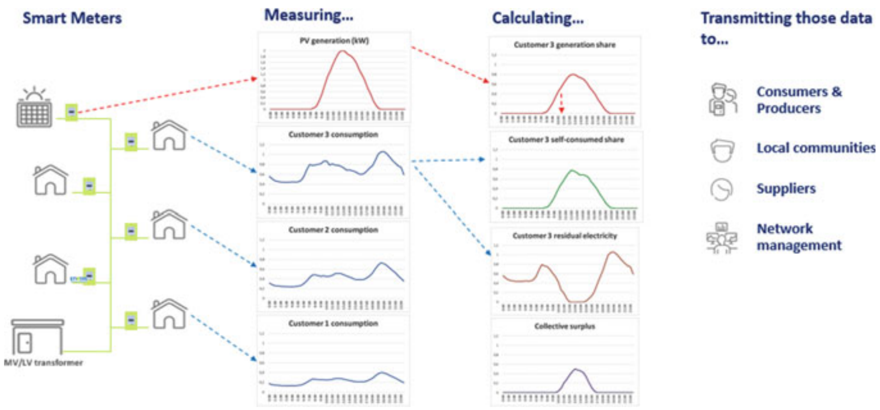

Fig. 6 Illustration of Enedis industrial data management solution

a neutral and transparent data public operator, which is regulation compliant and facilitates energy transition projects.

Indeed, the French energy transition law requires facilitation of energy transition projects: energy efficiency action, climate plan, etc. In this purpose, Enedis developed an access to open data. For instance, aggregated data at the scale of a region or a city, allowing local authorities to evaluate the evolution of electricity consumption and generation at the scale of their territory and take actions.

At the same time, French entities such as CNIL (commission in charge of the protection of citizen data) require a protection of this data. That is why open data sets are anonymized and aggregated, so that the determination of the consumption of an individual citizen is not possible. It requires expertise to be able to process reliable data.

The DSO is in charge of data quality as well. For instance, some characteristics were added by the DSO, such as the effect of temperature on energy consumption data sets.

On this open data platform, sixty data sets are available, and all stakeholders have access to different services:

- Data visualization,
- Online analysis (data table, chart, map, etc.),
- Data download (CSV, Excel, JSON, Shapefile, API, etc.),
- Tracking updates,
- FAQ/Online contact form.

Open Data sets are published under Open Licence, a French free licence published by Etalab, the entity that coordinates the public open data. This process guarantees:

- Transparency and quality of data,
- Replication, redistribution, adaptation and commercial exploitation of data,
- Guidance and legal certainty to producers and re-users,

- Compatibility with international Open Data Licences (Open Government Licence or OGL, ODC-BY…).

Benefits:

- Third parties satisfaction improvement in terms of energy transition projects facilitation,
- Open data is used by local authorities to monitor the evolution of the consumption and generation at the scale of their territory. They can also complete their territorial diagnosis to develop their energy climate plan,
- Start-ups, energy efficiency enterprises and suppliers benefit from these data to develop new customers services and offers,
- It is an opportunity to collaborate and share public data.

4.3 Public Lighting Management

This solution illustrates one of the services developed for local authorities, identified as key stakeholders for Enedis as they are at the same time customers, in charge of the development of their territory, and owners of the grid in France.

This service is based on an analysis of the smart meters' peak power feeding the public lighting system. If a threshold (decided with the local authority) is exceeded, the day following this event, an alert is sent to the local authority that will decide, if necessary, to send an operator for a field intervention. The majority of these alerts are relevant and related to a fraud or a breakdown.

Benefits:

- A concrete service affirming DSO role as an actor in charge of data services development for local authorities,
- Customer satisfaction improvement in terms of reactivity. With an alerting system, on a daily basis, the operator gives local authorities information on potential public lighting system irregularities (fraud, breakdown, etc.) detected the day before,
- Customer satisfaction improvement in terms of cost efficiency. Based on DSO information, local authorities will be able to verify the potential irregularities and correct it quickly, and thus saving costs (no time needed to qualify clients claims, and for the localization of the irregularity) and improving citizen satisfaction.

4.4 Customers Emergency Management

This solution aims at improving client satisfaction through real time diagnosis during customer's call to Customer Emergency Desk.

Individual and grouped Linky Pings allow Customer Emergency Desk operators to receive real-time information on the status of each meter. Grouped Pings can provide a clear view on the current quality of supply in a certain area or neighbourhood, making it easier for the operator to distinguish individual from collective incidents, and most important, distinguish network incidents from customer electrical installation. Then those Pings allow identifying issues, to report them, and to take the necessary remote actions.

Benefits:

- Customer satisfaction improvement by running remotely a real-time diagnosis and delivering quick response and solutions. A concrete service affirming DSO role as an actor in charge of data services development for local authorities.

5 Process for DSO Customized Solution Development

The following step-by-step process aims at creating added value for the DSO, from customized solutions development towards their industrial rollout. This process could be based on an existing AMI system or leverage a new AMI program roll-out or an AMI renewal program.

The main phases of the process are the following:

- Phase 1: Current situation analysis, business needs collection, evaluation of performance benefits
- Phase 2: Engineering phase and Proof of Concept
- Phase 3: Turnkey solution industrial rollout.

Phase 1 consists in data collection, interviews of concerned experts and professionals as well as site surveys. The identification of priority business use cases and applications to develop is a key-point of this phase. The second key-point is the estimate of costs and benefits per application, adapted to the DSO's context.

Phase 2 is dedicated to feasibility study, on both technological and organisational sides. It focuses on industrial policy in order to determine the better solution for the DSO: for instance, 'off the shelf' solution proposed by AMI market vendors or 'in-house" development by internal DSO's teams. At this phase, it is necessary to roll out a Proof of Concept (PoC) on a specific and priority use case, on a limited perimeter, in an end-to-end approach.

Phase 3 considers the industrial and operational rollout of the smart solution based on AMI system. Depending on industrial policy choices, the functional specifications and associated requirements such as performance requirements, will be redacted and submitted to market actors or internal developments. Then, based on PoC return of experience and specifications, the solution will be developed, delivered and integrated into the DSO's ecosystem. The change management, knowledge transfer and the operations and maintenance of the solution will be provided on an adapted timeframe.

6 Conclusion

The AMI infrastructure, with all the data it generates, allows the DSO to embody a new role of Data Manager, both for its internal needs in terms of network management and for its clients and stakeholders satisfaction.

A set of smart solutions for grid operations and client management are now industrialised in France, in parallel of Linky AMI system industrial rollout.

They are also proposed worldwide by EDF International Networks—the subsidiary that promotes Enedis know-how abroad. For example, EDF International Networks experts are currently working with our Uruguayan partner Usinas y Trasmisiones Eléctricas (UTE) on the development of Smart Metering based services for the Uruguayan distribution network.

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Electric Vehicle Charging Infrastructure Planning and Security Measures in Indian Urban Centres

Premachandran Aravind, Abinash Dash, and Abhijeet Ray

Abstract Electric Vehicle penetration in India could reach 30% by 2030 and this will generate an estimated savings of about 474 Million tons of oil import and 846 Million tons of CO_2 according to a study by NITI Aayog and Rocky Mountain Institute. Research shows that 83% of the consumers globally are hesitant to adopt EVs because of the battery life and range anxiety. The extreme price sensitive Indian customers are skeptical about siting charging infrastructure in the road network. In the past few years, researchers worked on the optimal deployment and sizing of charging stations using objective functions and different optimization algorithms. But most of the works have taken the European and other Western cities into consideration. This paper proposes a methodology to calculate the number of charging stations for EVs considering extensive environmental elements in designing the charging infrastructure in Indian Cities. Though there is a strong push for EVs, currently we are in the nascent stage of market development in India and thus it will be difficult to lay down a detailed plan. In this paper, the security factors that are to be prioritized for the installation of EV charging infrastructure in Indian Urban areas are also identified. Finally, the feasibility and viability of the methodology are applied in an Indian City as a business case.

Keywords Component · Formatting · Style · Styling · Insert

1 Introduction

The transportation sector profusely depends on the fossil fuels and contributes to almost one fourth of the total EU-28 greenhouse gas emissions. EVs have been found

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to be the most efficient and viable option to control the emissions currently [1]. EV adoption has reached its inflection point and EV penetration in India is predicted to reach 30–50% by 2030 generating about 846 Million tons less CO_2 [2].

Smart grids are carrying the power from the generating stations and information to control, monitor and automate the entire grid [3]. EV adoption put huge stress in the existing grid infrastructure. In this paper, we will discuss on the impact of EV adoption in the energy systems, measures to reduce the risks and the future planning of the infrastructure.

2 Charging Infrastructure Use Cases

Home Charging: EV Supply Equipment (EVSE) installed in the customer premise lets customers use it as per their convenience mostly during evenings and night.

Commercial Charging: The facilities available to the customers at the work locations, stores and restaurants.

Public Charging Stations: These stations are generally fast recharge stations, where the customer can recharge the battery in a short time. The public charging stations are a de-licensed activity in India and any individual can set up these stations once they meet the technical and performance standards.

3 Impact on Energy Systems

The rapid adoption of EV have great impacts in the existing energy systems testing the grid robustness, grid security, volatility, power quality as well as grid cyber security.

3.1 Data Security

As the number of endpoints increase with the increase in the nodes/charging stations the data is exposed to more risks (Fig. 1).

However, the prudent way to secure the data stored/in-transit is to adapt to cloud infrastructure to avail High Speed, Scalable Storage, Interconnectedness, Low Maintenance, Scalability with added features of security while allowing the users 'access from anywhere'.

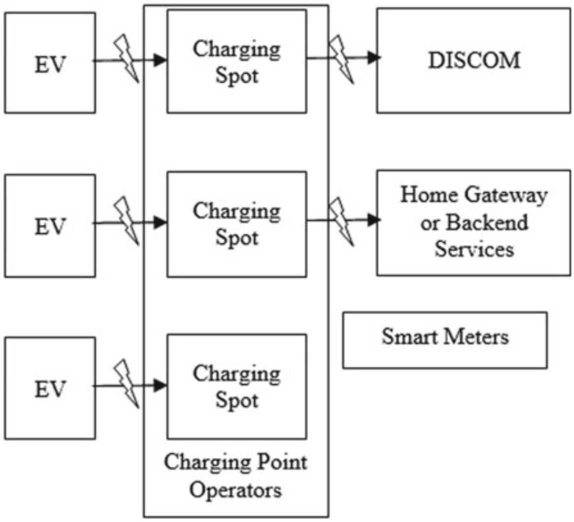


Fig. 1 EV charging endpoints

3.2 Grid Infrastructure and Security

The most pronounced effect of EV adoption is the increase in evening peak loads, as people plug in their EVs after they return home. The variation in the load curve has huge ramifications in the quality of the power supply.

One of the significant challenges the DISCOMs face is to continuously upgrade the infrastructure in the urban centers to cater to the increasing load demand locally. This has become even more important in the light of the recent regulations which provides for load shedding compensation.

4 Econometric Model

The econometric model analyzes the amount of energy, power, number of chargers required with growth in EVs and estimates its impact on the distribution grid. The model can be used to predict the infrastructure requirement in any city/region (Chandigarh in this study) while having the ability to aggregate with a vision of decentralized urban planning.

4.1 Assumptions

- Vehicles are categorized into 2, 3, 4 and 6Wheelers.
- EV adoption follows the technology adoption curve [4].

- Electricity usage per km is assumed as constant for each category based on the current industry benchmarks.
- Daily average distance travelled by cars, rickshaws and motorcycles are assumed.
- Utilization rate is assumed to be 30% for the charging station [5].
- Public Chargers are rated 50 and 10 kW.
- 70% of the vehicles registered in the city are used in Chandigarh, People from neighboring states purchase the vehicles from Chandigarh because of the lower taxation.

4.2 Methodology

- Number of vehicles sold for 2019–2030 is estimated based on CAGR and national growth rate
- Number of EVs are estimated using penetration rates
- Cumulative distance travelled by each EV Category is estimated
- Equivalent Electric Quantity (EEQ) [6] is determined based on per km electricity usage
- Power required for public charging, peak load and the number of chargers needed are estimated using the utilization rate [5].

4.3 Analysis

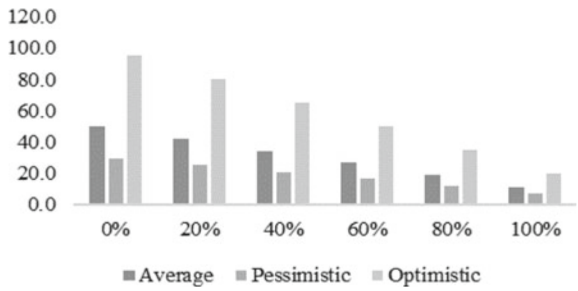
It is evident from Table 1 that the EV consumption, in the projected optimistic case, makes only 4% of the total energy consumption of 2030. Though 2Wheelers attribute 80% of the EVs, the biggest contributor to the consumption is 4Wheelers.

Figure 2 shows that dependence on residential charging may increase the peak load by 30%. The utilization period for residential charging is skewed towards the peak hours in an uncontrolled grid, whereas the public charging infrastructures are used ~16 h/day [5]. As the city depends more on residential EVSE, load in the peak hours increases significantly. Thus, it is always better for the grid to deploy more public charging stations for effective load management than the decentralized residential charging, especially in densely populated cities. Also, the utilities should

Table 1 Energy consumption in Chandigarh

	Year	Pessimistic	Average	Optimistic
Total EV consumption (MU)	2025	4.65	7.59	18.92
Total energy consumption (MU)	2025	1751.83	1890.04	2050.48
Total EV consumption (MU)	2030	34.54	53.13	93.73
Total energy consumption (MU)	2030	1888.41	2247.50	2702.20

Fig. 2 Public charging versus peak load



have flexible transformation capacity to cope up with the power fluctuations resulting from excessive load (Fig. 3).

The peak load due to increased EV usage in the grid is enhanced by 5–15%, calling for a radical change in energy management of SLDCs, PPA structures and energy banking (Table 2).

NITI Aayog proposes to have at least one charging station in 3 × 3 km grid. However as per our analysis, in Chandigarh, there should be 19 charging stations, one in every 2 × 2 km grids in order to build a healthy grid.

Fig. 3 Peak load

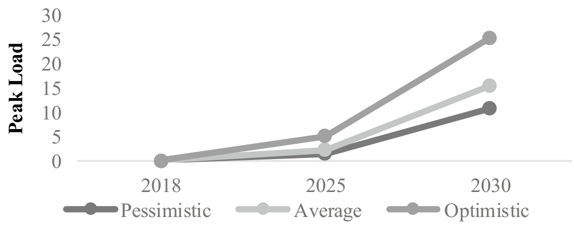


Table 2 Projected charging stations

Year	EV	Projected No. of charger stations		
		Average	Pessimistic	Optimistic
2025	Cars	3	1	8
	2 W	6	4	10
	3 W	1	1	3
2030	Cars	19	10	38
	2 W	38	30	53
	3 W	9	5	19

5 Mitigation of Security Threats

5.1 Role of Urban Planners

The industry experts expect a boom to the DC Fast Charging Stations only by the end of 2030. Urban planners, real-estate players and the EVSE suppliers should collaborate through the infrastructure planning, with increased focus on security to make it affordable, accessible and reliable.

5.2 Smart Charging

Smart Charging minimizes the load impact in the grid by attenuating the peak load and reduces the curtailment. Various methodologies are [7]:

- Time of Use Pricing
- V1G- Reduce, stop or start charging based on the communication from the grid
- V2G- Bidirectional, supply power to grid
- V2H- Supply power to home
- Dynamic Pricing.

5.3 Cyber Securiity

Connected systems across the world are vulnerable to hackers. Certain practices and tools which can reduce them are [8]

- Adopt best IT practices and Physical security
- Unidirectional Gateways
- Two Factor Authorization.

5.4 Remedies

The exigent measures that need to be adopted in security and infrastructure planning are:

- Incorporate the EV Charging requirements in the Grid Expansion Plans
- Innovations in making the infrastructure flexible and secure
- DISCOMs' role in residential EVSE setup
- Building competence for EV charging station O&M
- Strategic placement of fast charging stations for low grid impacts
- Increase storage capacity planning and deployment to deal with DER penetration.

6 Conclusion

Utilities are trying to find new ways to deal with power demand fluctuations arising out of EV usage and predicting the consumption pattern. The impacts and challenges remain in the decentralized grid, but the effect is amplified in densely populated developing economies like India. Innovations around deployment of public charging stations and EV data handling are paramount to brace for the future.

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A Sustainable Power Distribution Model

Aurabind Pal

Abstract Distribution is the weakest link of the Indian power sector. The last electricity reforms has ampullated the distribution from generation and transmission, but the problem is not evaded. Privatization of Distribution company is being recommended but failures of past cannot be repeated. Majority of the distribution companies has an amalgamation of urban and rural consumers. While urban consumers may find many suitors among private bidders because of better density and better returns, rural consumers may find it difficult to be managed by profit seeking entities. A more "atmanirbhar" or a self-dependent path may suit the rural consumers, for a sustainable power growth. This paper presents an electricity distribution model in which electricity supply is treated as a catalyst of development in rural areas and is treated as a market commodity in urban. It is proposed to separate urban and rural grids. While urban grid be licensed to lowest bidder, rural grid be managed by rural electricity cooperative society (RECS). Each RECS, to source its power from grid as well as from solar plants installed under PM-KUSUM scheme. The power produced to be utilized in battery swapping stations (BSS), for electric vehicles, in such a manner that power flow from grid remains unaffected and commercial transaction compensates for AT&C losses. Urban DISCOM shall bill for the net energy transacted, to RECS at the DTR level through pre-paid meter. The regulatory, technical aspect and financial modelling is dealt in this paper supported by experience in different countries. It also focuses on synergizing of various Government schemes implemented or under implementation.

Keywords Privatization · Rural electricity cooperative society · Prepaid meter · Battery swapping station

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1 Introduction

India has decisively achieved 100% electrification of all its villages and households. The difficult feat was achieved jointly by the effort and funding of Union Government and State Governments. The distribution companies have been handed over with this newly created infrastructure and a mammoth size rural consumer base for maintenance, electricity supply and revenue realization. The rural consumer base is characterized by higher cost of supply, geographical remoteness, dispersed consumer base, low consumption, high leakage and limited ability to pay. Initiatives are being taken to privatize the distribution business with an objective to improve the quality, security, reliability of power supply and consumer service, achieve global benchmarks in AT&C and achieve affordable and reasonable pricing of electricity. It is aimed to shift cost plus, regulated power distribution business to private or public highest bidder.

Past experience in privatization of distribution business has shown mixed results. While outcome in case of Delhi and Mumbai and many other urban cities, with mainly urban consumer base are encouraging [1] while case study of Odisha privatization is far from successful. Apart from many other issues, one noteworthy difference is Odisha has a big rural consumer base. With no special incentive to supply power to rural consumers, profit-seeking private companies usually de-prioritize rural supply. This paper proposes to separate urban grid and rural grid. Urban grids be privatized to the highest bidder, while rural grid be managed by regional co-operative societies, local government institution or ngo. A detail business model is investigated for the management of the co-operative society. A co-operative society that will be entrusted with not only supplying to its rural consumers but also producing power of its own and managing battery swapping stations for EV fleets.

2 Present Issues with Indian Power Sector

2.1 Privatization of Full DISCOM or Urban Areas

In India, many power distribution companies (DISCOM) are suffering from financial and infrastructure challenges. The financial health of most of the DISCOMs are dwindling, with debt ballooning in each passing financial year. The debt restructuring schemes did improve the debt liability, but they have rebounded [1]. The poor financial health of DISCOMs affects all the stakeholders of the power sector vertical. Financially viable DISCOMs are essential to the future stability of India's economy [1]. Government of India, quite rightly, is pushing for privatization of DISCOMs to improve their efficiency. Private sector investment is often believed to be vital for any programme's long-term sustainability [2]. Power sector in India, already, has some experience with privatization of electricity distribution business. Privatization in metro/urban areas have seen considerable success in reducing AT&C losses and improving consumer satisfaction. At the same time privatization of complete state electricity distribution has not yielded similar results. It is necessary that some course correction be done for better results. Separation of rural grid from the urban grid is proposed. While rural grids be managed by Rural Co-operative society, urban grid be licensed to highest bidder who can deliver power to its consumers at utmost efficiency, reliability and at cheapest price.

2.2 Concern of Rural Electricity Supply

One of the major factors that contribute to the DISCOM's ability to provide reliable and good quality supply is the recovery of revenues from consumers which can be used to strengthen the distribution network and for its periodic maintenance. Because of geographical remoteness of rural households and shortage of manpower with DISCOMs, billing is a major concern [2]. And arrears and poor power quality does not help in revenue recovery. And this vicious cycle continues. A community ownership for the electricity used, certainly lacks. World bank research finds in communities like India, initial rural electrification would not have been economically viable unless subsidized but could independently finance their maintenance and operating cost [2]. India has achieved 100% rural electrification by subsidy from union and respective state governments. It is important that the rural consumers feel responsible towards the assets that has been created and work towards its sustainability. A community centric Rural electricity cooperative society can prove to be a good alternative (Fig. 1).

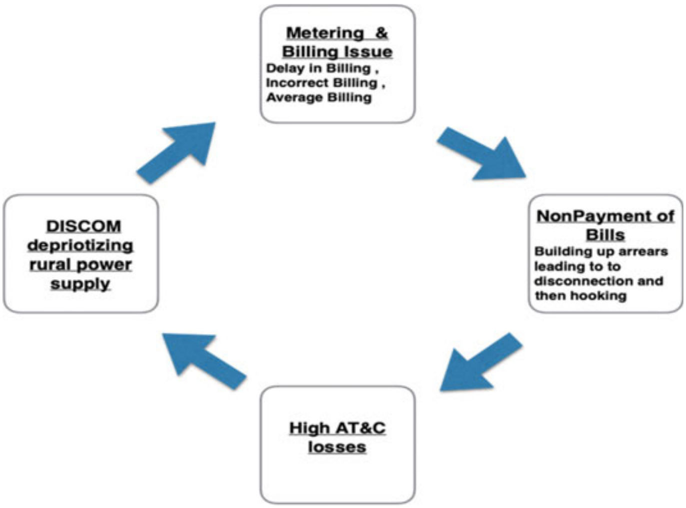

Fig. 1 Vicious cycle in rural electricity supply

3 Proposed Scheme of Rural Electric Supply

The domain of Rural Electricity Co-operative society (RECS) shall start from distribution transformer and downstream till service connections. In the operative area of RECS, power can be tapped from the main 11 kV feeder at various locations through a Pre-paid Net meter. The solar plants commissioned under PM-KUSUM scheme [3] or any others, shall be integrated to grid at various locations along the main Low Tension 3-phase line through a gross meter. All consumers shall be metered. RECS shall own a battery swapping station (BSS) and shall also own a micro finance wing that will finance and help in procurement of Electric autos without batteries. Batteries shall be owned by RECS and be available for hiring at BSS. RECS shall buy power from grid and solar developers. The revenue generated by selling power to domestic households, enterprises and BSS will be used for charging the pre-paid meters and paying solar prosumers. The tariff for all energy transaction will be determined by state regulatory commission. The tariff must have provision of penalty for non-availability grid power (Fig. 2).

The power exchange between the RECS and the distribution company, at the DTR level, shall be through a smart pre-paid meter. The meter, apart from having capabilities that a pre-paid meter already have, will have net meter capabilities, accounting import and export of power, as well. Prepaid arrangement has the potential to bring discipline in revenue collection. Although, consumer meter shall be normal postpaid meters. This arrangement shall rely on the community-led structure for its

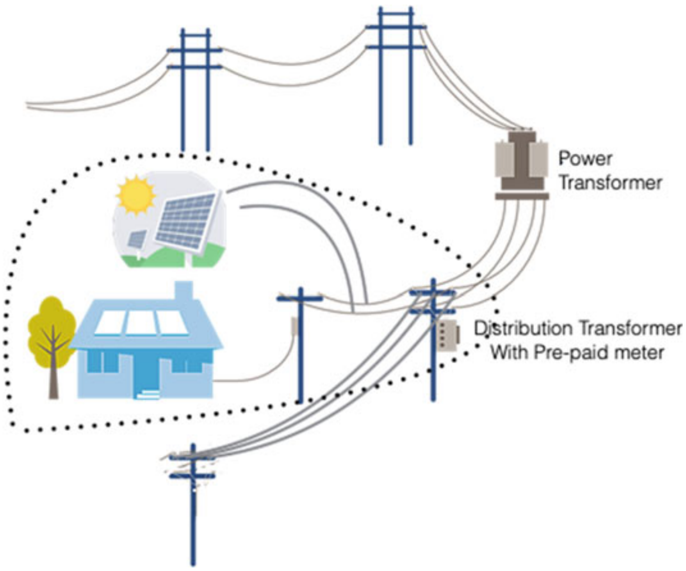

Fig. 2 Jurisdiction of a rural electric co-operative society

efficient and punctual revenue realization from the consumers. It also promises to bring ownership feeling, for the power utilized, among the consumers.

3.1 Urja Mitra: Outage Management

Penalty for non-availability of grid power, due to non-maintenance reasons, will be very relevant and pivortal to the scheme. Loss of grid power will also affect the on-grid solar power generations with financial losses to the producers. The scheduled and non-scheduled power outages must be reported to the consumers through URJA MITRA app [4] of Government of India. RECS will avail the facility of mapping its consumers not only in feeder level but also in distribution transformer level. Presently through URJA MITRA app DISCOMs intimate its consumers about power outages, planned and un-planned, through messages and notification in mobile handset. This initiative has helped DISCOM in generating consumer satisfaction and goodwill.

3.2 Adoption of e-Vehicles in Rural

Electric vehicle (EV) is slowly and strongly gaining traction in India. In (sub)urban areas, adoption of EV is a matter of controlling pollution, preventing resilience on imported crude oil and etc. but in rural, EV is a necessity. Most of the villages in India are, mostly, located far from the fuel retailers and rural mobility rely heavily on the black market, at inflated cost. But villages in India are electrified and EV can be a convenient alternative to fossil oil driven vehicles. The biggest hurdle, in EV adoption lies in high upfront cost. In the proposed scheme, RECS shall maintain a battery swapping station and shall operate by leasing batteries. The consumers can buy electric vehicles, preferably public autorickshaws, not necessarily with batteries. This will reduce the upfront cost of vehicles and increase its affordability. And micro-finance unit of RECS can finance its consumers in buying EVs with or without batteries.

3.3 Commercial Viability

The proposed arrangement has some unique advantages. Major chunk of power will be procured from solar plants whose tariff shall be lower than the procurement tariff. While power is sold in the form of charged batteries at battery swapping station for EV vehicles, at an equivalent tariff higher than procurement tariff, which shall be market driven. The solar power plants and solar pumps installed under PM-KUSUM scheme of Government of India, covered under jurisdiction of the co-operative society, will be encouraged to sell power. In the BSS maintained by RCS, there will be provisions

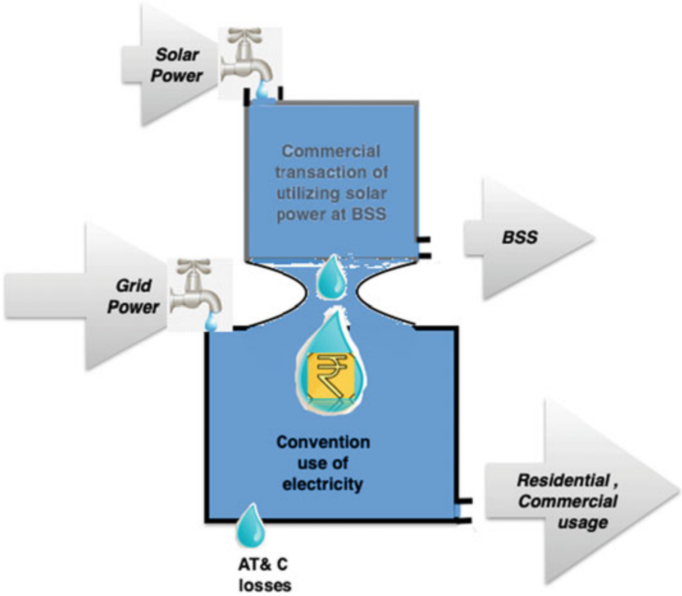

Fig. 3 A typical case of cross subsidy from green power transaction

of DC fast charging the batteries. In the proposed scheme of arrangement, it will be aimed that most of the energy procured from solar is utilized in charging the EV batteries, such that any disruption in load curve due to power flow from grid is prevented. The profit generated out of this transaction will compensate or cress-subsidize any prospective AT&C losses, excluding subsidy, due to distribution of grid power to consumers. While the approved subsidy, primarily be used for procurement and maintenance of assets. And subsidy be availed in the form of loan, backed by respective state Governments, from financial institutions (FI). This shall assure subsidy are given based on merit of works and monitored by FIs while loan repayment is done by state government fund (Fig. 3).

3.4 Subsidy

This paper advocates use of electricity in rural as a catalyst in development while a market commodity in urban. The power be purchased by RECS at a viable bulk supply tariff (subsidized) set by SERC considering the finances of RECS in common. But SERC shall also determine actual cost of supply bulk supply tariff. The differential be recorded and be notified regularly in the public domain. With the use of smart meters, above exercise must get automated.

RECS shall rely heavily on government subsidy for replenishing and creating infrastructure mainly in the form of government loan or loan from financial institution but backed by state government. This will ensure projects are sanctioned based on its merit and also monitored.

4 Structure of Rural Electricity CoOperative Society

India is not new to the concept of Rural electricity supply co-operatives, though not common. The most relevant being the Mula Pravara co-operative society (MPECS) in Maharastra. It distributed electricity in 183 villages with a connected load of 207 MW. The Maharastra regulatory commission has acknowledged its better efficiency over state electricity board (SEB) [5]. MPECS was treated as a licensee and was charged bulk supply rate applicable by the SEB. So, the legal framework for having a democratically governed businesses closely regulated by their consumers and regulatory commission in the form of local co-operative societies already exists in the country. Moreover, rural co-operative societies have proved to be a successful model for rural power electrification and supply in countries as far as United States of America and as near as Nepal and Bangladesh. Rural cooperatives in Bangladesh has gained worldwide recognition as a very successful model for rural energy services delivery with distribution losses around 10% and collection rates around 96% [2]. The society shall be governed by the respective state legislation and can employ engineers, overseers, technicians as per the requirement and fund allotted. RECS will also employ some social mobilizers (SM), whose work will be to educate its members/consumers about their rights wrt electricity distribution and create bridge between members and executive body.

With cooperatives in place there will be need of an overarching body that will provide them with technical assistance and expertise, lobbies for new legislation and advocates the members' interests with policy makers and regulatory commission. In Nepal they have National Association of Community Electricity Users-Nepal (NACEUN) a decentralized membership-based self-regulating body. In Bangladesh they have a government regulatory body in the form of Rural electricity board. India can have best of both the worlds. Electricity supply being a state affair in India, a body similar to NACEUN is proposed that will be a catalyst body between the state regulatory commission (SRC) and cooperatives. Its primary purpose will be to provide capacity building, technical training, administrative and management support for its member organization. It will engage with SRC in policy making and performance-based subsidy allocation to its member cooperatives. And above all it will maintain all records including subsidy disbursement, in public domain.

5 Conclusion

The India of today needs a electrical distribution system which is robust, resilient and above all financially stable. Power for all was achieved by predominantly government intervention but power 24 × 7 need community intervention. Proposed model of rural electricity cooperative society gives opportunity to the community to manage its power distribution of its own with strong hand holding by the Government. By providing reliable and cheap electricity and enormous employment opportunity for the locals, it has the potential to bridge the gap of urban and rural divide.

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Energy Storage System—Application in Green City Transport

B. B. Mehta

Abstract Keeping view of the NDC target for reducing CO_2 emission and facilitating the inrush mix of green energy into the main stream of power generation and footing further for a green city, a proposal of creating a central hub of energy storage which is interlinked with road side small packets of energy fuel banks meant for EV and HEV is analyzed along with the V2G concept. Stringent Govt. policy toward the mandatory run of only EV and HEV in the city road, facilitating the opening of battery fuel centers by the road-side, subsidizing the EV sector and providing loan facility with attractive subsidies for the general people may evolve the new world of clean city.

Keywords Central hub · Electrolyzer · V2G concept · Fuel bank

1 Introduction

"Energy can neither be created nor destroyed, rather it can be transformed from one form to another"… 1st law of thermodynamics teaches us the conservation or storing of energy i.e.; converting the energy into sustainable form. In a stable electrical network system, at any moment in time generation has to be equal to the consumption, otherwise system instability is observed. Footing forward to achieve the INDC target of 175GW RE generation by 2022, the enormous energy generation mix of various RE energy in the mainstream may make the Indian power system unstable. There arises the need of an energy storage system (ESS) for providing flexibility, reducing peak demand and balancing the real time difference in the energy system.

Electricity produced by renewables during off-peak demand times can be fed onto the grid during peak demand periods by adopting the storage technology. Also the reductions of carbon emission can be maximized by ensuring the mix of electricity used to charge the storage technology. It can help the new generation and transmission investment, improve grid reliability and stability at a lower cost and also very

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much effective during the extreme weather condition. In addition, energy storage can provide other benefits known as ancillary services such as frequency control, spinning and operational reserve—which are needed for an efficient, stable and reliable electricity grid.

2 Methods of Energy Storage

Presently there are so many numbers of energy storage technologies available, and all come with their advantages and disadvantages. Generally it includes various types of storage system like:

(a) Electrical [capacitor, super capacitor, superconducting magnetic storage etc.],
(b) Thermal [cryogenic, molten salt, ice storage air conditioning etc.],
(c) Mechanical [pumped storage hydroelectric (PSHES), CASE (compressed air storage energy), fly-wheel, hydraulic etc.],
(d) Chemical [biofuel, hydrogen storage, hydrogen peroxide etc.] and
(e) Electro-chemical (BESS—battery energy storage system) system.

All of these technologies can be paired with software which controls the charging and discharging of energy.

APPLICATIONS OF ENERGY STORAGE

Based upon the discharge duration (application based) we can classify them into three categories:

(i) Short term (second to minutes).
(ii) Medium term (minutes to hours). and
(iii) Long term (hours to days or more).

Long term system may fit for bulk energy application and renewable energy integration application. Short term and medium term systems are specifically suitable for ancillary and end-user energy application. Here in this paper we may discuss the end user energy application considering the cost benefit.

- ***Time of use (ToU) management/peak shaving***: It is observed that the demand is high generally at evening period, when the generation from solar or other renewable sources are unavailable, at that time ESS can be counted as cost beneficial.
- ***Diesel cost minimization***: The cost reduction in diesel consumption by DG sets with the help of ESS during power cuts.
- ***Enhancement of Reliability***: Ensuring the availability of electrical energy 24 × 7 in spite of power cut, severe critical weather condition etc. as the backup power source.
- ***Power quality and stability***: Optimal operation of the equipment and protection from the damage of equipment due to any unwanted surge/lighting, low voltage and any frequency variation.

- ***Demand Charge Management***: Basically this is only applicable for commercial and industrial users based upon the highest amount of power drawn during the block period. It can be avoided by the use of ESS and get benefited financially.

The present application of ESS in various fields or sectors like energy, agriculture, fishing, irrigation, transport and industries etc. is gaining momentum. Out of so many technologies, BESS technology is very popular and emerges as the most adopted one considering the case of end users due to its high energy density and efficiency point of view Although Pumped-storage hydropower (PSH) is having high energy efficiency but due to the long-term investments, geographical constraints and permissions etc., investor may show less interest for it. Similarly, because of their low-energy density, large size and short cycle and calendar life, the Lead Acid Battery is losing its popularity in comparison with Li-ion batteries.

Govt. of India has given priority on battery energy storage. The "Think Tank" of Govt. of India i.e.; NITI Ayog and Rock Mountain Institute (RMI) on joint report had proposed for (i) creating environment for battery manufacturing, (ii) Growth and scaling up supply chain strategy and (iii) scaling of battery cell manufacturing towards the India's energy storage mission [1].

But the present scenario shows hydrogen fuel as an emerging technology along with the battery energy technology, which we can take as hybrid technology for use in the transport sector.

- The below list (Fig. 1) shows the characteristic of some popular energy storage systems

Before choosing any suitable storage technology the following criteria are to be considered:

(i) Storage capacity availability, (ii) response time i.e.; the speed of the system to go from idle to full-discharge, (iii) Recharge Rate i.e.; the rate at which power can be put into storage. Sometimes the storage system may take more hours to recharge than to deplete. (iv) Self-discharge time: Energy discharge that occurs when the system is not being used, due to leakage and/or heat dissipation. (v) Capital/Operating Costs: Investment/operating costs on a per kW basis and (vi) Environmental Impact as some technologies like batteries potential use harmful chemicals.

We are here to propose for a green city transport system, which may be a hypothetical idea as the city road is to be run mandatorily by the only EV (Electrical Vehicle) which is battery operated and FCEV (fuel cell Electric Vehicle) which is the combination of Battery and Hydrogen fuel. Because EV has no emission and hydrogen fuel releases only clean water and oxygen (Fig. 2).

3 Description

- **Mandatory** run of BEV/FCEV (Fuel Cell Electric Vehicle) in the city road. So the city road will be the land of moving power packets. Every halting place

Diff. Energy Storage System	Max Power Rating (MW)	Discharge time	*Max cycles* or lifetime	Energy density (WH / Litre)	Efficiency
Pumped hydro	3,000	4h – 16h	30 – 60 years	0.2 – 2	70 – 85%
Compressed air	1,000	2h – 30h	20 – 40 years	2 – 6	40 – 70%
Molten salt (thermal)	150	hours	30 years	70 – 210	80 – 90%
Li-ion battery	100	1 min – 8h	*1,000 – 10,000*	200 – 400	85 – 95%
Lead-acid battery	100	1 min – 8h	6 – 40 years	50 – 80	80 – 90%
Flow battery	100	hours	*12,000 – 14,000*	20 – 70	60 – 85%
Hydrogen	100	mins – week	5 – 30 years	600 (at 200bar)	25 – 45%
Flywheel	20	secs - mins	*20,000 – 100,000*	20 – 80	70 – 95%

Fig. 1 Characteristics of selected energy storage systems (*Source* The World Energy Council)

(destination) is to be considered as a small energy storage bank or energy generator by adopting V2G technology.

- *V2G (Vehicle-to-grid)*: it is a system in which plug-in electric vehicles, such as battery electric vehicles (BEV), plug-in hybrids (PHEV) or hydrogen fuel cell electric vehicles (FCEV), communicate with the grid for either returning electricity to the grid or by throttling their charging rate. All the parked vehicles of Hospital, Offices, Apartments/Big malls etc. can be acted as the generator adopting this V2G technology. Those BEVs/FCFVs can store and discharge electricity generated from renewable energy sources such as solar and wind, with output that fluctuates depending on weather and time of day.
- *Central Hub*: It is to monitor and control the energy demand of the city transport by storing and catering. The current database/status of fuel energy (battery and

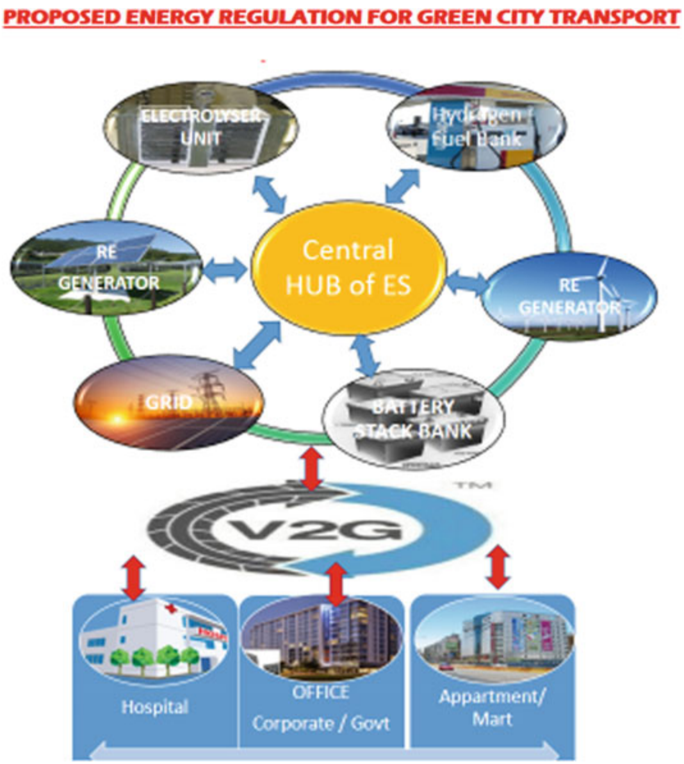

Fig. 2 Proposed model for energy regulation for green city transport

hydrogen fuel) of each fuel bank of the city is to be reviewed in 24 × 7. It will act as the city loads traffic. It will be connected with all generators, grid and also with the all roadside fuel pumps by electrical and communication networks.

- *Fuel bank*: Road side fuel banks/pumps are to be opened for catering plug-in fuel i.e.; battery stacks exchange and refilling hydrogen tanks to the vehicles. It is to be connected with the central hub of ES and nearby grid or RE generators for charging or any required energy exchange.
- *Hydrogen fuel bank*: Hydrogen is to be stored in gas or liquid state after harvested from water by the electrolyzer through a chemical reaction and transported to the roadside fuel bank. The electrolyzer may use the electrical energy from RE generators or Grids or the battery energy storage system (BESS). This bank can also support the grid at the time of need.
- *Govt. support* towards the strong infrastructure for the EV/FCEV industries, purposeful guidelines, financial support by providing loans and subsidies may fulfil the dream of a clean city transport by the use of ESS.

4 Conclusion

Keeping in view of India's present status, the use of ESS in this proposed energy regulation for green city transport system may be a hypothetical one. Adopting proper initiative, step by step action/planning by Govt. for implementing stringent policy, regulation and further encouragement towards the research and development of technology/infrastructure may guide the city life to be in a healthier environment.

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Access to Standardised, Transparent, and Granular Electricity Consumption Data: A Novel Engagement Model for the Indian Consumer

Bhawna Tyagi, Akash Goenka, and Sangeeta Mathew

Abstract Electricity consumers in India receive their energy consumption information through monthly bills with limited data (such as per-unit rate, units consumed). Application of advancement in digitisation of metering data limited to improving the billing and collection efficiency. Post the COVID-19 lockdown, consumers in different parts of India complained about inflated electricity bills. The bills in lockdown were generated based on past data and no opportunity for consumers to monitor their real-time consumption. This strengthens the need to provide consumers with easy access to transparent and granular electricity consumption data. The growing penetration of technology has evolved consumers into digitally-enabled consumers, and their requirements have changed significantly. One prominent example is telecom consumers who can track their real-time usage (internet data usage, calls, bill dues, economical plans as per usage). However, such flexibility is not available with electricity consumers to track their consumption to manage bills, evaluate the benefit to opt for ToD rate plans, etc. With this backdrop, this paper attempts to answer two key questions: Does the consumer have sufficient, straightforward and standardised electricity consumption data to make informed decisions? What are the potential value propositions for different consumer types? This paper will develop a standardised end-use (In the paper, end-use refers to the data of electricity consumers. Data access refers to consumer access to energy usage data.) data-sharing framework. It will also draw inferences from how end-use energy data is shared with consumers in other countries and with consumers in India's different sectors. The findings will help develop better energy efficiency interventions such as effective demand response programmes and customer engagement strategies.

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Keywords Energy data · Consumers · Utilities · Data-sharing framework

1 Introduction

With the growing penetration of technology, consumers are evolving into digital consumers throughout the world. This has resulted in a massive shift in their expectations and requirements. The transformation is primarily driven by the availability of web and mobile-based tools, enabling consumers to access more granular information about their consumption pattern in various fields ranging from personal finance to health, and fitness [1].

However, the experience differs when it comes to electricity consumers. Utilities' services haven't progressed much over the years with consumer interaction limited to the payment of electricity bills, complaints against outages, and getting or changing electricity connections [1–3]. In India, electricity consumers continue to receive their energy consumption information through monthly bills with limited data (such as per-unit rate, units consumed). The monthly bills provide little to no insights on consumer usage patterns [1]. However, some DISCOMs are advanced than the other. For example, in Delhi, if you are under time-of-use rate, they will give you consumption in the block, for net-metered consumer share self-generation and grid generation data. Another example is CESC Calcutta provides the consumption for the previous five months and the same six months of the last year. Application of advancement in the digitisation of metering data limited to improving the billing and collection efficiency.

The criticality of sharing granular data[1] with consumers became evident post-COVID-19 lockdown. Consumers in different parts of India complained about inflated electricity bills as meter reading couldn't be taken during lockdown [4, 5]. Thus, the bills during lockdown were generated based on past months' consumption and adjusted later on causing a spike in bills, with no opportunity for the consumer to monitor their actual consumption and manage their consumption if they choose to do so. Availability of standardised, timely-consumption data allows active consumer participation by evaluating available options and making informed decisions to manage their consumption [6]. One prominent example is the telecom sector where consumers can track their real-time usage (internet data usage, calls, bill dues, and economical plans as per usage).

Access to granular data by electricity consumers has significant energy saving potential varying from 6 to 18% as per different reports [1]. The detailed information about their energy usage will accelerate the energy efficiency behaviour in consumers and facilitate utilities to develop demand-side management (DSM) programs [6, 7]. Globally, several key drivers are changing consumer experiences such as solar

[1] Granular data is defined as electricity consumer energy usage data (frequency can be 1-min, 15-min, hourly, daily, or monthly depending on meter type), load curves, load factor, demand factor, cost information, etc. The extent of detailed information is contingent upon on meter type such as smart meter, conventional meter, bi-directional meter, etc.

rooftop penetration, electric vehicles, development of innovative devices, and smart appliances and forcing utilities to relook the consumer engagement strategy from being passive to active [2].

The energy sector is at the forefront of developing and implementing long-term strategies to meet climate action goals, especially for coal-based economies such as India. A special report on Energy and Climate Change highlight that energy efficiency can reduce the growth rate of world energy demand to one-third by 2040 [8]. In addition to energy efficient technologies, making consumers aware of their energy consumption can help nudge consumer behaviour towards managing or reducing their energy consumption. These factors further reiterate the need to provide consumers with easy access to transparent, standard, and granular electricity consumption data to undertake informed choices.

The availability of granular data is beneficial for consumers and provides monetisation opportunity for utilities [1, 6]. Additionally, the availability of standardised data will enable technology companies to develop innovative solutions to meet consumers' growing requirement [1, 6]. Role of technological advancements will be critical in transitioning from the traditional method of data sharing to a more customer-centric approach. Digitalisation can significantly reduce the transaction cost to disseminate the information to consumers compared to conventional channels [2] and to provide consumer-targeted messaging.

The present paper is a unique study which outlines the importance of sharing electricity data and discuss the potential value proposition of various stakeholders relevant to data sharing. The objective of the paper is to develop a standardised end-use data-sharing framework considering the value propositions and contextualising the experience of other countries for India. To the best of the author's knowledge, no holistic study is done on sharing electricity data and providing a framework for a common information-sharing model. The intent of the paper is to get the feedback and initiate discussions among policymakers on the requirement of a common information-sharing model in the electricity sector.

2 Information Sharing Models

Sharing of data with consumers is not a new concept, and it is already happening in several sectors, including finance, health, telecommunication, among others. Several utilities in other countries have recognised the need to share data with consumers and have made significant improvement in sharing real-time consumption data with electricity consumers. This section will discuss the information sharing models existing around the world and in other service sectors in India.

2.1 Other Countries

One of the leading examples concerning data sharing is Green Button (GB) Standard developed in the US. This initiative started with "White House call for action in 2012 to provide utility customers with easy and secure access to their energy usage information in a consumer-friendly and computer-friendly format for electricity, natural gas, and water usage" [1, 9]. It is formally known as the North American Energy Standards Board's (NAESB) REQ21, the Energy Services Provider Interface (ESPI) [2]. There are two options to share the data—download my data (DMD) and connect my data (CMD). In DMD, a utility customer can download their usage data into a file after selecting the duration, resolution, and data source. In CMD, a utility customer can authorise a utility to share certain defined data with a "third party" company that will provide services to the customer (solar financing, analysis of the usage, etc.) [1, 9]. This data sharing standard is widely adopted by utilities across the US [1]. The standard shares data in XML format and could be adopted irrespective of meter type—smart meters, conventional meters, or bi-directional/net meters. However, the amount/granularity of data shared is a function of the meter type.

Canada has already adopted GB standard, and South Korea is also in discussion with NAESB to translate the standards into Korean [10]. Another data sharing initiative is Midata in the UK which started back in 2012 to give consumers access to their personal data in a portable and electronic format across all sectors banking, energy and telecommunication sectors [11, 12]. This started initially as a voluntary regime, but the implementation of the program got stalled. There have been certain advancements in this program with UK Government publishing a Call for Evidence to seek inputs from different stakeholders to formulate draft regulations. This was further supported by the adoption of the General Data Protection Regulation (GDPR) in May 2018. The new data protection regime provided consumers with the right to request their personal data which will be electronically ported from a data controller, to them or to a third party [12].

Analogous to GDPR of UK, Australia announced the adoption of Consumer Data Rights (CDR) in 2017, which will allow consumers greater access to and control over their data [13]. The rights intend to empower consumers to make rational decisions by comparing products and services, promoting competition among suppliers, and encouraging innovative products and services [13]. These will be implemented in a phased manner, starting with the banking sector followed by energy and telecommunication sector.

The key learnings that could be drawn are that implementation of standardised data sharing framework is mostly driven by Government and complemented by data protection rules or rights in other countries such as the US, the UK and Australia. Additionally, success was limited in case of voluntary implementation (such as the UK) vis-à-vis mandatory (such as Canada and some utilities of US) [11, 14].

2.2 *Other Industries in India*

Certain industries are leading example in providing consumers with easy access to their own data such as telecommunication, banking, etc. Majority of the telecom companies have developed both web and mobile-based application to track the monthly bills, internet usage, different plan options suitable to consumer requirements, track previous consumption, among others.

On similar lines, the finance sector, including banking, allows consumers to operate their accounts through web and mobile applications and do away with physically visiting the banks. Consumers can update their passbook, transfer money, check account balance, account statement, open fixed deposits, and other facilities through mobile apps. Development of Unified Payments Interface is a successful example of creating standardised protocol in India's banking sector. It allowed the merger of various banking service under one umbrella. It simplified the process of payment from paying at retail outlets (grocery, restaurant) to utility bills (mobile, electricity), and money transfer [15]. One UPI Id is generated for each account and used to make payment both online and offline. The model is quite similar to IMPS initiative but with the flexibility to make instant payment beyond banks.

One of the key takeaways from other sectors is the ease consumers have in accessing their own data and taking informed decisions. Having a standard protocol for sharing electricity consumption data will enable compatibility between different service providers and apps and thereby provide more choice to consumers while also ensuring compliance to data privacy rules.

3 Potential Value Propositions for Different Stakeholders

Different stakeholders will benefit from the sharing of standardised end-use consumption data. First and foremost are the consumers who are the actual owner of the data. Second, utilities which are the custodian of consumer data. Other stakeholders include third party companies (such as energy management companies, demand response, solar, smart thermostat [1]), research organisations, and policymakers. The detailed value propositions for each of the stakeholder are identified (Table 1) and discussed in the next subsections.

3.1 *Consumers—Industrial, Commercial and Residential*

One of the primary beneficiaries of end-use energy data is consumers who are the ultimate data owner. Access to granular data in a standardised format allows consumers to better understand their energy usage (depending on the granularity of data, which will be contingent upon meter type) and identify potential areas to shift electricity consumption and reduce bills. This benefit is common across all consumer types.

Industrial consumers with insights into their energy consumption (by the time of day, and season) in a standard format can better plan their operation [6]. Standardised data access allows both industrial and commercial consumers to track their energy and carbon footprints. It saves the additional cost that industrial or commercial consumers may need to bear to track their energy consumption, such as sub-meters, data loggers, installation cost, etc. [6].

Industrial and commercial consumers stand to benefit more as availability of standardise data will empower them to compare their energy usage with similar consumers provided utilities or third-party service providers present such data to consumers (same locality, profile, size, etc.); compare with similar consumers within enterprise portfolio (e.g. schools having multiple branches in different states); compare against a benchmark for specific typology. For example, companies having offices in multiple locations (such as IT companies) can study their energy usage patterns, compare the differences, identify potential interventions, and implement energy management solutions to address it. Similarly, industrial consumers can save on electricity cost by using the information on their load curve and time-of-day (ToD) rates to shift the flexible load from peak hours to off-peak hours provided ToD rates are being offered by utilities.

For residential consumers, access to detailed and timely energy consumption data will enable them to track their energy consumption and manage or reduce their energy consumption. A study by AEEE and Oracle Utiltiy estimated the saving potential of 17–51 billion nationally of behavioural energy efficiency programmes in the residential sector facilitated by home energy reports [16]. Consumers will be not be shocked with high monthly bills as happened post COVID-19 lockdown if they can track their energy consumption. It also allows them to analyse their load curve and compare potential benefit of transitioning to ToD/ToU plans if utilities offer ToD rates. They can utilise the information to make short-term (such as postponing an activity based on usage and rate information) and long-term decisions (purchase an AC or not) about their electricity usage [6]. Appliance-level measurement is typically an expensive proposition for residential consumers. They can easily share the standardised data with a third party which can analyse it on consumer behalf and provide actionable tips for saving energy and money such as customised heating and cooling recommendations [1, 6, 17]. It also facilitates consumers to use the web and mobile-based tools to make more informed energy decisions or verify energy-efficiency retrofit investments [17].

3.2 Utilities

The utilities tend to benefit significantly from sharing granular end-use data with consumers. Sharing of data could also be the pathway for utilities for better consumer engagement [16]. Ease in accessing data enables the consumer to understand their usage pattern and rationalise their consumption and bills. The transparency afforded by this could help utilities engage with consumers for participation in DSM programmes, thereby helping with load management [2]. Another opportunity is to engage with the product/service companies to develop new products and services and emerge as an 'energy solution provider' with new revenue sources [2].

Utilities can effectively design their ToD rates as they can measure how much electricity is used during on-peak and off-peak hours and charge customers accordingly. They could also carry out targeted demand management programs that target a specific cluster inside consumer segment (residential consumers with xx demand during peak hours), which has high potential or a geography (local distribution area experiencing congestion). The utility will benefit from detailed energy data analysis as it would help them to plan for the addition of new types of consumers such as consumers with storage, prosumers, EVs etc. Generation of significant data further complemented by smart meters and IoT will provide monetisation opportunity for utilities after they establish robust mechanisms for data privacy and security [2]. The needs and requirements vary from consumer to consumer and to offer new services to consumers require an understanding of these consumer needs [6]. Using data analytics, utilities can provide customised service and build a strong relationship with their consumers and increase consumer retention by developing consumer-centric products and services [7, 6].

3.3 Technology Companies

The availability of end-use data in a standardised format has significant potential to promote innovative product and services (such as assessing solar potential, energy efficiency potential, insights on energy usage, energy management solutions, among others). It will promote the open standard ecosystem for application development and growth of smart devices, and third parties providing such services. It will help bridge previously unconnected aspects of consumers' lives and begin conversations about efficiency [1]. The consumer can use third-party companies' services by providing them consent to study the data on their behalf and suggest them energy efficiency measures to cut down their consumption and reduce their energy bill. One such example is WeatherBug Home (WBH) an application which provides hyper-localised meteorological data to governments and sports stadiums. They recently started offering energy efficiency services through their mobile applications. In addition to local weather forecasts, the app suggests consumer energy-saving potential; by changing their thermostat setpoints. They partnered with Honeywell and Nest, allowing the consumer to control their temperature from the application itself, taking advantage of weather conditions to heat or cool most efficiently [1].

Additionally, energy management companies can devise better solutions to manage/reduce their consumers energy usage by accessing utilities data with consumers' consent. Availability of data can facilitate peer to peer comparison, informed decisions concerning energy efficiency retrofits, and verification of benefits of energy efficiency investment.

3.4 Policymakers and Research Organisations

Scarcity of data, especially end-use energy data, is a significant hindrance faced by most research organisations working in India's energy domain. The availability of end-use data at a certain level of aggregation will significantly improve the energy demand analysis and enhance forecast accuracy, thereby, contributing to data-driven research and strong policy recommendations. Energy policies developed based on quantitative data insights will be far more effective compared to those developed with insufficient information. For example, adoption of demand-side management programs requires continuous engagement and feedback from consumers [17]. The data insights will empower the policymakers to make informed decisions and enable better planning and management. The easy access to the granular data will also allow the policymakers to monitor and evaluate various programs and contribute to energy benchmarking. It can also be used to conduct community and student energy efficiency competitions such as California's energy challenge where different schools participate, or Solar Decathlon Initiative, which started with the US now also running in India.

To realise the above listed benefits, Common Information Model for data sharing is needed. It will enable consumers, especially, industrial and commercial, to get their energy data in a uniform format from all their service providers or third-party services making it easier to integrate with their own systems for analysis while ensuring compliance with data privacy regulations. Sharing of information should happen in standard format instead of each utility developing their own. A standard will also enable utility to work with all compatible technology providers and win consumers' trust in terms of transparency, data privacy, and data security.

4 Existing Initiatives in India

This section will discuss India's existing initiatives concerning end-use data-sharing in the energy sector, their current status, outcomes and learning from such initiatives.

Table 1 Summary of the potential value proposition for different stakeholders

Stakeholder	Potential value propositions
Electricity Consumers	
Industrial and commercial	• Energy-aware—useful for reducing bills, managing energy use, managing demand • Energy management solutions and track their performance • Track energy and carbon footprint • Avoided cost to track their energy consumption, such as sub-meters, data loggers, installation cost, etc • Comparison with peers
Residential	• Energy-aware—useful for reducing bills • Better prepared for unprecedented events such as high bills post COVID lockdown • Compare potential benefit from transitioning to ToD/ToU plans • Track the performance of energy-efficiency retrofits
Utilities	• Peak load management • Design better energy efficiency programs, and ToD rate structure • Potential to engage with product/service companies • Make anonymised data available "commercial" use for a small fee; • Better understanding of consumer needs, offer consumer-centric services and build a strong relationship
Technology companies	• Energy management solutions: direct services for specific clients to manage/reduce clients energy usage • Business opportunities
Policymakers	• Energy data analysis • Benchmarking • Policy implementation, monitoring and evaluation • Conduct community and student energy efficiency competitions
Research organisations	• Energy demand analysis and forecasts • Data-driven research and policy recommendations

4.1 *Green Button Implementation in India—Case Study of MSEDCL*

A pilot was conducted in Vashi area of Mumbai to implement the GB standard in India [17]. This was initiated by IIT Bombay, along with India Smart Grid Forum (ISGF) [17, 18]. In this pilot, energy usage information (such as demand factor across days, load factor across days, consumption in different slots, etc.) was made available for 1388 consumers [17]. The key steps identified in the implementation were gathering of consumer information from the database, plan preparation to collect energy usage information, check the format definition, develop convertor to GB, develop GB database, develop consumer portal with GB download link, and innovate and implement a wide range of application for consumers engagement [18]. The GB implementation time typically ranges from two to six months, depending on the DISCOM database management practices. However, the green button standard implementation was a one-time effort to show possibilities of standardised data sharing. Still, it didn't scale up either in MSEDCL area or other areas. One of the key learning from the MSEDCL pilot was that the GB standard needs to be modified to adopt the Indian conditions taking into consideration such as records of extended load, power quality, prosumer activity, etc [17]. Apart from the pilot project, "Green Button educatIon Tool" (GamBIT) was developed to improve consumer understanding about green button standards and assist the user in building standardised consumer applications [17].

4.2 Formation of LITD10 Committee—Common Information Sharing Model

To adopt GB like standard for India, panel 3 of BIS LITD-10 committee is working under the chairmanship of Shri NS Sodha. They started drafting the national standard to pursue Green Button. However, it has been recognised that GB std is a standard specific to the US conditions. Therefore, there is a need to develop some standard on similar lines considering the Indian scenario. Additionally, there is a need to pay a royalty to use the GB standard [10]. LITD-10 committee is in-principle agreement to develop such standard but requested to develop a proof of concept first and present it to the committee before accepting it for roll-out [10].

5 Framework of Common Information Sharing Model

This section discusses the framework for common information-sharing model for end-use energy data. There are six major components of the framework—metadata, standard and protocol, testing and compliance, data privacy and security, stakeholders and regulations. They are discussed in detail below.

5.1 Metadata

To adopt a common data-sharing model, the first step is to prepare the metadata. Metadata will include information not limited to customer type, device, location, readings, interval data, unit rates, summary information and power quality metrics. There is a need to prepare the standard set of information that will be gathered and shared with the consumers across India irrespective of the Utility servicing them. The granularity of data points will improve further with the implementation of the Smart Meter National Programme.

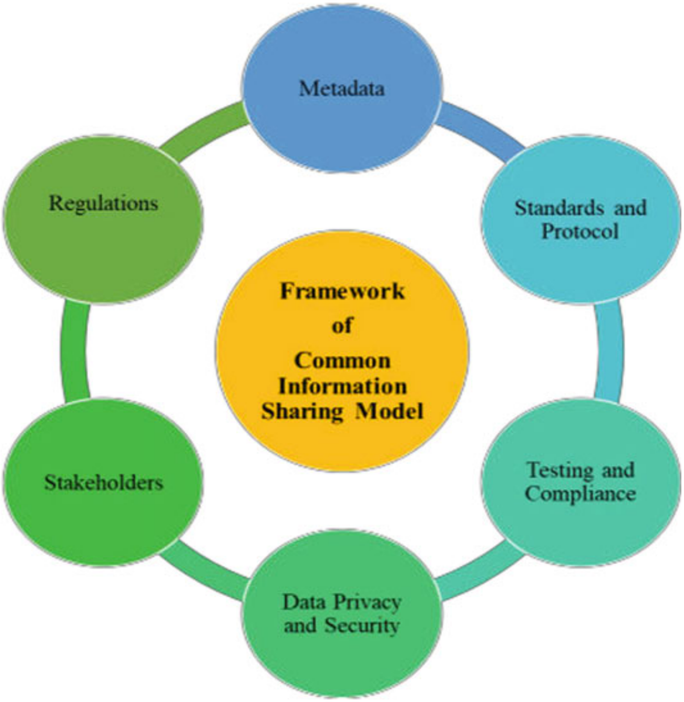

Fig. 1 Flow of customer data between utility, consumer and third party [6]

5.2 Standards and Protocol

The second critical component is the standard and protocol which will be used by all utilities throughout India. Inferences can be drawn from GB standard which is widely adopted with modifications as per Indian requirements. GB use extensible markup language (XML) including atom syndication format as CSV and EDI are not secure or have inconsistent formats. There is a need to have a standard format for data sharing. LITD-10 committee is already contemplating the development of standard similar to GB, and when developed, it will pave the way for standardised data sharing across the country. Figure 1 illustrates how the data will flow between Utility, consumer and third party.

5.3 Testing and Compliance

After developing the standard, there is a need to put in place a testing process for product and services to ensure compliance to the standard. It is a industry practice to do conformation testing to assess whether any product or service developed to comply with the set standards or specifications is compliant or not. This becomes more critical to ensure consistent data format and data security so that consumers receive standardised information anywhere in the country. There is a need to identify who will assume the role of testing agency in this. Some utilities do the testing in-house under GB while some of them have outsourced it to Utility API.

5.4 Data Privacy and Security

While providing benefits to consumer through standardised data sharing, there is a need to ensure consumer data privacy is not violated. To ensure this, there is a need to carefully interpret the existing policies that will guide this case. For example—the Information Technology (IT) Act, 2000 addresses the concern related to compensation or punishment in case of breach or misuse of personal data [19]. However, it is difficult to comprehend whether DISCOMs comply with the IT Act or not [19]. Supreme court of India has also recognised “Right to Privacy” as the fundamental rights.

One of the successful examples is how California implemented GB standard. They ensured that third party needs to meet certain criteria before they can access consumer data such as demonstrate technical capability, not be present on the Commission’s list of banned third parties, provide contact information and a federal tax identification number, among others. In case of a data breach for more than 1000 consumers, they need to notify to the Commission. Data privacy and security will become more critical with the implementation of smart meters [19], as smart meters collect more information about consumers such as appliance ownership, usage pattern, their occupancy etc. Some of these aspects will be addressed with the implementation of Personal Data Protection Bill (2019), which will be applicable even for consumer data with DISCOMs with or without smart meter [19].

5.5 Stakeholders

To implement any product or service, it is critical to identify who are the potential beneficiaries. The development of a common information-sharing model will benefit different stakeholders. First and foremost are the consumers who are the actual owner of the data. Second, utilities which are the custodian of consumer data. Other stakeholders include third party companies (such as energy management companies, demand response, solar, smart thermostat [1]), research organisations, and policy-makers. Detailed value propositions for each stakeholder group are discussed in detail in Sect. 3.

5.6 Regulations

Several countries worldwide have realised the potential of data and the need to put in place regulations to avoid data misuse and provide the right to consumers to access their data. This has also been highlighted in the Sect. 2.1 of Sect. 2. India has tabled the "Personal Data Protection Bill 2019" and also drafted "Non-Personal Data Framework" in 2020. Recently, the Ministry of Power proposed a new set of rules for the rights of electricity consumers and prosumers. But such rules existing or new provides no mention about consumer right to access their energy usage data or how data can be shared. There is a need to develop a comprehensive data protection framework providing information on consumer rights, consent to share data, access to data and data privacy.

Therefore, developing a common information-sharing model should be in conjunction with the Acts mentioned above concerning personal and non-personal data and Acts and policies related to the electricity sector to ensure compliance to the existing regulations and highlight gap, if any, in the current Act, policies or rules.

6 Discussion and Way Forward

The framework discussed in the paper highlights the key considerations relevant for data sharing in the electricity sector of India. It has significant potential benefits but there are certain challenges and barriers in developing and implementing common information-sharing models for end-use energy data. One of the critical barriers is the lack of consumer awareness. Utility will share the data if consumers starts asking for their own usage data. Consumer presently lack information about the potential benefits that will accrue from the availability of standardised data and need to be educated about the benefits and rights to demand their energy usage data. A second most important barrier is the cost of implementation. DISCOMs in India witness high loses contributing by several factors. Such standard implementation can be seen as an additional burden by them without considering its benefits. Another question which can arise is who will bear the cost of implementing such a standard.

As discussed in Sect. 2, such initiatives are primarily driven by the Government with complementing policies to support the initiative. Therefore, there is need for conducive policies and guidelines to support data sharing in India. There is a need to define consumer rights concerning access to energy data clearly, and data access should be considered as a requirement without charge. With more and more penetration of technology, data privacy becomes a critical concern. Presently, IT Act, as mentioned earlier deals with the disclosure and misuse of data.

Additionally, "Right to Privacy" is recognised as a fundamental right by India's Supreme court, including informational privacy. There is a need to clearly outline the aspect related to data such as access, rights, penalty on misuse, among others in the personal and non-personal bills that are under consideration. Common Information

Model can include provisions for data security and privacy, and will be strengthened by clearly defines laws.

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Pioneering Data Quality and Security in Smart Grid

Bright Roy, Prashant Tripathi, and Rahul Goel

Abstract The essence of a data lies in the hidden information inside it. If the data is not of good quality or not sufficiently protected, the outcome will undoubtedly be harmful. Quality and Security are two essential aspects that add value and meaning to the data and their implementation has become a real need and must be adopted before any data exploitation. Due to the high volume of data generated every day, the effective implementation of such systems requires well thought out mechanisms and strategies. This paper provides a detailed analysis and solutioning of Data Quality and Data Security in the context of Smart Grid. Through this paper we want to highlight the proposed solution and challenges that may exist during the implementation of data security and data quality management systems.

Keywords Smart Grid · Data quality · Security · Consistent · Accuracy · Machine learning · Utility

1 Introduction

With over 1000+ serving Customers in the Utility Sector, all Smart Grid utilities is ever growing with enormous amount of data which gets generated in the Smart Grids due to the huge number of endpoints, higher rates of measurement and various types of hops in between. Smart Grid data consists of some critical and important information about the grid. Applications which are driven by data are being constantly developed and improvised for better monitoring, operation and planning of Smart Grids. The outcome of data analytics heavily depends on the quality data coming of

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the attached Meters, Collectors. However, up till now we haven't seen much work that has been reported on the smart-grid data's quality assessment.

This whitepaper addresses the objective assessment of Smart Grid data quality and data security. Different Smart Grid data quality dimensions and security are identified in this whitepaper. Few mathematical formulas have also been proposed to quantify our Smart Grid data quality and the data quality metrics have been proposed to be applied on a newly built service: **Data Quality and Security Services (DQSS)**.

DQSS will be a potential service which will be capable to improve Data Quality of any data of Smart Grid utilities, imposed into it. From data security perspective, it will have additional customization features to put inbound and outbound port/protocol restrictions to the data as part of vulnerability test, apart from providing encrypting capabilities.

2 Problem Statement

The modern Smart Grid reflects a combination between Information and Communication Technologies (ICT) and Internet of Things (IoT), whereby data services such as aggregation of sensor data and analysis of voltage consumption from our smart meters offer a foundation for the concept of smartness.

The current data quality problems in Smart Grid are addressed still in an ad-hoc style. For example, we in smart utilities focused on the outlier detection of electricity consumption data through several application reports. Their solution tackles a specific quality aspect of electricity consumption data. However, this will obstruct our engineers to foresee the other data quality problems and delay the reaction on time for potential data quality problems.

Example: In the past utilities have experienced multiple firmware reset events in the field for a significant number of meters in hot/humid environments. The issue was initially looked at the outlier approach and engineers kept digging the problem in the network and work on the workarounds to address the issue whereas later it found, it's the behavior where a super capacitor shows symptoms of venting under certain hot/humid climate conditions. This venting can cause elevated counts of processor reset incidents within the meter or inhibit communications altogether. For example, an outlier in the energy consumption data may be caused by missing data items or data corruption.

Therefore, focusing on specific quality aspects can mislead the root causes of the data quality problems. Based on our review, there is a lack of a systematic framework for managing data quality in Smart Grids. Also, data quality is critical in the Smart Grid domain, as invoices of end users depend for example on the collected power consumption data.

Similarly, communication networks in Smart Grid bring increased connectivity right from meters, routers, collectors and interconnected and independent products like Meter Data Management (MDM), Head End System (HES) which involves increased severe Security vulnerabilities and challenges. Smart grid can be a target for cybercrime because of its critical nature. However, most of the classified attacks are based on confidentiality, integrity, and availability. These exclude the attacks caused due to compromise of accountability.

Data Quality and its Security are the two main pillars to focus as the utilities are now stressing on these components as their prime requirement and are must to survive in this competitive environment.

3 Problem Impact

Based on research by Gartner, "the average financial impact of low data quality on any organizations is $9.7million per year". Poor data impact financial resources, as well as it will also negatively impacts your efficiency, productivity, and credibility.

In fact, "IBM estimated that poor quality data cost the company $3.1 trillion in the U.S. alone in 2016".

3.1 Less Productivity and Growth

Bad data quality can obstruct growth of business and decrease the productivity all over the Smart Grid utilities. Even a single percent bad data can lead to many other issues and it can be very difficult to trace back to find out the issue and get rid of that cause. Even this will interrupt related processes and cause a lot of unwanted efforts. All these things will reduce the overall the productivity, as it needs a lot of effort to neutralize all the adverse effects.

3.2 Increased Financial Costs

Poor data quality will not impact only on business strategies, even it will increase the financial cost for the productivity, customer support and so on.

3.3 Data Security Breach

Poor data quality is the biggest threat to data security. As, characteristics of data quality: confidentiality, integrity, and availability can be the reason of the data breaches in any system like smart meters, collectors, and related products.

3.3.1 Revenue/Financial Loss

In Addition, considering the Cost of Data Breach Study in 2018, "the normal cost of a data breach in the U.S. is $7.91 million".

There are the following most significant consequences of data breaches. A non-functional product of Smart Grid utilities may trigger potential customers to explore other alternatives.

As per the analysis that "29% of any businesses which cope with a data breach end up losing revenue".

3.3.2 Damage to Brand Reputation

Apart from revenue loss, data security breach can affect the reputation of our organization which is the long-term practice for any organization.

Customers value their confidentiality and privacy too. New and existing customer can be uncertain to trust a energy business because of poor data security.

4 Mitigating the problem—The L&G Solution DQSS

4.1 Purpose

To create a service named as **DQSS** which will be able to validate the data quality and security of any kind of dataset as per the configured data quality dimensions and allow the user to optimize the data quality of any product/application of Smart Grid utilities. This whole process can be automated and integrated with any product/application of our organization.

To accomplish the purpose, we can divide the solution prominently into 4 layers as shown in Fig. 1.

4.2 Solution

4.2.1 Data Integration Layer

L+G system consists of multiple devices including smart meters, routers, collectors, HES and independent products.

Therefore, This **DQSS** product will be having the capability to integrate as Input data/output data layer with other existing Smart Grid utilities product. Even output of any process of MDM, HES can also be integrated to **DQSS**.

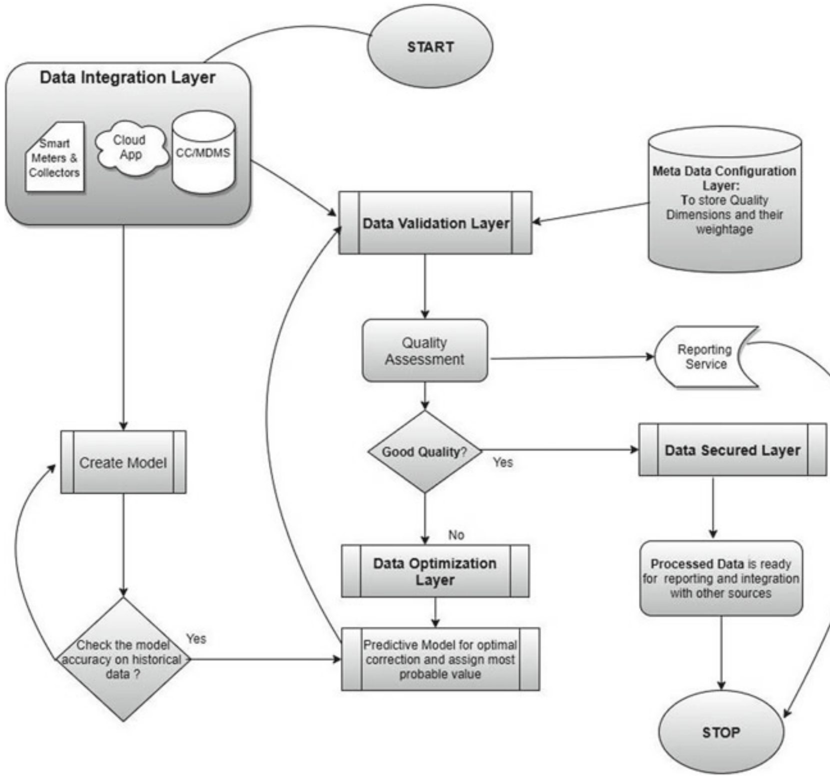

Fig. 1 DQSS solution flow diagram

To achieve this, **DQSS** will support connections to consume/produce structured, unstructured and semi structured data with the product/application. Whole data integration layer will support real time/batch streaming of any data set.

DQSS will be having UI capabilities to provide connectors for real time/batch streaming with the applications or products.

4.2.2 Metadata Configuration Layer

To check the data quality, **DQSS** will require data quality dimensions which can be configured as Metadata. We will create/configure standard dimensions set which will be applicable for all datasets. According to the relevance in the products/applications, we can also configure and assign the appropriate weights to each of the dimensions.

(1) Applications like MDM will give more weightage to accurate/complete/consistent dimensions data

(2) Smart Meter based application will give more weightage to validity/missing/consistent dimensions.
(3) Product like smart meters/collectors will give more weightage to timeliness dimension.

DQSS will provide UI to view the standard dimensions set and their weightage according to applications. Even with the help of UI, user can add, remove, and reorder all kinds of dimensions sets and respective weightage. The **DQSS** UI will even highlight the details of each dimensions as well.

The order of the dimensions in the metadata configuration will trigger the order of evaluation of the data quality Assessment layer.

4.2.3 Data Quality Assessments Layer

The objective of data quality assessments for Smart Grid data are based on the evaluation of the quality dimensions. This layer will generate the unified data quality index of the integrated source after evaluating each of the dimensions.

Internally, this process will apply the quality dimension sets to the source data and generate the statistical summary as an output for complete dimensions sets and individual dimension. Descriptions of statistical summary are shown in Table 1.

If source data like smart meters, collector are generating the logs then very first text mining will be used to convert freeform text into structured information, then quality dimensions sets will be used to generate the analysis.

(a) *Evaluation of each dimensions*

Validation of quality dimension can be evaluated based on its computation. Consider, for example, in any source data of application/product has m total records and n are the parameters (columns) like reads, voltage, rate, frequency etc.

- Consistency: Any application of Smart Grid utilities have data set can will be consistent if two or more values do not conflict with each other. The consistency will be checked for each parameter or with respect to total number of parameters at a certain time. The number of ambiguous instances will be equal to the number of such repeated values.

Table 1 Statistical summary of quality

Statistical summary		
Counts	Passed	Failed
A statistical summary of the records that passed and failed the rules defined in the ruleset	A list of all the records that passed all rules/individual defined in the ruleset	A list of all the records that failed any of the rules/specicfic rule defined in the ruleset, with detail giving the result of each rule for that record

Let t^k be the number of ambiguous entries of parameters denotes by k in dataset of m^k records, then quality of Dataset in terms of consistency is given by

$$ {}_{con}dqi_{ds} = 1/n \sum_{k=0}^{n} \left(1 - t^k/m^k\right) $$

- Timeliness: Timeliness calculates the promptness in storing/updating data. It provides an estimate of the delay involved in capturing the data with respect to the time at which the value got expected/changed in the system. quality in terms of data timeliness is given by

$$ {}_{time}dqi_{ds} = v_{expected} - v_{storage} $$

Consider, for example, smart meter application expects the register reads at the mid-night ($v_{expected}$), but its stored in the database ($v_{storage}$).

- Completeness: Any application of utilities has data set will be complete if all information is present in the respective database. The dataset will be incomplete if it is missing, missing data refers null values.

  Let t^k be the number of missing entries of respective parameters denotes by k in dataset of m^k records, then quality of Dataset in terms of completeness is given by

$$ {}_{comp}dqi_{ds} = 1/n \sum_{k=0}^{n} \left(1 - t^k/m^k\right) $$

- Availability: Any application of utilities has data set will be called available if the processed information is ready for the use.

  Let t_{req} be the time at which the processed data was requested by the application/user, t_{delay} is the time deadline within which the application/user must get the data and $t_{delivered}$ be the time at which the data was delivered to the user, then quality in terms of data availability is given by

$$ {}_{avail}dqi_{ds} = \left(t_{delivered} - -t_{req}\right)/\left(t_{delay} - t_{req}\right) $$

- Interpretability: Any application of utilities has data set will be interpreted if all information is represented using an appropriate notation in the respective database. The dataset will be not appropriate if data being entered under a wrong column or data values having wrong characters.

  Let t^k be the number of uninterpretable data points of respective parameters denotes by k in dataset of m^k records, then quality of Dataset in terms of Interpretability is given by

Table 2 Quality index of each dimesnion

Dimension	Index value
Consistency, accuracy, timeliness, validity, consistency, etc.,	It will provide the measurement of each quality dimension. As per this value, Smart Grid utilities set this value as threshold to optimize the data

$$_{\text{inter}}\text{dqi}_{\text{ds}} = 1/n \sum_{k=0}^{n} \left(1 - t^k/m^k\right)$$

For example, between integration of two system, mapping of two fields of sperate is wrong.

(b) *Evaluation unified data quality index*

As per the individual quality index and assigned appropriate weight to each dimension according to their relevance in the application (smart meters, collectors)/product like MDM, HES we will propose unified data quality Index. Let $_{i}QI^{k}$ denote kth quality dimension among n chosen dimensions and W_k be the corresponding chosen weights then unified data qualified index of the dataset DS, denoted by $^{u}DQI_{ds}$ is given by

$$^{u}DQI_{ds} = \sum_{k=0}^{n} {}_{i}QI^{k} W_k$$

where, $\sum_{k=0}^{n} W_k = 1$. $^{u}DQI_{ds}$ gives a measure of the data quality of any dataset irrespective of its size or number of parameters.

This complete assessment layer will generate the individual/unified data quality index as per the current dataset of integrated source. With new dataset, will come up by real time/batch streaming, these quality index will keep updating.

DQSS will be having UI capabilities to run the data quality assessment on the dataset of integrated source like MDM, HES, smart meters, collectors etc. and able to provide the interactive reporting analysis of statistical summary of dimensions, individual/unified quality index (Table 2) with other users.

4.2.4 Data Optimization Layer

The objective of this layer to enrich the quality of each dimensions. To enhance the quality dimensions, data analytics and data science will be the standard in **DQSS**.

To enrich the quality of dataset, there is the standard data quality cycle which has the process:

(a) *Analyze Data*

Data quality assessment layer will evaluate and create a matrix of the individual quality index for each dimension.

(b) *Clean Data*

Before enriching the data, it will be cleaned and standardized to meet the data quality goals according to the existing dataset of MDM, HES etc. Consider, for example, text mining will be used to convert freeform text into structured information, which will be used further for analytical methods.

(c) *Create Predictive model*

In current era, analytics and data science do not only demands on data quality, even they will be the best source to improve the quality dimensions. To use the analytics, we will create predictive model using machine learning (ML) for each quality dimension for the dataset of smart meters, MDM, HES etc. there are key points to implement the model in include:

Required historical data for the predictive modeling

Very first examines that whether the amount of data is sufficient for the analysis or not. Required data quantity will be managed in the Smart Grid utilities easily. In case if there are small samples of data, analytics also provides methods for modelling are events.

Consider, for example, for time series forecasting predictive model, analytics has so-called intermittent demand models that can be implemented on small samples of data.

Required variables for predictive modeling

As per the target quality dimension, selection of variables will be different from same input dataset, which will be required variables having strong relationship with target dimension.

Analytics provides number of methods for the selection of variables. Simple metrics like R-square and advanced metrics like LARS, LASSO and ELASTICNET are the methods to select the variables. Consider, for example, forward, backward, and stepwise model selection in regression modelling.

Using the selective variables over the Historical data, **DQSS** will train the model and test the model. Further it will be deployed for respective dataset of MDM, HES.

Monitoring of predictive model quality

Analytics tools are designed to create/trained the predictive model. We need to use the analytics also to assess the model quality time to time.

Re-training of predictive model quality

In case if the assessment of predictive model is low then **DQSS** need to re-train the model.

Even, with new data each time, we can schedule the re-training of the model to enhance the quality of the predictive modeling.

(d) *Enrich Data*

To enrich the quality dimension of data, **DQSS** will use created predictive model of respective dataset of MDM, HES, collectors etc. Let see the quality dimensions and how and which predictive model will be applicable:

Accuracy/Data outliers

With the help of predictive models and time series methods, the calculation of validation limits, optimal correction and most probable value will be done for data outlier dimension.

Missing values/completeness

Using computation algorithm, which are based on analytics methods like decision trees or spline interpolations for time series will compute the incomplete/missing data for average-based or individual values of respective application like MDM, HES, smart meters, collectors.

Consistency/Data standardization

This identification and elimination of duplications can be easily achieved using database analytics. Even measure of closeness and similarity between records will be also evaluated based on business information.

(e) *Monitor and Check Data*

Data must be regularly monitored and checked by data quality assessment layer to guarantee that it maintains the applicable data quality.

4.2.5 Data Secured Layer

The objective of this layer is to secure the qualified data. Sensitive data is encrypted before integrating to other system like MDM, HES etc. To encrypt the data most popular algorithm will be used: "AES, RSA, TRIPLE DES, TWOFISH". Encryption of data can be done on the file systems, block level, bare-metal server, virtual machine, or virtual disks.

Data Security is also applied by applying ports and protocols restrictions to the data.

DQSS will provide the UI capabilities to create a predictive model for the integrated source of MDM, HES etc. with the help of UI this model can be tested and deployed to optimize the data set of integrated sources.

Time to time with the **DQSS** UI, it can monitor, assess and re-train the model.

5 Achitecture and Design

DQSS has been conceptually designed in a 3-tier architecture. This means that the entire application is composed of mainly 3 tiers or layers which provides many benefits to production and development environments by modularizing the user interface, storage, and the business logic into different units.

In standard terms, these three tiers have been named as Presentation, Application and Data Tier. Figure 2 in the next page shows a clear bifurcation of these 3 layers based our product perspective. Let us map these 3 tiers (or layers) with our application.

5.1 Functional Tier

As shown in Fig. 2, the middle-represented box is the principal module which contains the business logic where algorithms to qualify and secure the data are written.

The backend language used here is Python with JavaScript for client-side interaction. The code has been modularized into independent pieces which makes the entire application easy to debug for errors.

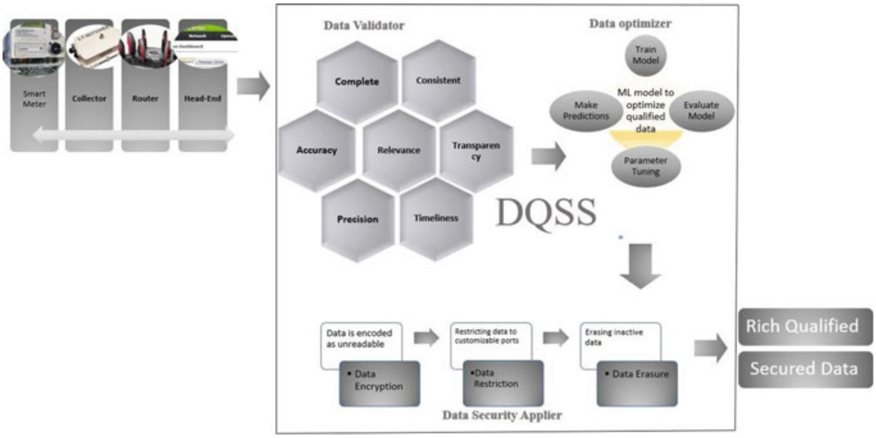

Fig. 2 DQSS design and architecture

5.2 Data Tier

The data tier comprises of the database storage and access layer. In this case, since the data source can be both relational, non-relational as well as cloud, hence the Data-Integration layer has been designed in a flexible way.

For example, Command Center of different utilities are built on different databases like Oracle, SSMS, Postgres. Other data sources also include Big Data.

5.3 UI Tier

The User interface tier also called the Presentation layer is the front end of 3-tier architecture. The UI tier is mostly the graphical one accessible either through web browser or a web-based application.

This tier is built on a web browser supported front end which displays content and information useful to the utilities.

DQSS UI tier is built on simple HTML and CSS templates which communicates to the Functional Tier through API calls using the Data tier.

6 Benefits of DQSS

DQSS as an organization level product is conceptualized keeping in mind the Smart Grid business. By improving the raw data quality and making the data more secured, will provide an economical as well as intangible value-add to the Smart Grid business.

6.1 Product Feature Benefits and Use Cases

6.1.1 UseCase 1: Smart Meter and Collector Logs

Smart meters and collectors generate the logs, which are the best source to optimize the quality of both smart devices. This DQSS will give Smart Grid utilities the capability to analyze the logs to ensure the quality of the smart devices. As per the assessment, it will be easy to find out the root cause of issues of meters/collectors and even help in knowing the root cause of missing/incomplete reads. In general, Smart Grid utilities manufactures the best smart meters worldwide, however DQSS will help the production unit to improve the quality and security of smart meters. Better quality is directly proportional to better security.

6.1.2 UseCase 2: MDM Data Quality

As per the requirement MDM has been able to enhance the smart meter data quality up to certain extent. There are few processes within MDM which has been able to achieve the true capability of the MDM system, though these processes have created redundancy of the data which are causing the issues in reporting and other area. DQSS can provide a second quality and optimization check over the same processes of MDM.

Even internal process had been built using rule-based approach only, which can also be optimized using ML approach of DQSS optimization layer.

6.1.3 UseCase 3: HES and Independent Portals

HES, which are first database source to hold reads, programs, location, rates data directly from smart devices, Therefore, there is a huge scope to enhance the dimension of each quality and security of smart meter data, which will be an additional edge to expand the business, reporting, decisions etc. with respect to Utility and End-Users. The ability of independent portals, which is offering the automated customize reporting, and other services will automatically be enriched.

6.2 Deploying DQSS as a Product to Any Organization

DQSS will be having the plug-play features according to customize requirement, therefore this will not only be effective to Smart Grid Utilities, even it can be deployed as a product to any organization to enrich their data quality and security.

6.3 New Business Leads

Due to capability and features of DQSS, this new generation product will also help getting new business leads for Smart Grid utilities in the Energy Consuming Sector and different domains as well.

7 Challenges and Issue

Although there are no major foreseen challenges in implementing thiss solution still there are few areas which needs to be considered while implementation.

- Testing effort might be high initially due to complex nature of Smart grid, HES and other products linked with HES. Thorough validation is needed to check if all the test cases are covered and data is validated at each interim step without escape.
- Because of the diversity and tremendous data volume generated by smart meters and ingested into command center HES, it is difficult to judge data quality within a reasonable amount of time. This could still be optimized to put minimal impact on overall performance.
- Due to the huge number of available data sources, variety of data types and complex data structures, there can be difficulties in data integration.
- There is an imminent need to setup a unified and approved data quality standards in Smart Grid utilities across all the products.

8 ROI from Proposed Solution

"Data quality: It's a journey, not a destination."

Though it is easy to assume that better data will benefit the organization, quantifying that benefit is critical to securing investment. By quantifying the impact of data quality in a methodical way, you can measure the impact of effort, the value to the business and a tangible return on investment. Later, this ROI can drive future investments and further promote data quality within the organization.

A robust data quality solution automates many profiling and discovery processes, so the business and IT team can accurately assess project risks and measure the enhancement of information performance.

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We hope this whitepaper finds the readers in good health and spirit and motivate us further to research and write more on booming IT technologies.

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Vehicle to Grid Integration and Strategies for Managed EV Charging in India

Chandana Sasidharan, Ishan Bhand, and Srijan Mukhopadhyay

Abstract Electrification of vehicles has its share of benefits and risks to the power distribution companies (DISCOMs). While EV adoption can potentially result in a substantial increase in revenue for DISCOMs from additional electricity sales due to EV charging, charging demand may increase the peak load in the DISCOM's service area. Unmanaged EV charging at the charging stations can hamper smooth power system operations by causing voltage instability, harmonic distortion, power losses, and degradation of reliability indices. To manage or avoid these impacts on the power system, there are both passive and active solutions. The passive solutions include specially designed electricity tariffs or incentives. The active management of charging is either unidirectional active management of charging referred to as V1G, or bidirectional active management of electricity referred to as V2G. Vehicle-Grid Integration (VGI) refers to this entire gamut of EV charging management solutions to mitigate the negative impacts of uncontrolled EV charging on the power system. The benefits of VGI extend beyond EV charging load, as it can provide useful services to the grid. The present paper is a discussion of VGI strategies for India for managing EV charging. The paper presents recommendations for VGI implementation in India.

Keywords Electric vehicle charging · Vehicle to grid integration · Smart charging · Time of use · India

1 Introduction

Globally growing climatic concerns have led to rapid electrification of transportation and the pursuit of sustainable sources of electric power generation. The growing concerns about vehicular emissions, air pollution, and energy security have resulted

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in a shift to clean mobility. Every Electric Vehicle (EV) is a new consumer for the power distribution companies (DISCOMs) and opens up a pathway for additional revenue. One of the primary focus areas for studying the impact of EVs is to examine power generation adequacy. The EV transition is interlinked in the clean transition of the grid, as EV loads are a supporting factor to promote the adoption of renewable sources of energy. Unmanaged EV charging load presents its own challenges for system operation. The impact of the EV charging load on the distribution grid has been an area of interest to researchers [1, 2]. EV charging load can lead to voltage instability, harmonics and impact the reliability of the local distribution grid [3].

The most significantly studied impact of EV charging is its impact on the peak power demand and its effects on distribution system transformers. With the addition of EV charging, DISCOMs can expect an upward shift in their peak load, which will result in purchasing electricity at higher costs to meet the demand [4]. The transmission and distribution losses will increase if the system, and investment is needed to upgrade the network to facilitate the additional load [4, 5]. However, electrification of transport happening in parallel with the rapid smart grid technology implementation presents an opportunity to effectively tackle the challenges from EV charging and use EV as a grid resource. This is possible through the framework of Vehicle to Grid Integration (VGI), which represents the charging strategies and pathways to use EV to provide valuable grid services. VGI represents the ways in which an EV can provide benefits or services to the grid, society, the EV driver, or the charge point operator by optimizing vehicle interaction with the electrical grid to contribute to reliable management of the electricity grid [6]. Two major approaches are primarily adopted to manage EV charging, based on controlling the time and current of charging. The control strategies can be either passive or active in nature [4].

Passive charging management includes strategies for influencing EV charging behaviour using specially designed electricity tariffs or incentives. Active management of charging consists of strategies which are for controlling charging and discharging of EV batteries, which are commonly referred as.

- V1G: Unidirectional active management of charging, such as ramping charging levels up or down
- V2G: Bidirectional active management of electricity, entailing power flow from Vehicle to grid

The entire canvas of VGI has multiple other possibilities, including Vehicle to Home (V2H), Vehicle to Building (V2B), and Battery to Grid (B2G), which are not focused on.

This paper discusses both passive and active management strategies that are relevant to the Indian ecosystem. In the case of India, electrification is not limited to the deployment of electric cars [7]. The mainstay of electrification of India is electric two-wheelers and electric three-wheelers [8]. Indian cities are also gearing up for the electrification of bus fleets [9]. The grid impact of EVs depends on the type of vehicles, the number of vehicles, and their charging pattern. The VGI strategies should be different for every vehicle segment and should also factor in when and where the vehicles are going to be charged. In the case of India, strategies are needed to tackle both residential and public charging. In addition to that, the strategy also needs to include battery swapping, which is a viable option for two and three-wheeler vehicles [10]. The paper presents recommendations for VGI implementation in India. The focus in on the strategies applicable for electric two wheeler and four wheeler charging in residences.

2 Passive Charging Strategies

The first and most common step for EV charging management is to adopt passive strategies to nudge EV consumers to shift their loads with time-sensitive electricity rates. Time of Use (TOU) rates are specially designed electricity tariffs to disincentivise usage during peak demand and incentivise use during off-peak demand [11]. TOU rates are popular in mature electricity markets and are being evaluated as a feasible option for managing EV charging [12]. In the US alone, more than 200 DISCOMs offer TOU rates to consumers and 87% of the current 31 eV charging tariffs are TOU tariff [9, 13]. Studies and pilot projects have shown a positive impact of implementing TOU rates on charging patterns to shift peak demand [12, 13]. ACEEE [13] research has shown that TOU rates are helpful for both EV consumers and the DISCOM. EV consumers save money by charging at off-peak hours with TOU rates, while utilities can reduce peak demand and improve grid stability. TOU is the most passive charging strategy for controlling EV charging load at Indian homes [12]. EPRI research [14] has found that utility TOU rates are very effective in shifting peak loads for all the charging that occurred at Level 2 (230 V).

Apart from the TOU rate, other passive strategies include rebates for low power charging [14]. The rationale behind incentives for low power is that the Level 2 (230 V) and Level 3 (415 V) chargers for electric cars could be 7 and 22 kW, respectively [7]. Even in advanced EV markets, this could exceed the maximum demand of a typical home, leading to additional cost for demand charges and upgrading the grid connection. In the case of India for electric two-wheelers, research has shown that all the chargers are less than 3.3 kW [8]. Research has also shown that the current Indian cars, apart from one model, have chargers that are less than 3.3 kW [7]. Hence unless there is a huge penetration of EVs with chargers more than 7 kW, the adoption of low power charging rebates can be deferred. However, the application of TOU rates might be critical, especially in handling the residential EV charging.

3 Strategy For Residential EV charging

In India most of the State Electricity Regulatory Commissions (SERCs) have introduced flat EV-specific tariffs for public charging. Many of these tariffs are flat tariffs and deemed to be promotional in spirit [11]. Indian regulators are familiar with Time of Day (TOD) rates, which is equivalent to the TOU rate mechanism. However, these rates are currently only applied to industrial and commercial consumers [15–17]. However, currently, these rates are not applicable for EV charging at homes.

Global statistics show that a significant amount of EV charging happens at homes. The current guidelines governing the residential charging of electric vehicles is that the existing tariff will apply [18]. The residential energy rates in India are quite low as they are heavily cross-subsidized. The tariff scheme followed is typically a block rate that increases as consumption increases. Inclining block rates are not a practical solution for EV charging as it is designed to disincentivise high energy consumption [12].

To showcase the impact of block rate and flat rates on EV charging, a sample case study is performed using the existing electricity rate for residential consumers and EV charging in Delhi. In Delhi, the EV charging rate is INR 4.5 per kWh and the residential consumers have a block rate that varies between INR 3–8 per kWh [19]. Only energy charges are examined for this case study for two-wheelers and four-wheelers for an average weekly travel of 300 km. The electric two-wheeler and electric car models are assumed to consume 2.7 and 10.6 kWh per 100 km. This leads to the additional electricity consumption of 40 and 140 kWh for charging the two-wheeler, and the four-wheeler, respectively. The additional cost for EV charging is calculated for a consumer with monthly consumption of 400 kWh and presented in Fig. 1. The results show that for Delhi, the flat rates are better than the block rates. A more detailed analysis, including a TOU rate that offers 20% rebate during off-peak hours, shows that the impact is presented in Fig. 2. The detailed analysis for different monthly energy consumption presented for 4 W charging shows that the relative increase remains higher for block rates. The difference becomes predominantly noticeable when the consumer originally had a lower electricity consumption. Between the TOU rate and flat rate regime, the relative increase remains comparable as there is not much difference in absolute value for a small tariff.

The first challenge to tackle would be associated with the block rate system on consumer bills. In the international markets, the residential energy rates and EV

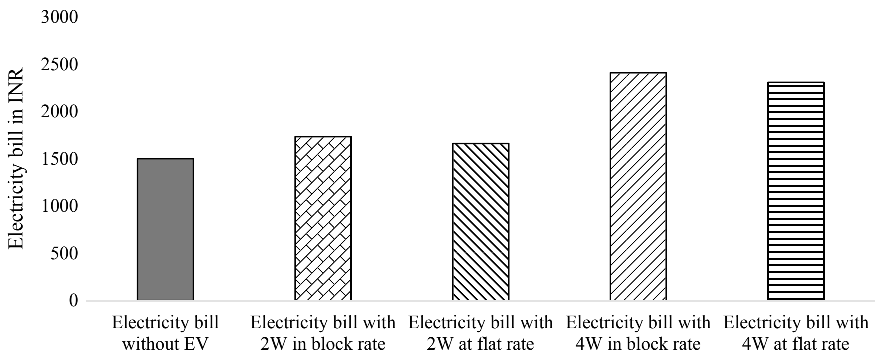

Fig. 1 Increase in residential energy charges under different rate regimes

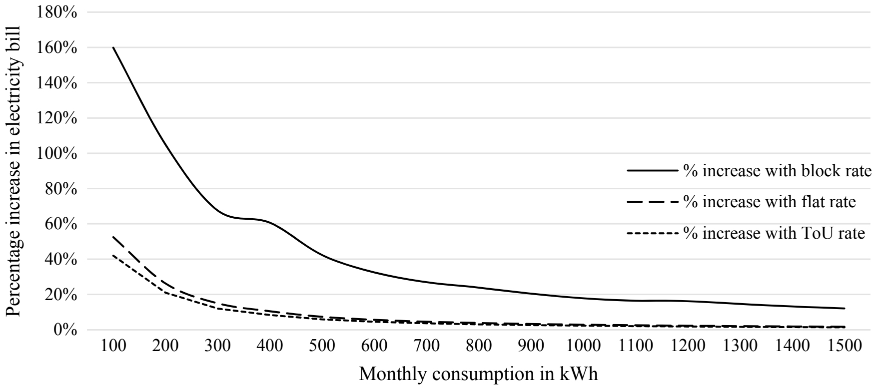

Fig. 2 Comparison of relative increase in residential energy charges in different rate regimes

specific rates as designed as TOU. Some of the utilities in the international market has extended another distinct EV specific tariff for the residential consumers, which comes with a separate meter. This would assist in handling the peak demand from EV charging and other residential energy consumption separately. India could adopt this strategy as with rapid urbanization and increasing appliance penetration, the residential energy consumption is increasing significantly.

It can also be concluded that a significant proportion of EV charging in residences. In the case of India, as there is no TOD tariff for residential consumers, the EV owner has no incentive not to plug the EV into the socket as soon as he reaches home. This leads to a situation where the electric vehicles are charged at the evening peak time. This will significantly impact the evening peak demand and ramping rate when the penetration of EVs increase. The ramping requirement and flexibility requirement are important considerations for a nation that is significantly increasing renewable energy penetration. Passive strategies like TOU rates are relatively easier to implement and but has limited benefits for grid flexibility.

4 Active Charging Strategies

Active charging control methods such as on–off control, increasing or decreasing the charging rate, and supplying power back to the grid will help in exploring additional value streams, especially in the flexible operation of the grid. The application of VGI technologies for grid services using active charging control is in the initial phases. V1G implementation can help in curtailing the rising peak demand, increasing renewable energy penetration, and providing grid support. V2G application though complicated, has the edge over unidirectional charging in extending the value streams from V1G. The value streams from active charging management from V1G and V2G is presented below:

- **Arbitrage opportunities:** The primary driving factor for the consumer to adopt VGI is price arbitrage. While V1G can assist primarily in reducing the cost associated with EV charging, V2G provides a chance for the consumer to earn more revenue using EV as a grid resource. With the implementation of V2G, an EV consumer may act as a prosumer or provide grid services in the local market.
- **Peak shaving:** The grid operator can also effectively use V1G to handle the rising peak demand that can be curtailed by implementing V1G & V2G. While V1G is suited for shifting the EV load to an off-peak period, V2G can help in further reduction of pre-existing peak demand. If a bi-directional flow of power is enabled, the energy stored in the EV may be discharged by the consumer to meet the local power requirement during period of peak demand.
- **Supporting Renewable Energy**: With V1G the EV charging load can be shifted to a period of high solar generation. With V2G, EV can be effectively used to store energy during periods of high renewable energy generation and subsequently use it during another time period. This can ensure higher utilisation of the generated Renewable Energy, and thereby EV can support higher penetration of Renewable Energy in the local grid.
- **Frequency Response:** One of the most sought out applications of EV is in providing grid support by frequency regulation through V1G and V2G. The supply and demand mismatch can be compensated with V1G implementation with increase and decrease of charging current in response to regulation up or down signals. With V2G the more is possible as the EV can be discharged or charged like energy storage units. In this case, the EVs can provide faster frequency response and act as a spinning reserve. To avail the best value proposition from VGI for frequency response and other grid support services, aggregation of EVs is critical.

It should be noted that the active charging strategies do not exist in isolation with the passive load management strategies. The existence of a time-sensitive tariff regime or incentives for low power charging will encourage the adoption of active control strategies. In that sense, it can be said that they are complementary to each other. However, in India, as discussed in the sections above, the application of TOU is limited. Secondly, in the existing TOD regime, the difference between peak and off-peak periods is not too high to encourage a shift to off-peak consumption. The tariff is also not designed now, such that there is a rebate during peak solar generation hours. The methods for determining the effectiveness of the TOU rate are also not in practice.

5 Case-Study For Load Shift

Two value streams from VGI that are particularly important in the Indian context is related to the time shift of loads. One is a shift of EV load from a period of peak demand to an off-peak demand. The second value stream is in a shift to a high renewable generation period during the day. Both of these applications become extremely relevant for India in handling the evening peak demand and ramping up of power plants. Charging of electric two-wheelers and four-wheelers in homes will compound the existing problem. However, the VGI strategy adopted should be based on the regional load pattern. A case study is performed considering three distinct load curve shapes where there are differences in the evening peak demand pattern, as shown in Fig. 3.

These load patterns are derived from the load shapes of the State of Uttar Pradesh, Delhi, and Maharashtra. For the case study, only the load shape is maintained, and the load curves are scaled down to showcase the impact of the EV charging load. In terms of absolute demand, the demand in these States is very high that at a low level of EV penetration, there is not much impact on the load curves. For the case study, the battery capacity for two-wheelers is taken as 2kWh, and for four-wheelers

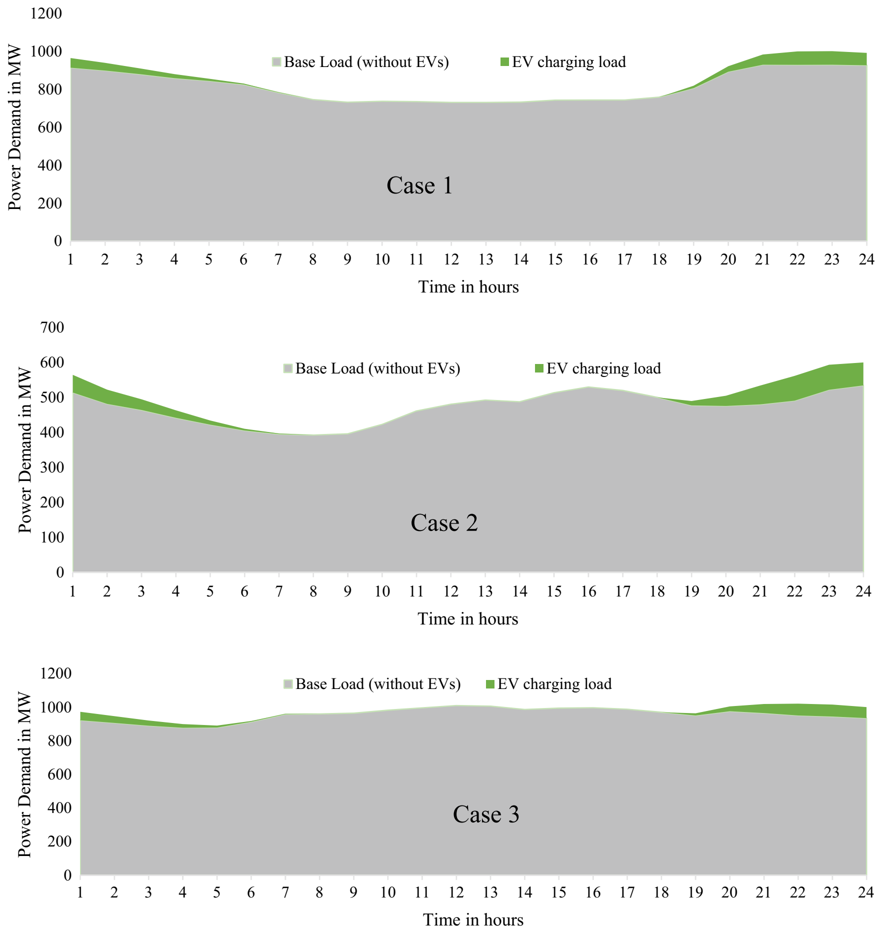

Fig. 3 Case study for EV charging strategies

is taken as 25kWh. Time taken to charge the battery between 30 and 80% is taken as 4 h for two-wheelers and 8 h for four-wheelers. The total number of two-wheelers and four-wheelers across the network are taken as 100,000 units and 10,000 units, respectively. The charge cycle is assumed to start from 6 PM onwards. Two scenarios are discussed for each case to shift the load, shift to an off-peak period at night, and shift to a high solar generation period during the day.

- **Case 1:** In this case, the VGI strategy should be to minimise the EV charging during evening ramping and shift the load after 2 AM when the demand starts to decrease. It also makes to shift demand to day time as the demand is low, especially if the state is planning for increasing share of Solar energy in the generation mix. Both these shifts are possible with passive strategies.
- **Case 2:** In this case, the VGI strategy should be to retain some of the charging during the evening in the 6–9 PM window and shift the load after 2 AM. In this case advanced charging control methods are needed to ensure charging between 6–9 PM, where was TOU rate can help in shift of demand after 2 AM. It is not advised to shift the load to day time unless the state is planning for a very high share of solar generation. In case this needs to be done advanced charge control methods are recommended.
- **Case 3:** In this case, as there no valleys in the demand curve, the strategy should be to distribute the EV charging throughout the day. Here passive charging strategies for time shift will have limited success. Active charging control strategies with aggregation is needed to distribute the load. It is not advised to shift the load to day time unless the state is planning for a very high share of solar generation.

The case study shows that it is important to adopt a mix of strategies to suit the existing load pattern. In some cases while passive charging strategies are effective in handling EV load, in other cases more advanced charging strategies are essential. VGI strategy should be case specific.

6 Discussion and Conclusion

The VGI strategy depends on multiple factors the type of Vehicle, concerns for battery health, and charging technology. The stakeholders have expressed that electric two-wheelers and electric three-wheelers are not good candidates for grid support through VGI. On the other hand, VGI using electric cars and e-buses could work, with favourable economics. Researchers have flagged that the issue of battery degradation with VGI and the impact of VGI on different battery chemistries should be studied further in the Indian context. Another factor affecting VGI is the availability of V2G enabled chargers. The Combined Charging System (CCS) chargers preferred by Indian EV manufacturers are not currently capable of bidirectional charging. Lack of a smart backend communication system with standardised communication protocols is a prerequisite to VGI. For a “smart” charging infrastructure Advanced Metering Infrastructure (AMI) and communication is also critical.

Deriving a foolproof VGI strategy for India involve a variety of stakeholders, including DISCOMs, fleet operators, charging service providers, and Research and Development (R&D) institutions. All stakeholders are positive about the benefits of VGI for DISCOMs. V1G is important in demand response, and V2G can assist in frequency regulation, voltage regulation, black start support, and reliability improvement. However, due to the lack of regulatory framework and incentives, there is uncertainty about the financial attractiveness of VGI. Another significant challenge to implementing VGI in India is the lack of an ancillary service market.

A favourable regulatory ecosystem is a prerequisite for VGI implementation, and the first step is true price signals for electricity. The first and simple step in providing appropriate price signals is implementing TOU electricity rates. Appropriate regulatory provisions are necessary to clearly define how EVs should be treated as a "resource" with its Vehicle with the battery, charging station, and aggregator.

If the Vehicle, along with its battery, is recognised as the resource, the Vehicle may need to have a meter to measure energy transactions. Necessary regulatory provisions should allow the "resource" to move around, and the Vehicle has to be registered as a consumer to the DISCOM. If the charging station is recognised as the "resource", transactional complexity is less with fixed geographical location with specific metering. If the aggregator is defined the "resource", it is a "virtual" and geographically spread out resource.

Enabling EV aggregation and allowing aggregators to participate in energy markets is essential to maximise value proposition from VGI. DISCOMs are an important actor in EV resource aggregation, and multiple operation models are possible with different levels of DISCOM involvement.

- DISCOM can the sole aggregator which would allow them complete control of EV charging or discharging and use it to effectively manage the power system.
- DISCOM can acts as the meta-aggregator, with another aggregator as the intermediary between the customer and the DISCOM. The DISCOM has no direct interaction with the customer, and the aggregator has no direct involvement in the wholesale market.
- DISCOMs and third-party aggregators can both act as aggregators in a competitive electricity market that allows aggregation. It is also possible to restrict the role of DISCOM as an aggregator and allow only other actors to compete.

Existing Indian regulations lack provisions that permit "aggregation" of EVs, to provide grid services. A potential solution would be for FoR to develop a model regulation on resource aggregation. Depending on the scale of aggregation, EVs can deliver to bulk power system and local distribution systems. Aggregated smart charging can offer system services such as demand response, voltage regulation, and other ancillary services and help avoid the need for investment in capacity addition. Unfortunately, India's electricity sector sees limited application of demand response and there is no retail market mechanism for energy and ancillary services. The use of EV to provide frequency regulation and other grid services is also limited as there no retail energy or ancillary market mechanism currently. Moreover, load aggregation is

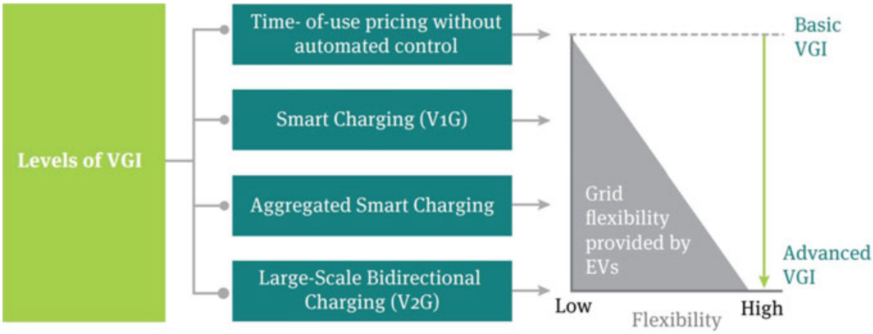

Fig. 4 Vehicle to grid integration strategy and flexibility

not currently not permitted, and aggregators are not allowed participation in energy market.

India is making great strides toward large-scale adoption of renewable generation for decarbonising the grid. The increase in penetration of variable generation increases the need for flexibility in grid operation. Electrification of transport will increase the electricity demand and support in reducing the emissions from the transport sector. Apart from EVs, rapid urbanisation, an increase in the standard of living, and a rise in appliance penetration are factors that will lead to a significant increase in electricity demand in the upcoming years. It should be noted that electrification of transport, while only be one of the leading causes of rapid increase in electricity demand, needs to act as a flexible load to support the integration of variable generation. Hence it is imperative that the VGI strategies for India should factor in the grid flexibility, as shown in Fig. 4. There are four main levels for VGI for India—TOU rates, Smart Charging (V1G), Aggregated Smart Charging, and Large-Scale Bidirectional Charging (V2G). The first two levels can be achieved in India within the existing regulatory framework. Considering the level of maturity of India's e-mobility and power regulatory ecosystem and market mechanism a phase-wise VGI implementation roadmap could be effective for the country.

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Journey of Implementation of Line Differential Protection at Distribution Utility "Tata Power Delhi Distrbution Limited"

Himanshu Lalchandani, Deepak Agrawal, and Lalit Kumar

Abstract Protection Relays and the Communication Systems brain and heart of a power system network. Utilities in India have been using electro-mechanical and static protection relays since a very long time and have already adopted conventional protection schemes. With the advancement in Protection Relay technology, a shift is however imperative to achieve efficiency and cost optimization in an ever growing distribution network. Being a front-runner in the adoption of latest technologies in the utility space, TATA Power-DDL has successfully revamped its Protection and Communication Infrastructure by commissioning modern numerical relays having capability to integrate on IEC 61,850 communication protocol. A Smart grid roadmap has now been adopted by TPDDL and various technologies have already been successfully implemented like Grid Substation and Distribution Automation, SCADA/ADMS, GIS, AMI, DSM, Smart Meters, Communication Infrastructure and RF Canopy. Traditional protection schemes have worked successfully alongside all the recent advancements in technology as stated above. One of such schemes is Line Differential Protection wherein Line Differential Relays are installed at both ends of a transmission line and communicate with each other through a medium.

In TATA Power-DDL network, there are around 200 sub-transmission line circuits, most of them being of short length (2–3 km). Initially, these lines were protected by Back-Up protection—Over Current and Earth Fault Relays. But difficulties started to be observed while doing relay coordination based on current and time margin. Some cases of cascaded tripping were also experienced, resulting in MU loss and customer dissatisfaction. However, Distance Protection scheme had already been implemented as Main Protection in Boundary Line Feeders. But, the reliability and selectivity of distance protection is lost in the following cases:-

- Shorter lengths of Line Circuits

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- Inaccuracies in available Line Parameters.

Taking the fact into consideration that TPDDL network is having significant Circuit-Kilometers as compound (Overhead and Underground Cable) sub-transmission lines, distance protection relay may operate inadvertently. Hence, the organization decided to shift to Line Differential Relays. Ever since, two major revamping projects have been implemented in TATA Power-DDL, based on the type of Communication technology adoption. The two technologies currently in service are:-

- Direct (Dark) Fibre Communication- Implemented on around 45 Circuits
- IP-MPLS (IEEE C37.94) based communication-Implemented on around 140 circuits

Technological Upgradation in tele-protection systems got our attention and we decided to implement the IP-MPLS infrastructure. The IP-MPLS based Line Differential communication offered us following advantages:-

- Lower Latency time
- Ease in remote health monitoring of the communication ports.

Moreover, all the IED project files of Line Differential Relays have been kept in a secured central server for easily accessing Fault Data Records and checking relay communication.

This major advancement has improved our reliability indices and have played an important part in reducing Uncoordinated Trippings.

Keywords Line differential · Numerical relays · Direct fibre · IP-MPLS · Three-terminal

1 Introduction

Since its inception in 2002, TATA Power-DDL has been successful in creating benchmarks in the electrical utility industry. After the unbundling of the erstwhile State Electricity Board (Delhi Vidyut Board), the distribution license area of North and North-Western Delhi came under the purview of TATA Power-DDL. Now, TATA Power-DDL was entrusted with the responsibility of taking electricity from the Transmission Company- Delhi Transco Ltd. (DTL) and supply power to various classes of HT and LT consumers. The next few years saw the implementation of basic utility infrastructure like Billing and Collection Facilities, Network Upgradation etc. Subsequently, advancements in technology were adopted which led to implementation of SAP based Enterprise Suite and SCADA Control Centre with OMS and DMS packages. The SCADA and associated applications were finally unified into Advanced Distribution Management System (ADMS) in 2018. The substation equipment particularly the Protection infrastructure also witnessed significant advancements during this period. Electromechanical and static relays were gradually replaced with much more advanced Numerical Relays. Meanwhile, the electrical network kept on growing at a rapid pace. A general increase in fault levels was also observed. These situations led to decrease in current and time margins for effective protection coordination at the Sub-transmission and Distribution Level. In the process of overcoming these challenges and adopting advanced protection technology, Line Differential Relays were introduced to be implemented on Sub-Transmission (66 kV and 33 kV) Line Circuits of the network.

2 Line Differential Protection

2.1 Scheme Details

The line differential scheme is an established and successful protection scheme. It is an application of Differential Protection principle based on Kirchhoff's Current Law (KCL) which states that all current into a network node shall add up to 0 in an ideal system. The scheme uses two or more differential relays at each end of a transmission line. All the relays communicate with each other through a dedicated communication link. High speed and secure communication medium is required to transfer data among all the relays so that each relay can perform its calculations and issue a high speed trip command.

Line Differential Relays operate when a difference in current is observed going into a line compared to current coming out of the line. Considering ideal situation, this difference occurs only if there is a fault in some part of transmission line. In the cases of normal operation and a through fault (out-zone fault) event, relays at all the ends of the line measure same value of current through the CTs. But, in case of an internal fault, the relay at one end measures a high magnitude fault current while the other ends measure no current, which prompts the relays to issue a trip command. Generally, line differential tripping command is configured to be issued instantaneously. Factoring in the relay contact operating time, Master Trip Relay operating time and Circuit Breaker tripping time, the circuit can be isolated in around 50–70 ms (Fig. 1).

In the figure, I_L and I_R are Local and Remote currents respectively. CT polarities are shown by direction pointers on each end of the line. Note that the relays at each end would measure phase opposition in each phase currents during normal condition.

2.2 Experience with Relay Settings

Although in ideal situation, the Line Differential Protection principle is a beautiful and primitive concept based on vector subtraction between two quantities, but the presence of certain conditions require the use of advanced stabilization methods to

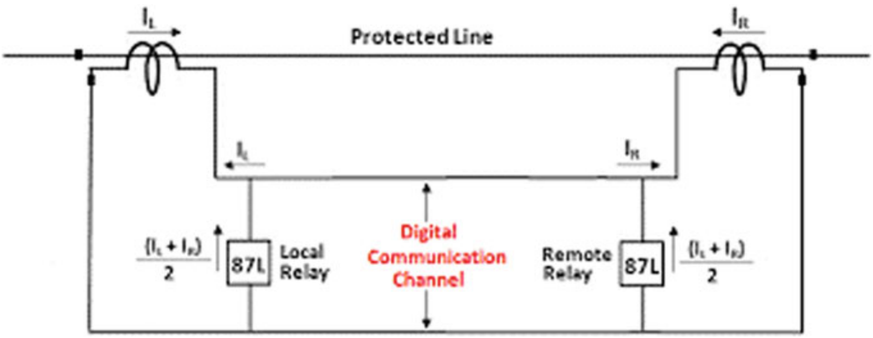


Fig. 1 Basic line differential protection scheme

implement a reliable protection scheme. Presence of cable charging currents, CT errors, communication delays etc. may lead to maloperation of the relays leading to unwarranted trippings.

Various OEMs have tested their own different versions of calculation algorithms and have implemented the same in their Differential Relays. In TATA Power DDL network, 90% of the Line Circuits having differential scheme have GE L90 and Micom P543 relays installed at each end. Further discussion would be based on considering Micom P543 Relay only.

Generally recommended differential settings are described below:-

- I_{s1} (Minimum pick-up level)—0.2 p.u.
- k_1 (Lower percentage bias setting to compensate for CT errors)—30%
- I_{s2} (Bias current threshold level)—2 p.u.
- k_2 (Higher percentage bias setting for through fault conditions)—150%.

It is recommended to use k_2 slope setting as 150% (2 terminal connection) and 100% (3- terminal connection) to prevent inadvertent tripping of the Line Differential Relay in case of High intensity Out-Zone (Through) Fault (Fig. 2).

Another important consideration to keep in mind is the CT Ratio compensation. The CT Ratio of CTs in grid stations at the terminals of transmission lines may or may not be same. In case they are not equal, CT Ratio Correction Factor (CF) must be entered in the Relay.

Calculation of CT Ratio Correction Factor

A 33 kV line circuit goes from 33/11 kV Wazirpur-3 substation to 33/11 Wazirpur-1 substation. CT ratio at Wazirpur-3 end is 750/1 while at Wazirpur-1 end is 800/1. At both the ends, Micom P543 Line Differential Relay is installed.

Lower CT Ratio Primary is considered as base value. So here, base value is 750.

(a) ***At Wazirpur-3***- *CT Primary = 750 A*

Base Value = 750 A.
Secondary Current when primary is 750A = 1 A.

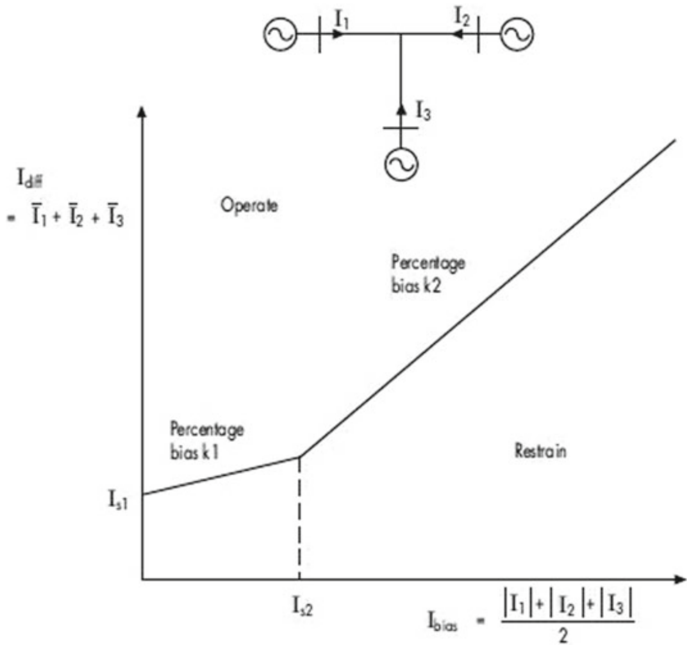


Fig. 2 Differential operate and restraint region in percentage bias settings

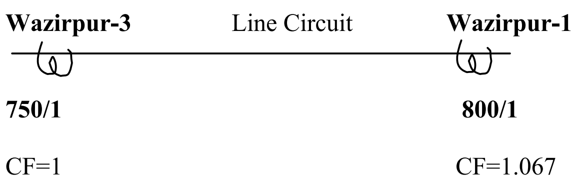
CF = 1/1 = 1.

(b) ***At Wazirpur-1-*** *CT Primary = 800 A*

Base Value = 750 A.
Secondary Current when primary is 750A = 750 / 800 = 0.9375A.
CF = 1/0.9375 = 1.067.

Hence Correction Factor to be entered at Wazirpur-3 substation is 1 while at Wazirpur-1 substation is 1.067.
*(Under **I diff Configuration** menu in P543)* [1] (Fig. 3).

Fig. 3 Calculation of CT ratio correction factor



3 Phases of Line Differential Commissioning in Tata Power-DDL

Based on the availability and prevalence of communication infrastructure, Line Differential Relays have been commissioned in TATA Power-DDL in 2 phases:-

(1) **LDR Phase-I**—The project began in 2011. It marked the beginning of the use of Line Differential scheme across TATA Power DDL. The Relays installed in this project were GE L90.

Dark Fibre communication technology was utilized for establishing link between the relays at the two ends of the circuit wherein 1320 nm single-mode Fiber Optic was used.

Around 90 Relays (45 circuits) covered during this phase.

(2) **LDR Phase-II**—The project began in 2017.Micom P543 relays were commissioned in this project on around 140 line circuits. Line Differential Relays require low latency and synchronized data for initiating effective trip decisions. Both these conditions are fulfilled by utilizing IP/MPLS networks. IP/MPLS or Internet Protocol/ Multi-Protocol Label Switching is a method of transporting multi-protocol data on a pre-engineered path. This protocol provides L2/L3 VPN and hence keeps different services of different consumers separate and secured. Relays in the substations are connected to IP/MPLS Provider Edge (PE) routers through multimode Optical Fiber (840 nm). IEEE C37.94 optical interface has been utilized in this setup. It is recommended to keep the following aspects in mind while establishing Line Differential Relays link over IP/ MPLS:- (For P543 Relays)

(1) It is recommended to use 2 pairs of optical fibre cables (one for each channel) to provide redundancy. Differential Setting is blocked in case communication channel is failed. It is to be ensured that **Dual Redundant** option is selected and Relay Address at one end is 1A while on other end is 1B (can keep 2A and 2B…20A and 20B etc.) under **I diff Configuration Menu**
(2) Proper labelling and tagging on all Optical Fibre ends (Relay or Router) is to be ensured.
(3) Test Loopback option to be **disabled** (under **Commission Tests** menu)
(4) After taking the Relays in service and performing On Line Stability Test, latency time needs to be recorded from **Measurement 4** menu. Recommended values can range between 2 and 5 ms. (It is advisable to check latency time of the network beforehand)

4 Commissioning of Three Terminal Line Differential Relays

There are many T-Off circuits in the TATA Power-DDL network. They provide the Power System Control Centre with the necessary flexibility while ensuring power flow in the network.

However, these circuits were either not having Line Differential Protection or Line Differential Relays have been installed at 2 ends of the circuit (T-Off created at later stage). So to provide power flow in both T-Off sections, Line Differential protection had to be disabled. Also, if Line Differential required to be enabled, then breaker at the other T-Off section needed to be kept OFF. (2 terminal LDR will give trip command if power is flown in both T-Off sections). Hence to enable Control Center to take load at all the three substations simultaneously as well as enhance the flexibility in load management without taking Main Protection out of service, Three Terminal Line Differential Scheme was implemented in Nov, 2020 for the first time in TATA Power-DDL (at Wazirpur-1, Wazirpur-3 and Azadpur substations) (Fig. 4).

Three Terminal connection can be established by implementing following configuration in each relay:-

(1) Three Terminal option to be selected under **I diff Configuration** menu.
(2) Relay Address to be kept as 1A, 1B, 1C for each of the three ends for a particular line circuit (2A, 2B, 2C……. 20A, 20B, 20C can be used)
(3) Relays need to be connected with each other in Ring Formation as described further.

(Note that each relay gets the Analog Value data of other two remote end relays and can issue a trip command) (Fig. 5).

In above figure, communication link from Channel 1 of a Relay are connected to Channel 2 of another relay.

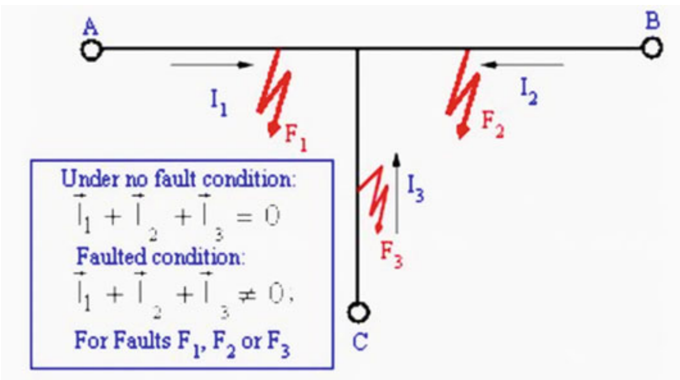


Fig. 4 Tapped (T-Off) circuit configuration [2]

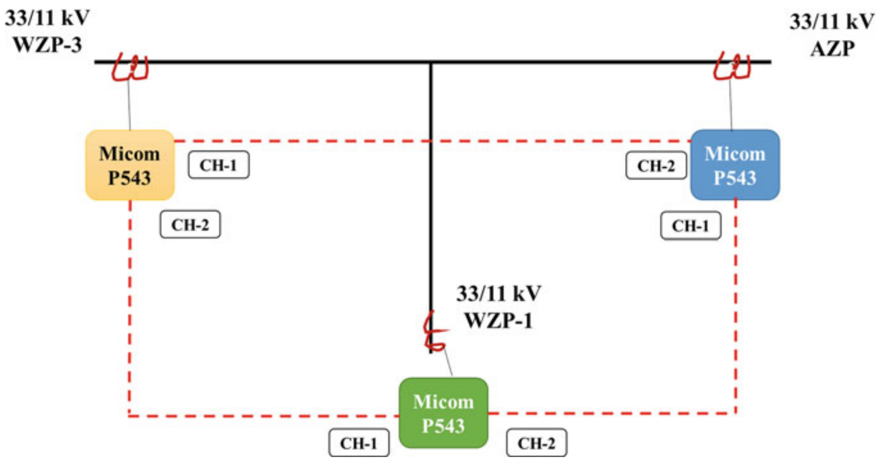


Fig. 5 Three terminal line differential relay with communication links at Wazirpur-1, Wazirpur-3 and Azadpur

On Line Stability Test

After successful installation and commissioning of Relays in three terminal arrangement, online stability test can be performed. For this test, Differential pick up setting (Is1) is increased and the circuits are loaded. Then Analog values like Currents, Differential Currents and Restraining Currents are noted on the relays at all three locations. Differential Current should ideally be 0 during normal operating condition. If magnitude of differential current is appearing then it may be a case of reversal in polarity of the PS class CT at that substation. So, polarity needs to be corrected wherever applicable and then Differential pick up setting is normalized. Results of online stability test have been tabulated in Table 1.

5 Conclusion

The journey of implementing Line Differential Relay infrastructure in the complete TATA Power-DDL network has been very challenging yet rewarding. In this process, complete data digitization has also been achieved enabling easy access of IED and panel drawings for the operation and support engineers.

Table 1 On line stability test results while taking line differential relays in service at WZP-3, WZP-1 and AZP substations

GRID	CIRCUIT	LOCAL						Remote-1					
		Ia	Angle	Ib	Angle	Ic	Angle	Ia	Angle	Ib	Angle	Ic	Angle
WZP-3	AZP T-OFF WZP-1 CKT-1	122	0	120	-118	121	122	64	-171	60	71	64	-47
WZP-1	WZP-3 OFF AZP CKT-1	62	0	62	-119	62	-120	58	-18	58	-135	58	105
AZP	WZP-3 T-OFF WZP-1 CKT-1	58	0	58	-120	58	120	120	-169	120	70	120	-49
WZP-3	AZP T-OFF WZP-1 CKT-2	110	0	109	-119	111	120	56	-167	54	72	54	-45
WZP-1	WZP-3 OFF AZP CKT-2	53	0	53	-120	53	120	54	-30	56	-153	56	89
AZP	WZP-3 T-OFF WZP-1 CKT-2	55	0	56	-116	57	120	111	-117	111	73	111	-46

GRID	CIRCUIT	Remote-2						Differential		
		Ia	Angle	Ib	Angle	Ic	Angle	Ia	Ib	Ic
WZP-3	AZP T-OFF WZP-1 CKT-1	58	170	60	48	62	-65	0-4	0-4	0-4
WZP-1	WZP-3 OFF AZP CKT-1	120	170	120	52	120	-69	0-4	0-4	0-4
AZP	WZP-3 T-OFF WZP-1 CKT-1	60	16	60	-101	60	138	0-4	0-4	0-4
WZP-3	AZP T-OFF WZP-1 CKT-2	58	163	56	47	58	-76	0-5	0-5	0-5
WZP-1	WZP-3 OFF AZP CKT-2	109	167	109	47	113	-71	0-6	0-6	0-6
AZP	WZP-3 T-OFF WZP-1 CKT-2	59	23.4	59	-96	59	145	0-7	0-7	0-7

Acknowledgements The encouraging and timely support from the Business Associate—General Electric (GE T&D India Ltd.) has played a role in enabling TATA Power-DDL to embark on this journey of technological advancement.

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Development of Smart Data Analytics Module Enabling Access to Electric Vehicle Usage in Smart City

Surekha Deshmukh

Abstract The progressive acceptability of E-mobility is a key performance indicator for any City Authority. The trend of citizens towards acceptability for the personal and public E- transportation usage is increasing recently. Under the urban development, new initiatives towards Green Energy is socially welcomed such as increased use of Solar PV Renewable Energy Integration as well as Electric Vehicle. Both these green initiatives have opened up many business opportunities for participants under V to G and G to V integration and solar PV integration to grid due to restructured and deregulated power sector. The 'Electric Vehicle' is the source of innumerous diversified data useful for City Authorities to leverage, enabling insightful strategic planning for future growth, development and investments in the initiatives benefiting citizens and stakeholders of the city. This paper provides proof of concept of development of prototype hardware with the optimum cost along with applicability to maximize the visibility.

Keywords Data · E Vehicle · Smart City

1 Introduction

Many Countries including India have embraced green technologies and green initiatives with ambitious plans, there is need to design and develop affordable, efficient, modular IOT based DATA Analytic-unit for recording and billing of electricity consumption, enabling owner of electric vehicles to be aware of techno-economical aspect of e-vehicle.

This objective of the paper is to discuss about the DATA driven opportunities in leveraging the presence digital enablers such as IOT, AI based algorithms to address two major dimensions of DATA. The first aspect is DATA relevant to usage of e-vehicles, vehicle performance management and second aspect is DATA used for various challenges in Vehicle to Grid (V2G) mode of connectivity in today's smart grid. The data received from sensors to trip logs, once analyzed can be used

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for developing policies for siting charging stations, developing smart charging algorithms, solving energy efficiency issues, evaluating the capacity of power distribution systems to handle extra charging loads. With a growing EV market, the impact of EVs on the power grid is a matter of concern, especially at the distribution level. The technical challenges need to be addressed are peak loading, increased losses, voltage unbalance /deviations, and need for additional network reinforcements at grid.

The module should predict the malfunctioning battery cells, heating and cooling details and finally, determining the market value for the services provided by electric vehicles.

Along with technical and mathematical treatment, the hardware details for development of unified module of DATA analytics will be shared in detail in the paper with expected outcome and practical applicability to users, policy makers, vehicle manufactures, service providers, inventory and logistics managers etc. Electric vehicles are next future of mankind. In big residential societies using such hardware facility will make an E-vehicle user an easy way for rate charge of consumption of the vehicle as hardware will eventually generate relevant statistical data.

To develop prototype hardware, enabling to keep accounting of consumption of electricity for charging of the electric vehicle at big residential societies.

Add and maintain record of power consumption:-In order to add up new records of consumers for power consumption, there will be storage of that information on the cloud (In order to make it platform oriented). So that information will be accessible for everyone.

Provide convenient solution of billing pattern:-It will take input from energy meter (i.e. number of unit consumed by consumer) and then calculate the bill using program. Calculated bill will be send to consumer on their cell phone through text message.

It will facilitate the decision of payment towards electricity consumption for charging electric vehicle. This will eventually generate relevant statistical data such as number of electric vehicle owners, types of vehicle, time of use of charging point, charging hours, electricity consumption, battery storage capacity etc. at City level, State level, National level.

2 Prototype Hardware

The objective of prototype hardware is to record as well as create the bills of consumption of power exclusively for charging of batteries of vehicle.

Taking examples of business—corporate—industry premises, having charging points, there is need to keep record of who is consuming the power for vehicle battery charging purpose.

The organization may participate in green power initiatives by knowing the data such as number of associates with electric-two wheeler, four wheeler, per shift. They can also get information about the frequency of changing of batteries per associate, time of changing, time required to complete charging-pattern of power consumption per associate.

For the same, there can be IOT based energy meter reading system with automatic billing system. Based on the requirement of design various components are selected. Assembly of components will be done.

2.1 Components of Hardware Model

Following components are important parts of hardware model.

- 128*32 OLDE Display
- Raspberry pi 4
- RS485 Converter
- Digital Energy Meter
- End Terminal Resistor

2.2 Generalized Block Diagram for Developing Module

To generate the required database regarding vehicle usage, the hardware is developed with processing of input information and applying logical criteria, the output is communicated to the owner of vehicle and regulatory authority too (Fig. 1).

The type of the micro controller, communication protocols and communication technology is the choice of the developer. Based on the required inputs to be fetched to calculate power consumed, the details gets decided.

It has straightforward information flow of load ie vehicle- battery connected at the charger, Ac supply will get converted into DC and batteries will get charged.

The voltage and current magnitudes will get recorded and AC power utilized for battery charging after getting converted to DC, will get used to evaluate actual power consumption. Also the time of login, logout of the unit will be recorded by the timer.

The identity of the user along with the vehicle identity will also be get recorded each day. The data logger can be attached to computer and software will perform rest

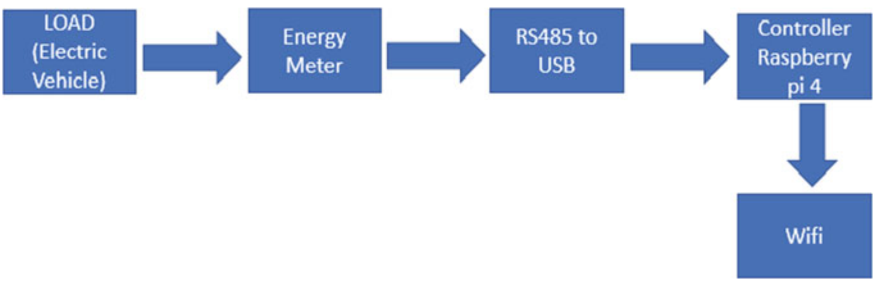

Fig. 1 Hardware flow for power consumption

of the functions of analyzing the database along with evaluating the cost of power-consumption. Based on the tariff structure at LT sector, the cost of consuming energy can be easily calculated and even communicated to the user. This will not.

only make user of E-Vehicle be aware of the energy consumption, but also can plan for investing required green energy Solar PV generation system, in case of possibility of roof top availability and initial investment budget.

There are couple of peer to peer trading opportunities for such chargers, once Solar PV power generation system is installed, based on availability of excess un-utilized power [1, 2].

The smart controller can keep track of load demand as well as Solar PV generation to match them [3, 4]. In case of unbalance such as excess generation, the communicable switchgear can be operated to connect the Vehicle as a load. This is going to be dynamic in decisional as well as operational aspect (Fig. 2).

This controller can also be developed with the logic of prioritizing the loads.

Figure 3 provides generalized idea of measuring and recording and communication of energy consumption using voltage and current sensors, processors, storage as well as RS 485 as major components.

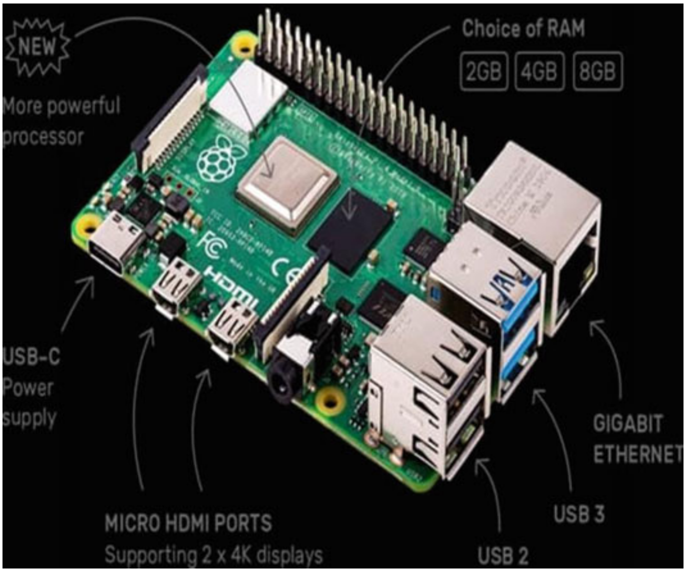

Fig. 2 Development of controller

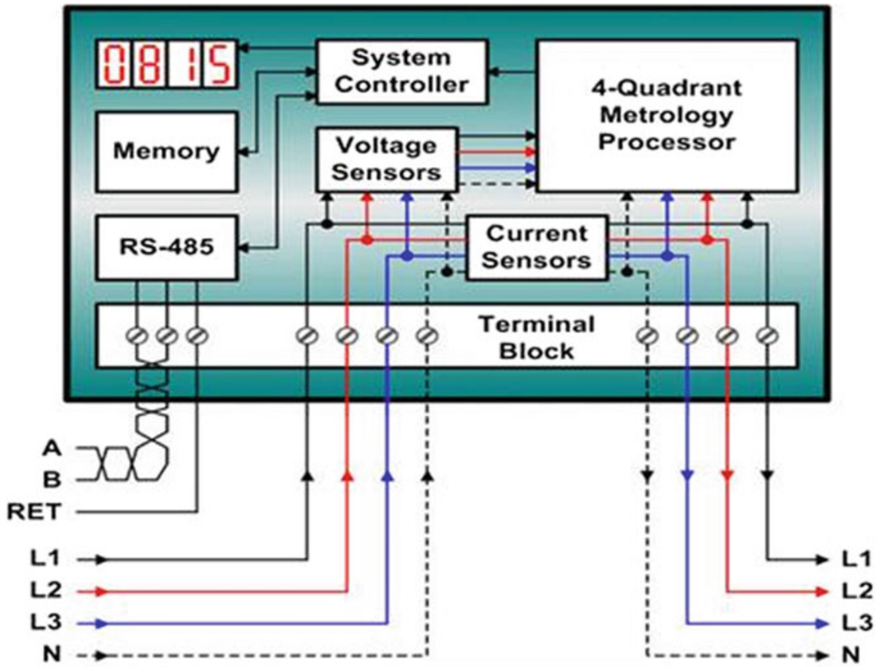

Fig. 3 Meter details

2.3 *Logic of Fetching the Data*

The portable module will consists of three stages, first is the input-collection, second stage is building mathematical and logic modeling, the third stage is communication based interconnect with multiple stakeholders such as user of charging unit, campus authority, City Authority etc [5–7].

This module can be shared with multiusers, unlikely individual Energy Metering infrastructure.

Each user will have to input his/her identity code as the first input before enabling the record of power consumptions.

As the same module keeps the record of identity of user, type of vehicle, time of connection, time of charging etc., it will generate huge amount of important data.

Multiple usage of the module can be Industrial hub, housing societies, “V to G” and “G to V” integration, Peer to Peer trading, load priority and participation in demand response.

Combination of time of use of tariff and generation and resource management is another techno-commercial opportunity for citizens who are HT customers.

Logic of using data of charging pattern, pattern of usage of vehicle, frequency of charging, consumption, time of charging, number of E vehicle owners, geography wise literacy and social towards e vehicle, social survey, attitude and acceptability towards two wheelers, four wheelers, common charging stations, adaptability, city perspective towards.

Encouragement to use of green energy and Use of Green energy for batteries will be the outcome for this exercise.

The transition of operational responsibilities from network to system stage has opened up such customized granular level possibilities of creating visibility of load as well as availability of power as and when required.

Indirectly the effect of Correlation with the road condition, weather conditions etc., mood of driver in applying breaks etc., loading of vehicle, ramp and straight roads, smooth roads can be mapped with the charging information.

Diversity of data is useful for the City Administers, Mayor who can encourage green energy programs involving citizens.

Insights of data—type and make of vehicle, popularity of product, life expectancy of battery etc.are the important.

2.4 Sample Code in Python

The software part of logic building is developed using Python. The Fig. 4 shows script of sample programming.

It mainly highlights the Flowchart of logic to build hardware to leverage data.

This sample shown in Fig. 4 is the script of the communication to be made with the user. This includes details as name of customer, consumer id, time of usage, energy consumption and cost of energy consumption.

2.5 Practical Applicability

- The prototype hardware is multifunctional, hence can be used for different application to record database and communicate the same to analytics tool
- The regulatory authority as well as system operators along with HT prosumers can prepare action plans for real time participation in terms of load curtailment or load enhancement and resource management.
- The opportunities of power trading can be explored based on the data analytics
- The City authorities can utilize the database in projecting the Green Initiatives and increasing the visibility of the city in support of adapting towards technology advancements and smartification.

Fig. 4 Sample script of software

```
# -*- coding: utf-8 -*-

from twilio.rest import Client

# Your Account Sid and Auth Token from
twilio.com/console

# and set the environment variables. See
http://twil.io/secure

account_sid=
'ACd32982eca45f6c564365cd367125683a'

auth_token =
'67ff09ef96ff9051b4b6482e5524c978'

client= Client(account_sid, auth_token)



message = client.messages \

   .create(body=("Name Of Consumer - Vaishali
Awhad, Consumer ID - 1999, Time Of use of
charging- 7:56 PM, Charging Hurs - 2 Hours,
Electricity Consumption - 30 Units, Total Bill
Amount - 180 Rupees"),
```

3 Conclusion

The increased acceptance of citizens towards Electric Vehicle has brought in cultural shift at the city. The technology driven green initiatives are very widely executed all over the world. The opportunities such as peer to peer trading, real time participation of consumer in system parameter stabilization through economic benefits etc. have encouraged all stakeholders of power sector under restructured scenario.

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Hosting Capacity Analysis and Managed Charging Solutions for Electric Vehicle Grid Integration

Shivani Sharma

Abstract It is important for the DISCOMs to ascertain the location and time of charging in order to manage demand response. Electric Vehicles as additional load potentially run the risk of overloading local transformers especially during peak hours of the day. This paper includes a sample HV/LV N/W case study for E-mobility specific Studies in a Software Tool "NEPLAN" covering the typical Outputs of Load Profiling, Hosting Capacity Analysis (HCA) by Connection Point Power / Aggregated Power, Load Flow Time Simulation; and Sensitivity of Bottleneck Equipment wrt to Max ΔV. Charging of fleets would also require special attention from utilities for Depot and cluster charging since they would have strong geographically concentrated load with a distinctive charging profile depending upon the nature and use of an EV Fleet. All this increased load if unmanaged would have an impact on the distribution network leading to irregular load patterns. Additionally, since majority of EV charging is expected to be done at home, during nights the EV loads may also alter the daily load pattern for the DISCOMs. It also highlights the latest trend of Charging Management Systems focused on providing cheaper charging tariffs and the use of smart or managed charging solutions. Managed Charging could be divided into two major categories: Passive Managed Charging solutions that rely on customer behavior to affect charging patterns; Active Managed Charging that relies upon a bi-directional flow of information through multiple communications technologies. However, there is lack of industry protocols for the managed charging.

Keywords E-mobility · Neplan · Hosting capacity analysis · Load flow time simulation · Charging management systems

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1 Introduction

With the exponential growth of electrical vehicles soon, utilities need to be prepared to maintain reliability of the grid. The primary impacts on electrical systems are generation adequacy, generation flexibility, transmission grid capacity, and distribution grid capacity.

The main challenge of electrification of transportation expansion lies in the distribution networks and the overloading of network assets:

- Medium voltage substations may be needed (exceed feeder hosting capacity)
- Replacement of the head feeders and the distribution transformers
- Cable sections downstream may still lead to voltage limit violations
- Peak winter or summer demand, heating and cooling

Central challenges for Distribution System Operators consist of communicational and computational barriers, low visibility on distribution grid, optimal allocation of charging infrastructure, lack of regulation and market rules, and network codes devolvement.

2 Challenges of EV Growth

The typical challenges of EV growth that all the stakeholders face are:

- Lack of Regulation and Policy
- Low visibility on distribution grid
- Optimal allocation of charging infrastructure
- Medium voltage substations may be needed (if feeder hosting capacity exceeds)
- Replacement of the head feeders and the distribution transformers
- Cable sections downstream may still lead to voltage limit violations
- Peak winter or summer demand, heating and cooling
- Unmanaged Charging
- Analyzing regional scenarios with different e-mobility diffusion levels
- Potential challenges caused by the uncontrollable charging in different parts of power systems
- Technical solutions which can mitigate potential grid issues

Figure 1 indicates the EV charger types and typical integration in the Grid.

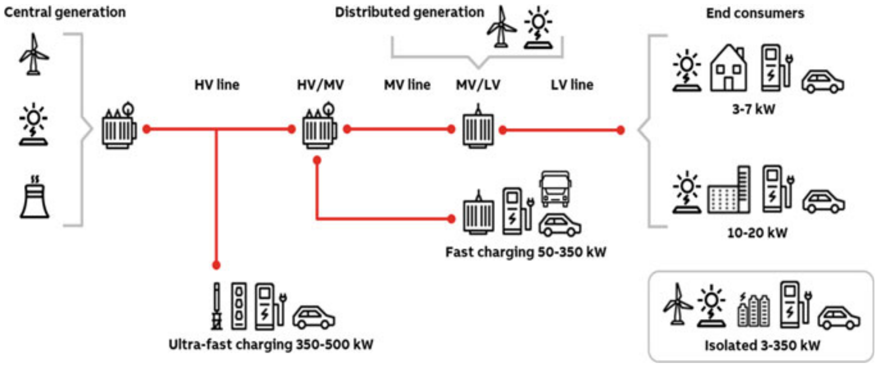

Fig. 1 Electric vehicle connecting to the grid

3 Grid Integration Analysis

The optimized solution for e-mobility charging, power grid management, and planning, Grid integration impact analysis of EV would typically require the following:

- Electric Vehicle (EV) load demand pattern
- Evaluation of distribution grid hosting capacity
- EV impact on distribution grids power quality
- Generation flexibility and response impact
- Cost–benefit analysis
- Analysis of international regulatory frameworks

The detailed E mobility specific power system analysis may be performed by very few software's, one such Simulation Software "NEPLAN", with the feature Hosting Capacity Module is detailed herewith. The Calculation criteria must be selected based on the application. "System Aggregated Power" would give a glimpse of total maximum power a network can support, whereas "Connection Point Power" would give the maximum power that can be connected on a specific location/node (Figs. 2 and 3).

Typical Analysis outcomes are as below:

These Integration have also to be aligned with the International, National and Local DER integration guidelines, few of them as specified in [2–7] and [8] (Figs. 4 and 5).

4 Managed Charging Infrastructure

Managed electric vehicle charging is an intelligent system that can control the time and/or rate of charging of one or more electric vehicles. Managed EV charging

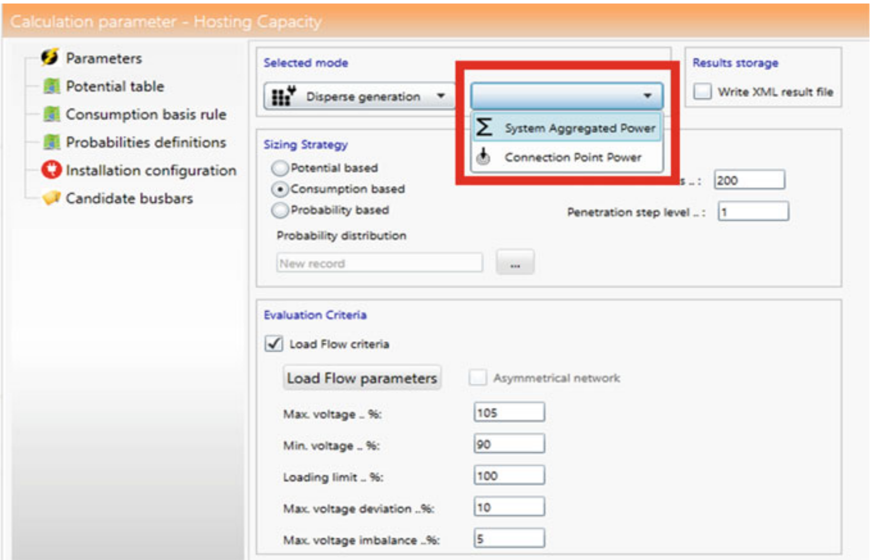

Fig. 2 Calculation strategy for hosting capacity analysis [1]

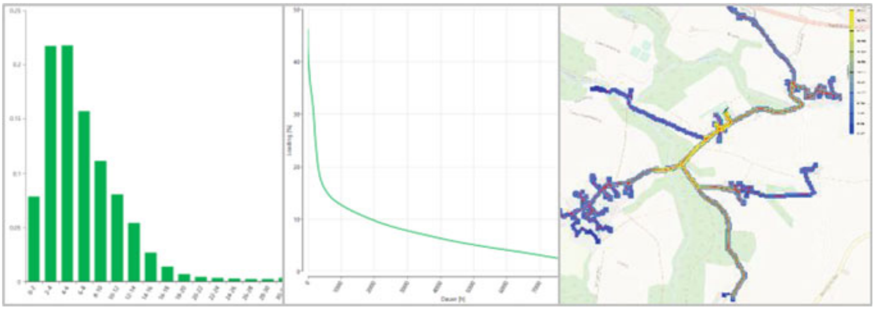

Fig. 3 Result of a time simulation—histogram, duration curve and heat map of the loading [1]

systems generally consist of three key components; a smart charger, a control system and the service user.

EV Assisted DSM: The development of EVs offers benefits not only in environmental protection and economics but also in demand response. Employing EVs in load scheduling enables the consumers to help alleviate the network load burden while reducing their own electric bills. For a household network, EV can be used as an auxiliary power supply for energy consumption of home appliances on special occasions, Energy Sharing Model can be developed for a cluster of houses. However, various factors like EV Behaviors, Scheduling patterns, user preferences must be taken into consideration while designing any such model.

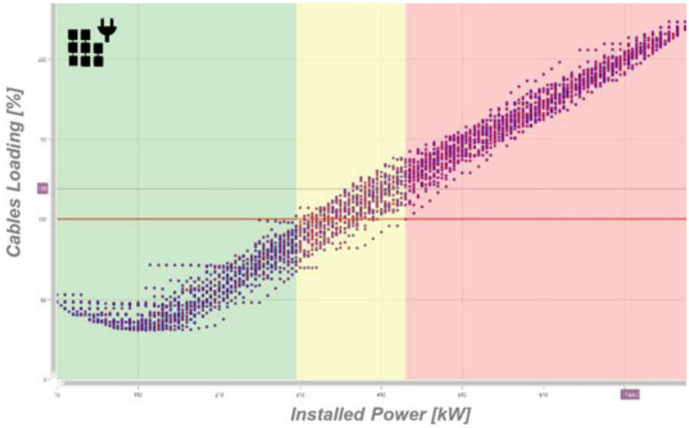

Fig. 4 Result of the module hosting capacity: maximum loading depending on the additional charging power [1]

Fig. 5 Analysis of module hosting capacity—different penetration levels of charging stations in a distribution network [1]

Integration of Solar PV and Battery with charging Infrastructure: The application of renewable sources such as solar photovoltaic (PV) to charge electric vehicle (EV) is an interesting option that offers numerous technical and economic opportunities. An energy management strategy based on optimal power flow is also proposed by integrating a solar PV generation system with charging station to alleviate the impact of fast charging on the grid. The combined system along with the power output of

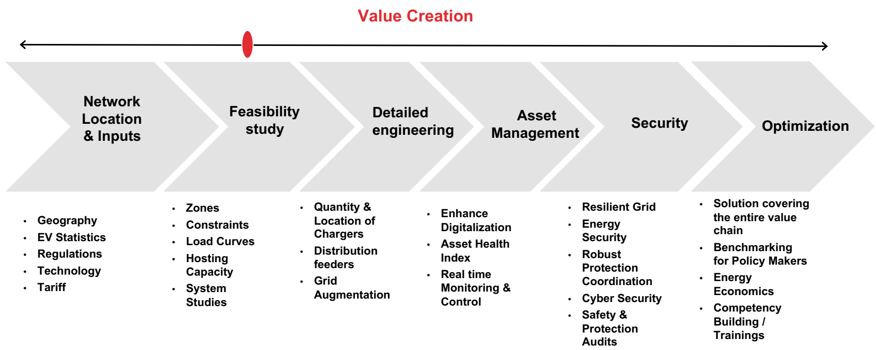

Fig. 6 Optimized solutions for various EV integration stages

EV fleet batteries available at the charging station reduces the net energy provided by the grid, thereby decreasing the overall load on the grid as well as minimizing the conversion losses.

Managed Charging could be divided into two major categories: Passive Managed Charging solutions that rely on customer behavior to affect charging patterns; Active Managed Charging that relies upon a bi-directional flow of information through multiple communications technologies. However, there is lack of industry protocols for the managed charging.

5 Conclusion

It is interesting to note that by a detailed Hosting Capacity Analysis, the challenges of Grid integration can be met with. The Electric Vehicle (EV) load demand pattern, Evaluation of distribution grid hosting capacity, EV impact on distribution grids power quality, Generation flexibility and response impact, Cost–benefit analysis and Analysis of international regulatory frameworks are significant aspects that would accelerate the growth of upcoming EV technology. Glimpse of value creation at various stages is also presented in Fig. 6.

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CFIP—Water Inhibitor Cable Jointing Kit

Sanjeev Atri, Vineet Tripathi, Gagandeep Kaur, and Sanjana Rani

Abstract The Objective of this paper is to work out and highlights the major causes of failure in Power Cables and further to propose solution to restrict cable faults. The average time to repair the fault is 2.0 days i.e. Utility has to sacrifice w.r.t its reliability parameters in case of Power cable failure. Nowadays, Joint box failure is contributing significantly w.r.t total numbers of cable failures and it is majorly due to ingress of water inside the cable and cable joint attributed to external damages. The inhibition of ingress of water is possible using well designed cable joints that would include components for inhibiting the water flow through the cable joints. We have developed an unique solution which is to be provided in the joints to prevent water ingress in the cable and cable joints. After installation of this unique design No such failure has been observed till date.

Index Terms Power cable · Cable joints · OEM (original equipment manufacturers) · W.r.t (with respect to)

1 Introduction

Power Cable which is capital intensive asset of any electrical utility is an integral component of the Power System Network. The average life of operating cable is 25–30 years. However, if number of faults get increased, it reduces the useful life of cable. Further, this will impact the system reliability, Customer satisfaction, revenue, men hours and Restoration time.

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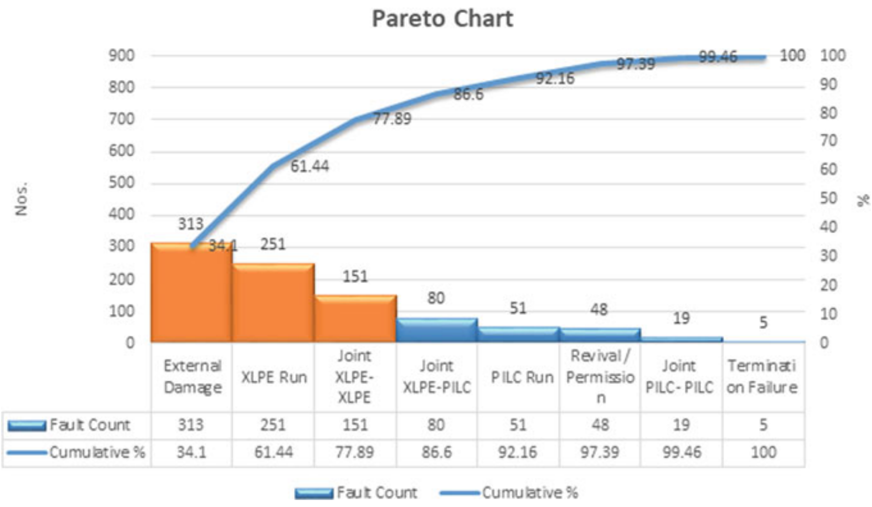

Graph 1 Pareto analysis on cable faults

A study has been done to identify the reason of cable faults. Total 918 no of cable faults were analysed which occurred in FY (19–20). Joint Box Failure, External Damage and Failure of XLPE insulation came out as the major causes of failures in Power Cables. Further, Joint Box Failure was surprisingly contributing significantly w.r.t total no of faults (250 no of faults).

After in-depth analysis, it was found that in case of joint box failure, water gets ingress through the cable, which leads to tracking, increase in vapour pressure, oxidation of conductor and increasing the conductor temperature which leads to failures of cable joints (Graph 1).

The conventional designed cable jointing components did not include any feature to inhibit the flow of water to entire cable lengths. This lead to water ingress through long cable lengths, even after cable jointing sections.

2 Challenges

On an average, an 11 kV residential feeder feeds about 1500 number of consumers. Cable fault to any one 11 kV cable affects the power supply to 1500 number of consumers. This causes power supply inconvenience to public at large and also to the operating/ maintenance team of power utility to restore the breakdown.

For recovery of cable failures, cable joints come into picture for restoring the power supply. Usually cable jointing is being done between two cables. Depending upon the extent of damage, cables are again jointed while removing the damaged sections, by specially designed cable jointing kits (Picture 1).

Supply and Installation of Cable jointing kits is being executed by OEMs.

Picture 1 Cable fault through water ingress

OEMs are bound to abide by warranty clause of joint failures within 5 years w.r.t installation & quality deviations in components. But in case of ingress of water, the guarantee clause gets void. Thus, there arises need of replacing the cables and cable jointing kits, before the expiry of their respective guarantee period. Cable and cable jointing kits are prone to failures within a year or two, due to tracking and components deterioration. Thus, the cost of failure caused to cable and cable jointing kits by water ingress is mainly borne by the utility.

3 Solutions Proposed

To mitigate the issue of water ingress in the Cable and 'Cable jointing kit':

The inhibition of ingress of water through the cable lengths was possible using well designed cable joints that would include components for inhibiting the water flow through the cable joints. Thus restricting the damage to only short cable lengths due to degradation of components caused by water ingress.

We explored various options available in the market for inhibiting/restricting the flow of water through the cable lengths. Following were the options available:

(a) One of the components available with the OEMs for preventing the water ingress as a part of cable jointing kit was Mastic tapes. During breathing effect of cable, these mastic tapes could not seal flow of water through it. Further, over a period of time, the quality of these tapes deteriorated.
(b) Another option available with the OEMs is Silicon Gel are also used to fill in the cable jointing kits to prevent water ingress, but it is limited to only LV cable.

Thus, none of the available solutions was suitable to mitigate water ingress in the cable and the cable jointing kits.

UNIQUE SOLUTION: We developed a unique component as a part of Cable jointing kit, named 'Compressive Forced Ingress Protection WATER INHIBITOR BARRIER' (Picture 2).

Picture 2 Water barrier components incorporated in cable jointing kit

This component creates a compressive force to seal the water during breathing cycle of the cable. So in any of the adverse condition, the sealing by this component remains intact. This feature is not available in mastic tapes or gels.

4 Uniquenesss/Scalability

1. 'Compressive Forced Ingress Protection Water Inhibitor Barrier'—developed and incorporated in the technical specification of Cable jointing kit, to be compatible with all the OEM cable jointing kit design.
2. Hybrid wrap sleeve has been developed and incorporated to reduce Road Restoration charges.

Unique Solution:—not adopted by any Utility so far at India/ International level, for cable jointing.

5 Impact

Significance of the innovation:

(a) Total cost incurred to the Company = Rs. 15.02 Cr. (Revenue loss + Opex cost)

Cost implication towards MUs lost due to failure in cable & cable joints = Rs. 2.30 Cr. annually (Revenue loss).

Cost implication towards repairing failures in cables & cable joints = Rs. 12.71 Cr. annually (Opex cost).

(b) Most significant KPI (Key Performance index) impacted = Customer Satisfaction & SAIDI (System average interruption duration index)

(c) Safety of personnel and public, owing to frequent cable & cable joint faults

(d) Impacting the asset life of cable & cable joints

The innovation shall have a major impact on the organization's objective of:

(a) Improving SAIDI (System average interruption duration index)
(b) Improving Safety
(c) Saving man hours
(d) Reducing restoration time
(e) Increasing revenue generation
(f) Operational excellence
(g) Cost Saving w.r.t procurement & maintenance of cables & cable joints.

6 Benefits

1. Productivity: Increased revenue generation.
2. Quality of Product or service: Uninterrupted power supply, Asset life cycle improvement.
3. Cost optimization: Optimized Operation and maintenance Cost.
4. Delivery: Reliable Supply to customer.
5. Safety: Cable Damage mitigation/Safety for man and material.
6. Morale: Internal Customer Satisfaction—failure reduction.

7 Standardization in Cable Jointing

Standardisation of cable jointing specification has been done. After introduction of CFIP Water Inhibitor barrier, No. of cable joints prepared is 144 nos. So far, there has been no failure or tracking in the installed joints.

8 Conclusion

The performance of CFIP Water Inhibitor barrier has been observed and proved as a very helpful and very effective solution for reduction in number of cable jointing faults. No. of cable joints installed in Water ingresses cables is 144 nos. So far, there has been no failure or tracking in the installed joints. The Future plan of the solution is to Inclusion of Water barrier in LT 1.1 kV Cable conductor for LT cable and cable joint fault reduction. The same has been proposed to TATA POWER—ODISHA, TATA POWER-MUMBAI.

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AI Based Alert Voice App for Customer

Gaurav Sharma, Shachi Jain, Srishti Prakash, and Kumari Bharti

Abstract We want to discuss about AI based alert voice app for customer support. Our responsibility is to provide better services for the customers. Sometimes customers forget to submit their electricity bills before the last date. So, this app will send a voice alert message before customer last date to remind him to pay the bill. This app will also be useful for visually impaired customers as they can open this app and speak about their concern.

Keywords Visually impaired · AI · Voice command

1 Introduction

These days customers face many problems.

Some of them are as follows:

1. Visually impaired customers face highest degree of challenges, in availing facilities which are easily accessible to others. With this app we have aimed at resolving these problems with the use of artificial intelligence.
2. Customers forget to submit their electricity bill on time. Reminder message is also often ignored or forgotten.

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2 Ease of Use

2.1 New Connection and Complaints by Voice Commands

For the second problem voice support would be provided for new connection and complaints in the app. Thus, the visually impaired customers would be able to access the features of the app via voice command. They would get voice response from the app.

2.2 Voice Alert

Regarding the first problem, a voice alert message would be available to all customers using this app, few days before the last date of submission, thus acting as a reminder to them.

3 Implementation

Different methodology has been used for both sections.

3.1 Methodology for Section 1

Here we will describe the process for visually impaired customer. In this process, mainly three types of technologies are used, namely:

1. STT (Speech-to-text)

   In this process, speech is converted into text.
2. TTS (text-to-speech), This method is the opposite of STT. In this method, text converts into speech.

For implementation, python Speech Recognition module would be used.
pip install speech recognition.
PyAudio: sudo apt-get install python3-pyaudio.
pip install pyaudio.
Python pyttsx3 module:
pip install pyttsx3.

As soon as the app is accessed, voice commands would be activated. App would convert consumer's voice to text using STT, understand the sentence and form an answer. Further, it would use TTS to answer the consumer in voice command.

4 Example

App: Welcome to NPCL. What can I help you?

User: I want to take new connection or complaints.

App: Please fill the details.

User: Ok.
App: What is your first name?
User: My name is Gaurav.

Audio voice will work to help users move forward (Fig. 1).

When a user opens the app for the first time, he would be prompted to fill a registration form. The user will be guided very well with the help of voice commands. Whenever the user will fill any details with the voice commands, the voice commands will first ask about essentials details, starting with first name. Customer name is then stored in our database. Let us go to the next point. The voice app will ask user, "What is your last name?". If the user name is wrong, then the user can tell that my name is wrong. The voice command will store the name again. When a user speaks, it would be typed automatically.

After registration, the user has to go to the login page.

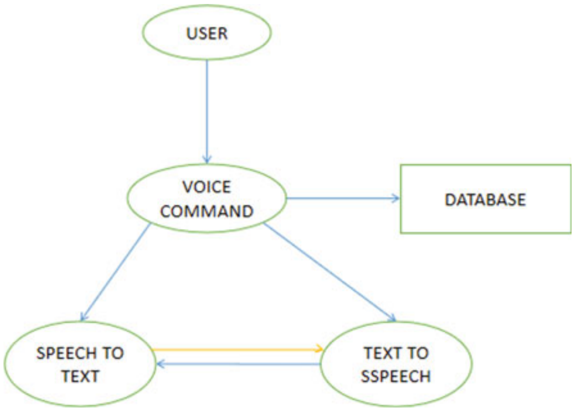
At the login page, user will type user-id and password, which will help in correct identification through the database.

The user can now gain access to their account. After successful login user could take a new connection or register a complaint. This overall process will be configured by voice commands.

Steps to be followed:

Registration Form:

Fig. 1 User voice command use case



When a user opens the app for the first time, he would be prompted to fill a registration form.

Consumer can fill the registration form by typing or use the voice command option. The registration module will get all the details. User has to fill in the information based on voice command.

Login:

After registration, whenever the consumer accesses the app, he would be required to provide consumer number and password (provided by him at the registration time) via typing or voice command. If the details are correct, he would be allowed to move forward. In case of incorrect details, voice command will inform the consumer regarding the same and prompt the consumer to try again. Then the user is authorized and is able to access the new connection and complaints section. Users can be login in two ways, through the image or through the consumer number and password. The image section is further explained in detail in the second section.

New Connection/Complaints:

On this page, user have the list of all the steps to be followed to pursue either of the two options. Further, he can use voice command to fill the application for his desired option. Details provided by user will be saved in database for future use.

4.1 Methodology for Section 2

We will provide to user two types of Login phase. The first one is "Image Recognition" and another Login by "Consumer No. and Password". If user wants to login by image then user can take picture or upload an image. Once the image matches with database, the user can login. Alternatively, user can login by providing the consumer no and password. These details can be typed or provided by voice command (Figs. 2 and 3) [1].

Create Model

We will build a network. We will use a sequential model. We can stack the layers by adding the desired layer one by one. We will use the Dense layer, also called the fully connected layer since we are building a feedforward network in which all the neurons from one layer are connected to the neurons in the previous layer. We will add the ReLU activation function, which is necessary to implement non-linearity in the model. This will help the network to learn non-linear decision boundaries.

Configure Model

We will configure the optimizer to be the RMSrop algorithm. We will also specify the matrix (accuracy in this case) that we will track during the training process.

Train Model

In this step we will train the data. It will be done by using the fit() function in Keras. User image will be verified in training model.

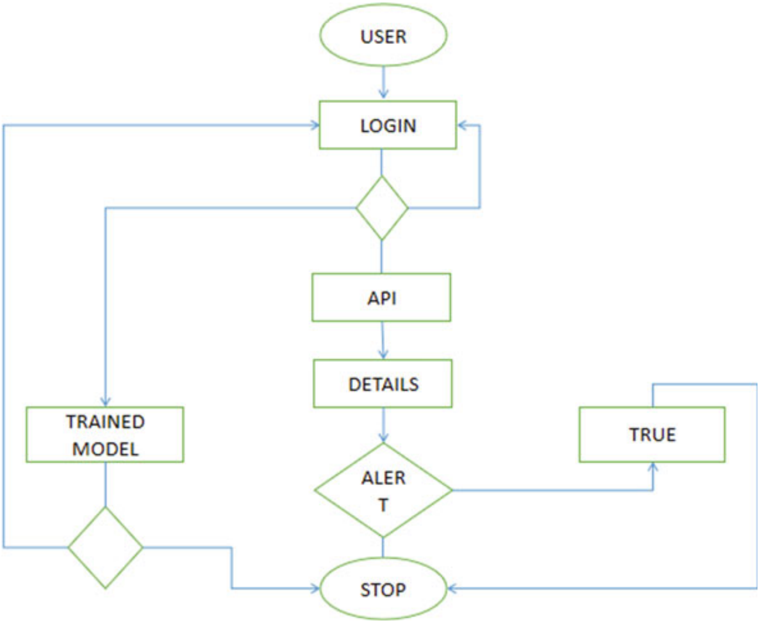


Fig. 2 Architecture

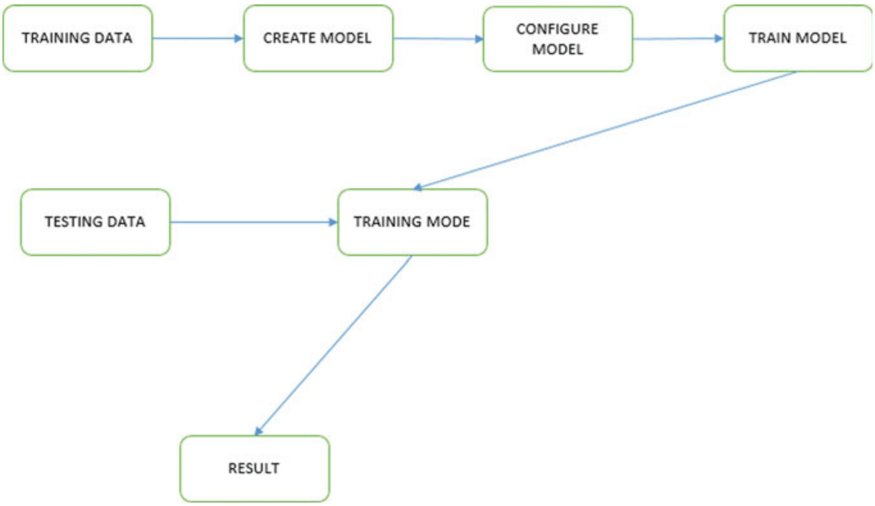


Fig. 3 Trained model dataset

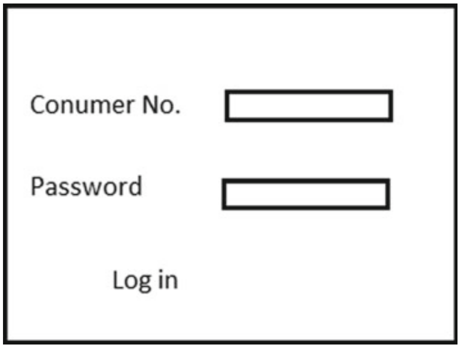


Fig. 4 Login interface

Result

User will get the result (Fig. 4).

User will input their consumer number and password in the login interface. This consumer number will go and hit the API; API will serve as an intermediary to fetch the details. For the alert voice response, we will use python PyPi beepy. Beepy is a Python language module that allows users to easily play notification. Beepy relies on a Python package called simpleaudio, which can be also be installed using: pip install simpleaudio [2].

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Assessing the Impact of Integrating Electric Vehicles and Solar Rooftop Photovoltaic System into the Power Distribution Network

G. V. Hanumanth Raju, E. V. Mallik, K. V. Harikrishna, and P. Sagar Singh

Abstract This paper presents our analysis of the impact of integrating electric vehicles (EVs) and rooftop photovoltaic (RTPV) on the power system distribution feeders at the 11 kV level. For the assessment, we selected a sample urban feeder that served both domestic and commercial consumers within Bengaluru city limits. The EV-demand projection was considered on the basis of a report by Indian Institute of Technology, Kanpur, while the RTPV potential was estimated using CSTEP's Rooftop Evaluation for Solar Tool (CREST). The feeder was modelled and simulated using the Electrical Transient Analyzer Program (ETAP) software tool. Various load-flow scenarios were run to analyze the feeder capability for integrating EVs and RTPVs for horizon year 2025. The simulation results reveal that the selected feeder will be critically loaded due to the EV-charging demand, during the evening peak hours. With optimal integration of RTPVs and daytime EV charging, the increased demand can be met without augmenting the feeder capacity.

Keywords Feeder · Electric vehicle · Rooftop photovoltaic · Distribution transformer

1 Introduction

The emerging technologies that employ renewable energy sources are crucial for India's clean energy transition. However, since their inclusion involves a changeover, these technologies have to work alongside the conventional systems till the required

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infrastructure is ready for their large-scale employment. Therefore, while integrating these technologies into the system, it becomes necessary to understand how they will impact it. Here we talk about two emerging technologies: electric vehicles (EVs) and rooftop photovoltaic (RTPV), and assess their impact on the distribution network infrastructure, in terms of feeder capacity, loading of distribution transformers (DTs), and feeder losses. While several studies have highlighted the potential of EV and RTPV, few have assessed their impact on the grid. This was our motivation for conducting a feeder-level power flow analysis.

Considering the potential growth of EVs in the urban sector, an 11 kV urban feeder was selected for the analyses in Bengaluru city. The 11 kV Hanumanthappa/F-05 feeder that emanates from Jayanagar 66/11 kV GIS substation, has a total feeder length of 4.54 km, and 52 distribution transformers (11/0.44 kV). Our study assesses the effect of integrating the projected EV and RTPV capacity into the Hanumanthappa feeder for horizon year 2025.

2 Process and Methodology

2.1 Data Collection

A field survey was conducted to collect the relevant data for the 11 kV Hanumanthappa feeder. The survey traced the feeder path from the substation to the DT level, and collected information on conductor type and capacity; section-wise length of cables/overhead lines; details of the 52 DTs; Distribution Transformer Lifecycle Management System (DTLMS) code; energy consumption; and geo-location (latitudes and longitudes).

2.2 Power System Model

The entire feeder, along with the loads for each DT, was modelled in Electrical Transient Analyzer Program (ETAP) power system simulation software. Figure 1 shows the snapshot of the feeder model.

2.3 Power Flow Analysis

This was done to benchmark the model for a particular instant in April 2019, to mimic the real-time loading conditions. The benchmarking was done by comparing the real-time power flows with the simulation results. This was followed by the

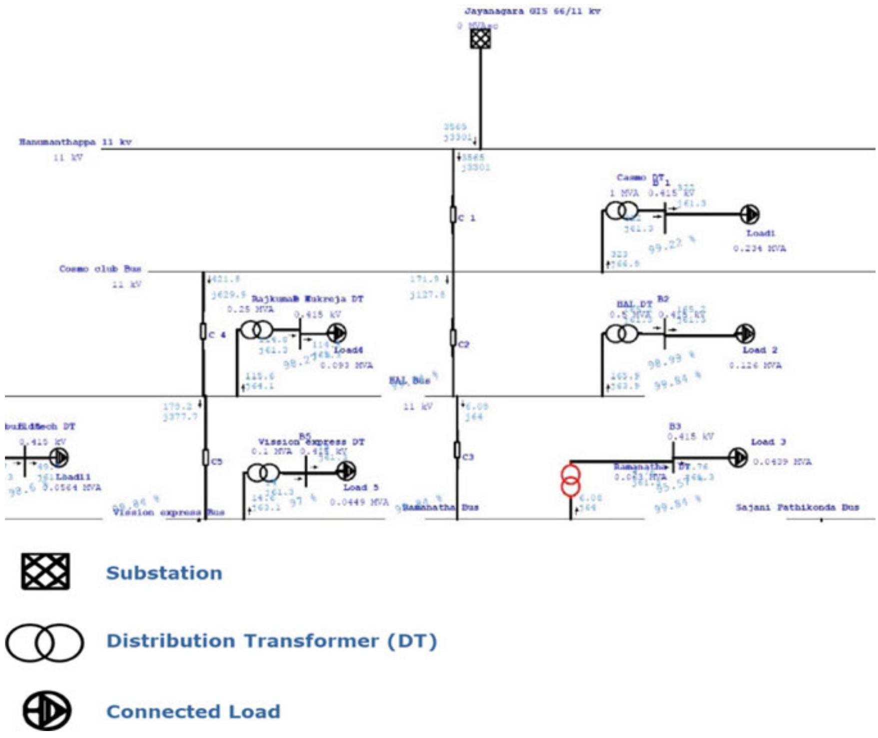

Fig. 1 Snapshot of the feeder modelled in ETAP

analyses for horizon year 2025 considering different load-generation scenarios, using the Newton–Raphson method.

3 Data Analysis and Assumptions

An hourly load profile of the feeder was analyzed for a typical day in the month of April, 2019, showing an evening peak of 3.9 MW at 19:00/20:00 h, and a morning peak of 3.8 MW at 12:00 h. Off-peak hours were observed from 1:00–6:00 h. This is shown in Fig. 2.

For the analysis, we:

- considered 40% growth in EV load by 2025 in Bengaluru [1]. Additional EV load at evening peak in 2025 is 1.9 MW for the particular feeder.
- considered 3.20% as CAGR for peak-demand forecast for Bengaluru in the year 2024–25 [2]; assumed feeder loading of 4.7 MW at 19:00/20:00 h at evening peak scenario.

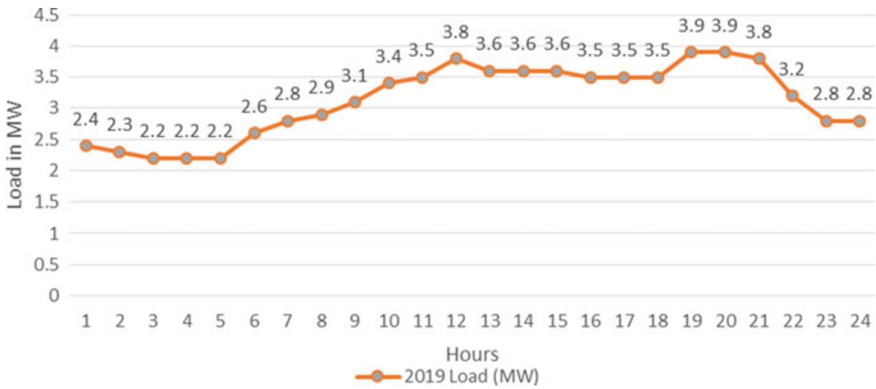

Fig. 2 Hourly load profile of Hanumanthappa feeder

Table 1 Summary of the scenarios considered in the study

Scenario	1	2	3	4	5
EV	No	No	Yes	No	No
RTPV	No	No	No	Yes	Yes

- considered morning peak on the feeder as 4.6 MW at 12:00 h in April 2025 for RTPV scenarios.
- Considered feeder maximum loading capacity as 6.85 MW.

4 Scenario Details

The following scenarios were analyzed, as summarized in Table 1.

1. **Base Case**: Feeder analysis for 2019 network conditions.
2. **Business as Usual (BAU)—2025**: Forecasted demand growth of CAGR 3.2% for base-case scenario, without EVs and RTPVs.
3. **BAU—2025 with EV**: BAU demand, with estimated EV demand.
4. **BAU—2025 with RTPV**: BAU demand, with total RTPV potential equal to 90% of total DT loading and estimated EV demand.
5. **BAU—2025 with RTPV**: BAU demand, with total RTPV potential equal to 80% of total DT capacity and estimated EV demand [3].

5 Results and Discussion

The simulation results for the different scenarios are given in Table 2.

Table 2 Simulation results of different scenarios

Scenarios	Feeder loading (organic load)	EV load	RTPV potential	Results
1	3.9 MW	n/a	n/a	• Feeder loaded up to 57% of its rated capacity • Feeder can handle an additional load of 2.96 MW • One DT is critically loaded
2	4.7 MW	n/a	n/a	• Feeder loaded up to 68% of its rated capacity • Feeder can handle an additional load of 2.16 MW • One DT overloaded
3	4.7 MW @ peak scenario	2.1 MW	n/a	• 137 EVs (total load 2.1 MW) can be connected for charging at peak instant • Feeder critically loaded to 100% of its rated capacity • Another feeder required to bifurcate the load • Three DTs overloaded
	2.7 MW @ off- peak scenario	4.2 MW	n/a	• 269 EVs (total load 4.2 MW) can be connected for charging at off-peak instant • Feasible time for charging the EVs is 22:00 to 8:00 h
4	4.6 MW @ daytime peak-load scenario	n/a	4.24 MW	• During morning peak scenarios, RTPV (3.96 MW) meets most of the demand; rest met through grid (0.65 MW) • Additional 2.25 MW of EV load can be connected for charging during the daytime peak load

(continued)

It can be seen that irrespective of EV integration, the load on the feeder increases in the year 2025. In scenario 3, an EV load of 2.1 MW, equivalent to 137 EVs (69 two-wheelers, 7 three-wheelers, and 62 four-wheelers, of 3, 9, and 30 kW, respectively) can be charged at peak instant, while at off-peak instant, 4.2 MW of EV load, equivalent to 269 EVs (135 two-wheelers, 13 three-wheelers, and 62 four-wheelers, of 3, 9, and 30 kW, respectively) can be charged.

Table 2 (continued)

Scenarios	Feeder loading (organic load)	EV load	RTPV potential	Results
5	4.6 MW @ daytime peak-load scenario	n/a	9.56 MW	• 100% of feeder load met through RTPV generation • Excess RTPV generation of 4.90 MW injected back to the grid substation • Additional EV load (2.25 MW) can be connected for charging during the daytime peak load

As the feeder loading increases, the Transmission and Distribution (T&D) losses at feeder level also increase. With the load increasing from 3.9 MW in scenario 1, to 4.7 MW and 6.58 MW in scenarios 2 and 3 respectively, the T&D losses increased from 0.78, to 0.94% and 1.34%, respectively.

The T&D loss (0.36%) in scenario 4 is comparatively negligible, owing to the integration of RTPVs near the load center. However, in scenario 5, the T&D loss is very high (1.18%), caused mainly by the excess RTPV generation (4.908 MW) exported back to the grid.

6 Conclusion and Recommendations

The analyses lead to the following conclusions and recommendations:

- A feeder-level analysis is mandated for identifying the actual value of EV and RTPV that can be integrated at the feeder level.
- The high uptake of EVs warrants integrating RTPVs at the feeder level to ensure peak shaving.
- Daytime EV charging is recommended, as RTPV generation is high during the day, enabling it to take care of the increased load, and thereby avoiding additional infrastructure cost.
- For successful integration of EVs and RTPVs into the grid, DISCOMs should focus on load forecasting and the associated infrastructure planning.

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Key Learnings from a Successful AMI Project in Indore (Learnings from Smart Grid Projects)

Hiranmoy Mukhopadhyay, Ajay Sinha, and Navdeep Sharma

Abstract Advanced metering infrastructure (AMI) is one of the foundation pillar of Smart Grid. It is not only designed to collect, analyze live data and bring losses down on monthly basis but it has host of other benefits to consumers which leads to an adaptive, intelligent, smart and collaborative grid. Effective implementation of an AMI project encompasses much more than installing just the smart meters like any other conventional metering projects. An AMI project will succeed only when three pillars of the project viz. ***Technology Selection***, ***Contracts and Execution*** and ***Operation***—form an equilibrium. This is where the role of a Systems Integrator is so very important. Indore AMI project covering 120,000 Smart Metering nodes is well accepted as the most successful project in India so far in similar size. This paper brings out the Key Success factors of the project from an SI's perspective. It deliberates on the possible challenges faced in all the three areas of Technology, Execution and Operation and how a deep-rooted Project execution methodology and customer collaboration helped to anticipate, handle and mitigate challenges. The paper also brings out clearly how the choice of SI is directly linked to the success of a project of this nature and how it tracks and helps to achieve an attractive Return on Investment (ROI). These learnings can be emulated to all other AMI projects to achieve a fast and successful rollout.

Keywords AMI · Smart metering · Hybrid communication · Systems integrator

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1 Introduction

The System Integrator plays a significant role in any successful rollout of AMI Project. AMI system is not a meter installation activity, rather it is an integrated IoT project with an end-to-end connectivity, including seamless integration with various IT and OT applications to run a modern Utility. Analytics is an integral part of the system which drives utility towards better operational efficiency and customer satisfaction. To achieve this, an equipped and capable Systems Integrator with a sound technical backbone plays a pivotal role.

2 Project Informartion

For the deployment of AMI solution, MPPKVVCL selected Indore city area which covers approx. 120,000 electricity consumers in the area of 225 sq.km. The project area covers 15 zones which comprises 42 high loss feeders of Indore city having billing efficiency of less than 80%.

3 Scope

The project started with initial phase of 75,000 consumers and based on the success, it got extended to 120,000 consumers. System integrator was responsible for effective implementation of end to end solution for 120,000 Smart meters with best levels of SLA for each data set. System integrator started the technical evaluation of different technologies available in the market to get the best outcome and to ensure the compliance of defined SLA. After complete technical evaluation and site survey, system integrator suggested a hybrid communication model to the Utility. The proposed communication model comprised of a combination of RF canopy and Cellular through gateway's along with Cloud based IT Infrastrcuture.

This project included various integration of Smart Meters to Head-End System (HES) to Meter Data Management (MDM) to Mobile app and Consumer Portal. Integration with existing legacy system like RAPDRP applications mainly Billing and Energy audit system was also done.

Broad scope of the Project comprised of following supplies and services:

- Single phase, Three phase WC & Three phase LTCT Smart Meters complying to IS16444 standard
  - nos.
  - nos.
  - nos.
- Network Interface Card for integrating with Smart meters—nos

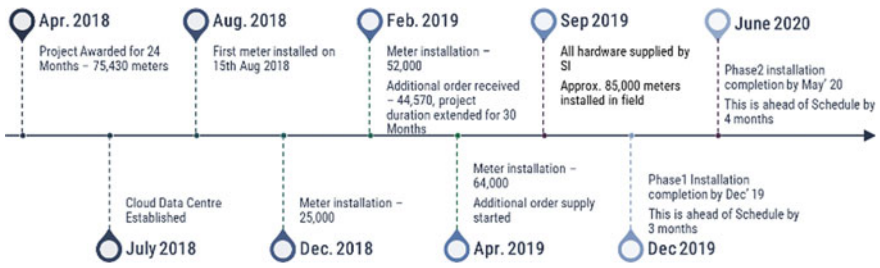

Fig. 1 Journey [1]

- Establishment of RF Canopy within Unlicensed Frequency Band of 865-867 MHz for 15 Zones covering 225 Sq. Km Area of Indore city.
- Field Implementation of Smart Meters and communication infrastructure.
- Deployment of Application software in cloud infrastructure (MEITY empanelled).
- Last Mile connectivity and Backhaul integration thru MPLS.
- Integration of MDM with Existing MDAS and Billing System for comprehensive Management reporting.
- Facility Management Services (FMS) for 5 years.
- Advisory Services for Dashboard Designing, KPI Monitoring, Data Analysis and Preparation of Action Plan for Loss Reduction, Handholding and Capacity Building for Utility's core team to Manage the project (Fig. 1).

4 Handling the Challanges

Major challenges, whose mitigation played a critical role in the success of the project were.

A. *Change Management*

- Mitigation of site implementation concerns of the field team (utility end):
  - Training on the Smart meter and related applications gave confidence to the filed team thus clearing doubts on the implementation challenges.
  - Proper planning and engaging the local authorities in potential disturbed areas.
- Mitigation of end user concerns on increase in bill amount with the smart meter replacement:
  - Check meters installed along with the old meters to showcase the accuracy.
  - Advertisement through print media projecting benefits to end users.

B. Availability of correct field level data

- Site survey was conducted prior to installation to achieve accurate consumer coordinates and network planning data. This ensured better network mapping and effective establishment of RF Canopy.

C. Infrastructure Availability

- Storage and Testing setup:
  - With unavailability of proper storage area for the 120,000 meters, SI deployed professional experts for maintaining warehouse. This warehouse included customized inventory management applications and extended ERP to meet the statutory requirements. This further facilitated the Testing and Installation activities to meet the accelerated schedule.
  - To meet 100% testing at Utility meter testing lab, additional setup was recommended to be implemented in the Lab and manpower was augmented to complete the testing process as per project schedule.

D. Logistics

Logistic coordination which facilitated smooth execution through usage of Smart Logistic software tool:

- Manufacturer location to Site warehouse.
- Site warehouse to Utility testing labs and back.
- Site warehouse to Intstallation sites.
- Installation site to utility's store for smart meter.

E. Co-ordination with All Stake Holders (Fig. 2).

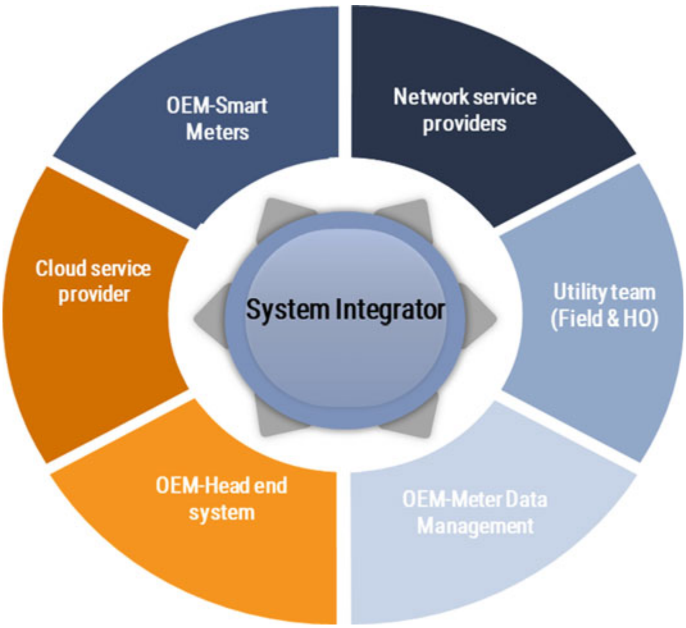

Fig. 2 Critical role of SI: coordination [1]

F. Availability of Skilled Manpower

This being the first of its kind project, there was a shortage of skilled manpower in executing site activities. However, with proven set processes, the SI facilitated in identifying manpower and sharpening the skills through regular classroom and onsite training. Skilled and unskilled manpower deployed for smooth execution of the project were:

- Project Manager
- Project Leader
- Planner
- Site Manager
- Circle coordinators
- Domain Experts
- Data operator
- Store manager
- Storekeepers
- Team of Skilled technicians and helpers.

G. HES & MDM Integration

HES & MDM integration is an important milestone for success of such projects. Activities are covered through this integration include:

- Integration with Technical Master Data.
- Integration with Business Master Data.
- Individual data set wise integration for metering parameters.
- Execution of schedulers.
- Control of automatic and manual commands.
- On-demand command execution.
- Bulk or Individual command execution.
- Management of Role and Authorization for users.
- Attribute change management.

H. Socio-political Challenges:

The project was not only about implementing a technical solution, but also to initiate a transformation in the relationship between Utility and consumer. From the era of receiving and paying monthly bills, consumers are now equipped with their actual consumption data on near real time basis through the mobile App and thereby, enabled to take conscious decisions to control their spends. Similarly, any blackout or anomaly is immediately visible at utility end. However, this transformation has direct impact on the socio political dynamics. While the honest consumers are happy about this transparency, the elements who were used to adopting malicious means to avoid paying for consumptions, tried their best to create impediments. On the other hand, some consumers had few apprehensions on the accuracy of these meters and feared increased bills which was clarified in course of time.

All these challenges were taken care by transparent and cohesive actions by Utility and SI. Meter operations were demonstrated to sample consumers to prove that consumption was accurately recorded. Similarly, eliminating human interface with miscreants and using technology to control and disconnect their connections was very helpful to clear up payments issues.

5 Key Succes Factors

The key success factors of this project can be categorized into:

A. Right selection and deployment of technology.
B. Impeccable Contracts management.
C. Operations and Execution excellence.

5.1 Technology Selection

Based on the geographical conditions and site survey, our expert team evaluated the different communication technologies available in this space and suggested the most effective solution which was hybrid communication (RF + GPRS). Also, team deployed various technological advancements in this project for speedy and accurate installations like.

- Mobile Meter Replacement App.
- Digital Stock Reconciliation platform.
- Development of MDM as per utility requirement.
- Digital MCR.
- Real time meter reconciliation tool.
- Tracking of meter life cycle.

5.2 Contracts Management

Right contracting is a mandatory attribute of a successful project. Drafting and negotiating a win–win contract with various partners created an eco-system amongst the partners for long term success of the project. It provided a space to all the individual parties to serve the end customer with the ownership of their respective scopes. Technology partners, OEMs and Service providers facilitated smooth execution of the project. Various tools like MS Project, Power BI used for monitoring timely progress and advance information on possible bottlenecks helped unscheduled stoppages or hindrances to the progress.

5.3 Operations and Executions

- Consumer Master:
  - Utility shared the Feeder Wise Consumer Master Data with SI.
  - MDM team ran the sanity check and displayed the Consumer Master Data on Mobile App.
- Field Installation:
  - SI's field team identified the location to install the Smart Meter using IVRS in Mobile App.
  - Used Mobile App to enter the New Meter Sr. No., Old Meter Sr. No. and Seal Information against IVRS.
  - Quality check by Utility for Installation Practice and Sealing of Meter.
  - Data was saved and paper receipt was printed for acknowledgment from the consumer.
- HES & MDM:
  - SI team did the Data Validation.
  - Validation logics for IR, FR, duplicity etc.
  - Checked the comms with Meter, IS, BL, Daily samples verified by Utility and SI.
  - After the above, MDM started displaying meter reading data.
- Billing:
  - Monthly Billing data started flowing to Billing Engine of Utility.
  - Bill information made available on Consumer Mobile.
  - Consumer could pay the bill online using Credit/Debit Card or Mobile Wallet.

6 Key Learnings—Role of System *I*ntegrator

- Utilise available Project Management expertise/experience
  - Micro level clarity of Scope.
  - Awareness of geographical conditions.
  - Technology adoption and innovation for process improvement and ease of execution.
- Focus on Contract Management and Partnerships
  - Strong Contracting with Partners.
  - Short, efficient and transparent procurement process.
- Create efficient and responsive site management process
  - With clarity on execution workflow.
  - Less turnaround time to deploy resources.
  - Allocation of right skill set.

- **Involvement of Domain Experts towards**
  - Designing system architecture.
  - Integration methodologies.
  - Design & deploy value-added services like Analytics, Revenue Protection System etc.
  - Robust testing of end to end system.

7 Way Forward

It is important for the Utilities to appreciate the role of a technically sound SI who would become their partner for the AMI deployment. It should not be seen from the lens of a traditional meter supply and installation job.

It is also to be understood that after the award, the SI-Utility duo needs to work as partners with complete ownership to achieve the result of the project, rather than getting entangled in bureaucracy of contract terms.

Based on the practical experiences, it is true that just selection the most reputed OEMs does not guarantee a successful AMI project. There needs to be perfect harmony amongst all of them along with the Utility—which is the role of a sound SI.

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Implementation of Robotics and Drones in Power Distribution

Check for updates

Kaushal Pandya, S. M. Javed, and Abhishek Das

Abstract Drones are considered as one of the aspects of energy industry. Under the Robotics heading, there are six categories which includes AI, automation and IOT. Drones are considered as a broad spectrum pertaining to emerging technology. Drones are very effective tool with the right sensors for data collection. Through the Drone Inspection process data collected through Drone inspection process can be protected and analyzed. Power sector is realizing that condition-based maintenance and running assets has consequences and will not be acceptable. Organizations can also use Drones effectively to enhance safety at project sites as one can constantly monitor real time data and notice the safety violations, if any which may have negative impact on the overall project execution. Considering the Serious injury and Fatality rate in Electricity as a utility, to tackle various high risk jobs, implementation of Robotics is the way forward across globe. This paper highlights the scope of drones, implementation of robotics and artificial intelligence in various dimensions on the power sector.

Abbreviations

SIF	Serious Injuries and Fatality
GPR	Ground Penetrating Radar
UAV	Unmanned Aerial Vehicle
AI	Artificial Intelligence
IOT	Internet of Things
MIR	Mobile Industrial Units

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1 Key Areas of Work

In the power distribution, Drones can also assist for following activities

(1) Surveying (Detecting underground utilities before trenching thru GPR (Ground Penetrating Radar) system).
(2) Measuring and monitoring depths of excavation and prompting in case of deviations (typically in underground power distribution network).
(3) Identification of hazards.
(4) Documenting job progress and prompting if the work is difficult for working party.
(5) With the light, Heat and temperature sensors it enables project in charge to monitor the parameters.
(6) Access to confined spaces/places which are not accessible.
(7) Supporting tool during working at height/Scaffold inspection.
(8) Immediate inspection of the premise/consumer sub station/meter rooms caught in fire/short circuit which is not immediately accessible for humans (Fig. 1).

1.1 Surveilance Through Drones

With 4 K HD Cameras with infrared capability, 24 × 7 surveillance can be achieved through Drones [2] As the GPR (Ground Penetrating Radar) system is taking evolution, Terra Drone Indonesia has recently completed pilot project—a Drone equipped with GPR system by scanning the areas which has potential hazards, locate underground utilities, detect pipeline leaks or gauge condition of assets [3] (Figs. 2 and 3).

1.2 Robotics at Receiving Stations or Distribution Substations

- Industrial Robotic arms coupled with iOT can be adopted assisting following jobs

  A. High Risk jobs such as during power outages.
  B. Ooperating a discharge rod.
  C. checking the Phasing before charging the feeder.

  For illustration purpose, industrial robotic arm is represented below.

All the above high-risk jobs can be easily done by virtue of implementing an industrial robotic arm without a physical human touch present during the said jobs. This eliminates any risk to human life.

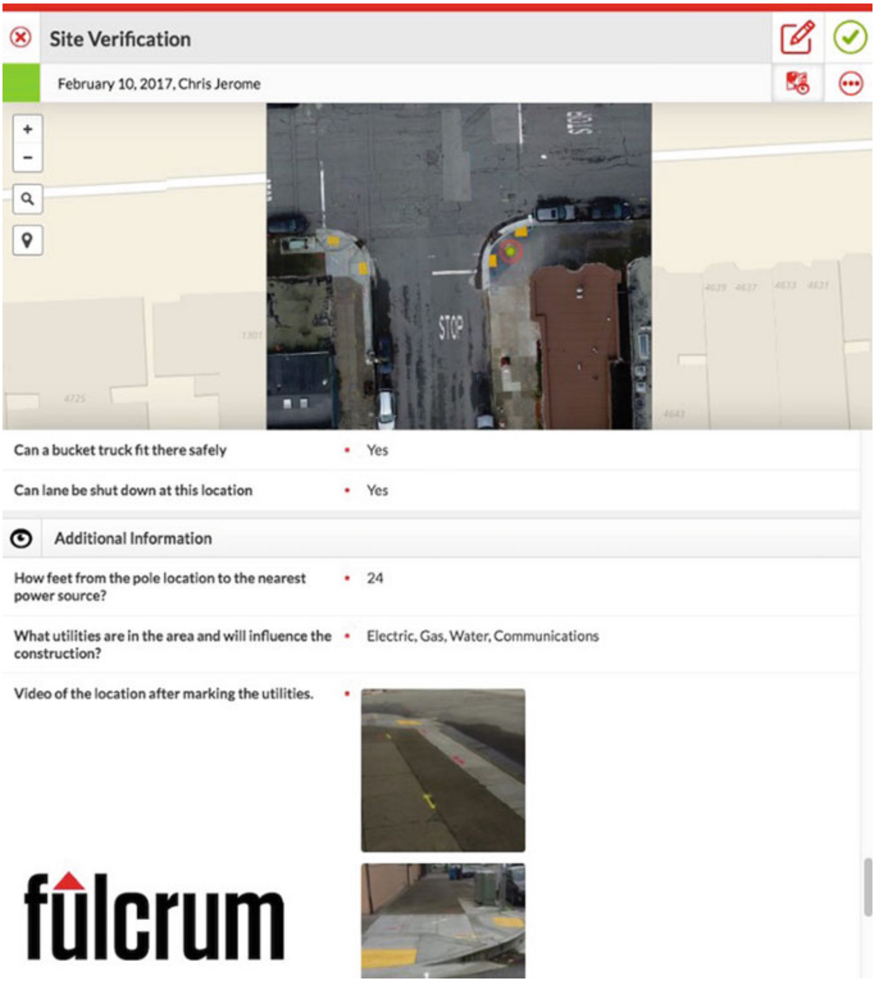

Fig. 1 Drone maps, along with ground photos and site videos, are uploaded into Fulcrum in order to create a complete inspection record [1]

1.3 Robotics and Drones in Transmission Lines and Projects

Addressing Tree trimming challenges in transmissions lines and various associated projects through implementing Drones and Robotics.

- Combination of industrial robotic arms (as illustrated in Fig. 4) coupled with climbing robot can be effectively used in transmission lines.
- While working at height for tree trimming or associated activities or to achieve and execute desired operation and maintenance, assistance of industrial robots ensures safety.

Fig. 2 UAV drone equipped with 4 K HD cameras with infrared capability for surveillance [4, 5]

Fig. 3 Pilot project—drone equipped with GPR (ground penetrating radar) system [3, 4]

- It also eliminates any possible hazard (slip trip fall) to human life while tree climbing or tree trimming activity (Fig. 5).

2 Understanding Serious Injuries and Fatality Rate in Power Sector

A recent report indicates that Utility sector across the globe is at extremely high risk of very serious injuries as well as fatalities.

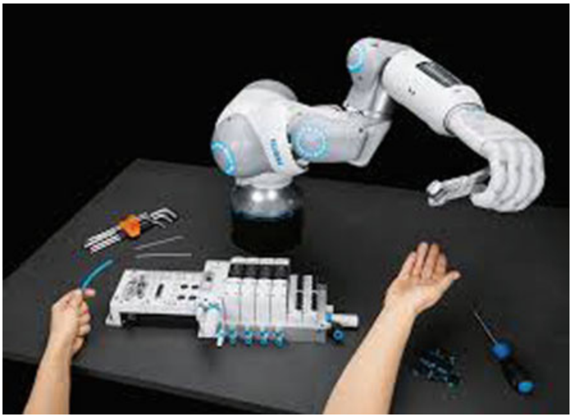

Fig. 4 Illustrative industrial robotic arm [6]

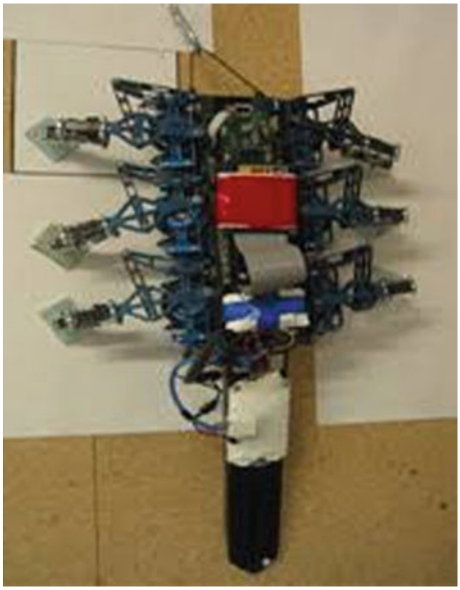

Fig. 5 Illustrative climbing robot [6]

As per the report, SIF (serious injuries and fatality) rate in utility sector is on higher side compared to rest of the industries such as manufacturing, construction, FMCG or mining etc. [7].

Major reason behind this is partly because utility staff most of the time deals with extremely high hazardous environment. For example, working at height, confined spaces, vicinity of live circuit, EHV/High voltage environment, presence of toxic gases etc. (Fig. 6).

It is evident from the above table that Electricity as a utility has the second highest serious injuries and fatalities rate i.e. 32% followed by 26% for Gas [7].

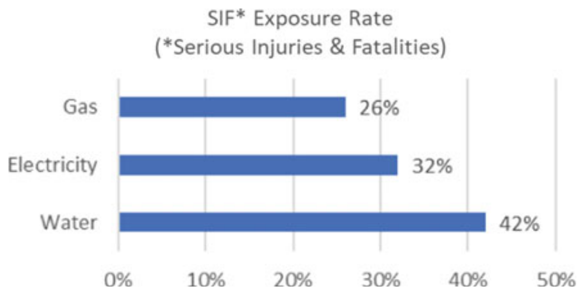

Fig. 6 SIF exposure rate across various utilities [7]

Humans being one of the most valuable assests for the organization, there is a need for line of thought how these incidents can be eliminated or reduced to greater extent.

Acccording to the author R. Scott Stircoff, only procudures and intensive training are not sufficient for eliminating fatalities and serious injuries [7].

It may be noted that SIF is defined as life threatning, life altering and fatal incidents at sites or designated work places [7].

3 Arising Need for Implementing Robotics and Drones in Power Sector

- Robotics and Drones can play extremely crucial role to tackle risky operations, assets which are difficult to access for humans, and maintaining these crucial assets for improving efficiency [3, 5, 8].
- As per the reports of GlobalData, a leading data analytics organization it is learnt that robots and drones are set to enter the power sector and exploring different applications like Distribution, transmission, wind, solar, thermal hydro power etc. [8].
- Key applications:
  - Daily inspection.
  - Reaching 100% automation.
  - Achieving remote maintenance.
  - Handling very critical—nuclear operations [8].

4 Emerging Trends in Robotics and Drones in Power Sector Across Globe

- Commercial drones typically designed for utilities, especially power sector is set to enter the market very soon.

Fig. 7 LineScout climbing on live power lines for routine inspection [9]

- R4 Robotics, ULC Robotics and MIR (Mobile Industrial Units) are aiming at bringing disruptive trends in power sector.
- MIR Robotics is expected to be the front runner which shall be adopted for inspection of high voltage power lines [8].
- LineScout is the product which is specifically focusing on executing various maintenance activities associated with live transmission lines [8] (Fig. 7).

5 Conclusion

It is evident that Robotics along with the intelligent Drones will shape up the future of power sector with cutting edge technology thereby enhancing safety at sites, monitoring projects effectively thereby achieving considerable cost reduction and other overheads associated with project cost. As implementation of Robotics and Drones getting more prevalent, utilities such as in power industry will have to update themselves with the emerging trends of Robotics and Drones which will directly infulence the demand patterns as well as distribution network requirement. Robotics and Intellignet drones are gearing up to disrupt the power sector with cutting edge technology thereby ensuring safety as well as greater precesion and control over the various projects as well as various operation and maintenance related activities.

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Two Capacity Transformer for Technical Loss Reduction

Keshav Raghav, Sanatan Kumar, Krishna Porwal, and Tarun Singh

Abstract This paper proposes a modification in distribution transformer design to reduce losses occurring inside transformer during light loading conditions. Month wise Loading analysis of a particular financial year of all distribution transformers installed in network of TATA Power DDL was done to identify the light loading periods and under loaded transformers in the system. Further All day efficiency of transformers was calculated to establish their inefficiency during under loaded conditions. Further modifications in design of winding, their termination methodology inside tank and inside terminal box is discussed to operate transformers efficiently throughout the year. In the end analysis of efficiency with new design is done.

Keywords Distribution company (DISCOM) · Distribution transformer · System average interruption duration index (SAIDI) · Aggregate technical and commercial loss (AT and C) · TATA power DDL (TPDDL) · Consumer satisfaction index (CSI) · Smart meters · Single line diagram (SLD) · All day efficiency · Current transformer (CT) · Output (O/P) · Input (I/P) · Iron loss (Pi) · Copper loss (Pc)

1 Introduction

Transformers are primary units of Power distribution network. Also with high number of units installed in the system their efficiency has major impact on technical loss occurring in the system. Power Distribution Sector is a major loss-making Sector which adversely affects the economy of a country. Two main Causes of high Technical

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loss are Low Efficiency of Power equipment's (Transformers, Lines, Distribution Boxes, Cables etc.) and their Poor Power Quality. Load in the distribution network is fluid and hence while network planning considerations are made on power factor, total installed capacity and load growth in near future.

When transformer Unit sizing is done we take the total installed capacity of the locality/building into consideration. Load in the distribution network changes throughout the day and there is major drop in load with changing seasons. We get peak demand during summers and as we move towards rainy or winter Season the load comes down to 30–40% of peak. Thus the transformer unit installed on site as per summer peak is under loaded for rest of three quarters of the year. Distribution transformers remain charged for whole day and hence they are designed to operate for maximum efficiency on 50–70% of loading thus under loaded transformers run inefficiently during rainy and winter season.

In this paper design of split winding transformer is discussed to achieve maximum efficiency at light load conditions.

2 Annual DT Loading Analysis

Power flow in lines varies throughout the day. DT installed at consumer end transforms voltage for feeding consumers at reduced voltage. Smart Energy Meters with CT installed on low voltage side of transformer measures power output of the transformer. At regular intervals these meters send data of energy flow through the transformer and using this loading on DT is captured. Using these data collected throughout the month maximum and minimum loading on DT is extracted. We collected monthly data of FY 19-20 of approximately 3900 nos of distribution transformers installed in 510 kms^2 area of TATA Power DDL (Fig. 1).

In peak summer periods around 70% of transformers were 30–90% loaded and hence operating on optimum efficiency and capacity. As the climate cooled and winter stepped in loading of transformers decreased and only 20% of total transformers were on optimum loading condition.

3 All Day Efficiency of Transformer and Maximum Efficiency

Transformer have two types of losses, One is fixed at all loading conditions which we call Iron Loss and other which varies with load known as copper loss.

Distribution Transformers are connected directly to load, which fluctuates throughout the day. As the copper loss occurring inside transformer varies all day hence efficiency of distribution transformer can be judged by some special means. Hence efficiency of distributions transformers is defined as All day efficiency. All

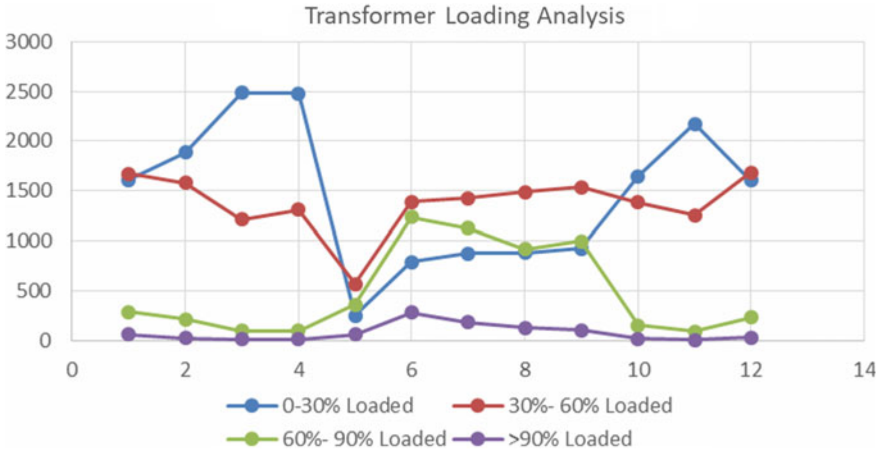

Fig. 1 Loading analysis of 3600 No's of DT

day Efficiency is ratio of output energy in 24 hours to Input energy in 24 hours.

$$\text{All day Efficiency of Transformer} = \frac{\text{Output } Energy(In\, 24\, Hours)}{Input\ Energy(In\, 24\, Hours)}$$

As we are calculating efficiency at fixed loading conditions hence for this paper we will consider general formula for calculating efficiency, which is ratio of output power and input power lined to transformer.

$$\text{Efficiency of Transformer} = \frac{\text{Output } Energy}{Input\ Energy}$$

This formula of efficiency can be further defined in terms of losses as,

$$\text{Efficiency of Transformer} = \frac{O/P\ Power}{O/P\ Power + Pi + Po}$$

where,

Pi = Iron Loss Occurring in Transformer

Pc = Full Load Copper Load in transformer

Differentiating above equation with respect to load current gives us condition for maximum efficiency. For efficiency to be maximum the Iron Loss occurring in the transformer must be equal to copper loss.

R = Winding resistance

For Maximum Efficiency Pi =Pc

Iron Loss remains constant throughout and Copper loss varies with changing load and thus Pc at X % loading (Load at which maximum efficiency occurs) can be said to be X^2Pc. Thus, for Maximum efficiency

$$X = \sqrt{\frac{Pc}{Pi}}$$

Distribution transformers designed for a maximum efficiency at 60% to 70% of full load. As transformer runs all day therefore, transformers are designed to have lower Iron loss.

4 Design Modifications

The conductor constituting transformer winding is wrapped around the core. Each limb of core holds both Primary and secondary winding of a phase which are superimposed over each other. The high voltage winding is wound over the low voltage winding, tap changers are provided in high voltage winding which changes number of turns of only HV side to vary voltage of Transformer. In distribution transformers each phase winding is split into multiple stacks, which are further interconnected to each other and other phases by bolting or brazing inside the transformer tank (Figs. 2 and 3).

As distribution transformer loading reduces much below 50% during winter and rainy seasons hence transformers installed in distribution network are inefficient for almost 3 quarters of each year. Under light loading conditions by reducing number of turns of both HV and LV Side of transformer we can reduce winding resistance which brings down the copper loss inside transformer.

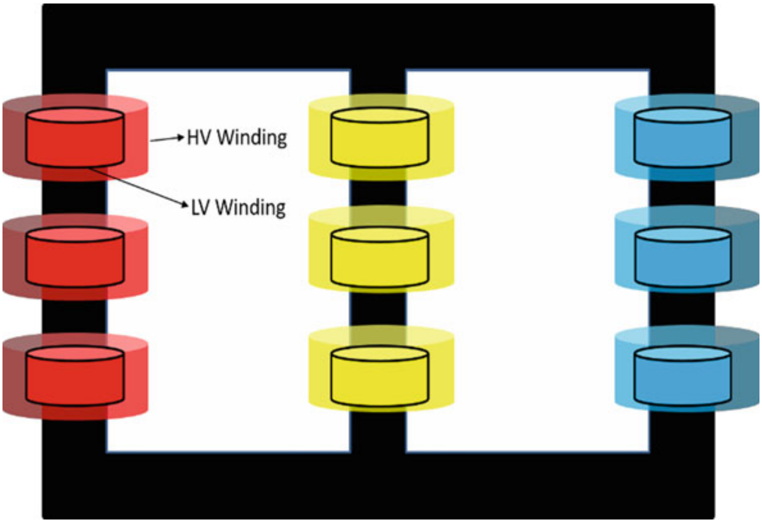

Fig. 2 Overlapped LV and HV winding of transformer

Fig. 3 Internal view of transformer

As of now, we have tap changer inside transformer which enables us to vary voltage by changing number of turns of only High Voltage Side of Transformer.

If we bring terminals of one or two stacks to termination box, we can vary the number of turns of both HT and LT Side.

This would change the winding resistance and Full load copper loss or indirectly make our transformer underrated which will help us to operate it efficiently under low load conditions (Fig. 4).

5 Terminal Box Alterations

The Proposed changes in termination methodology of winding stacks in transformer core demands certain alterations in termination box. The terminals R4 to R6, Y4 to Y6 and B4 to B6 which were earlier terminated inside core are to be exposed to termination box along with R1, Y2, and B1 as earlier (Figs. 5 and 6).

Using this methodology we can change the number of turns of both HT and LT side of transformer and reduce the transformer capacity.

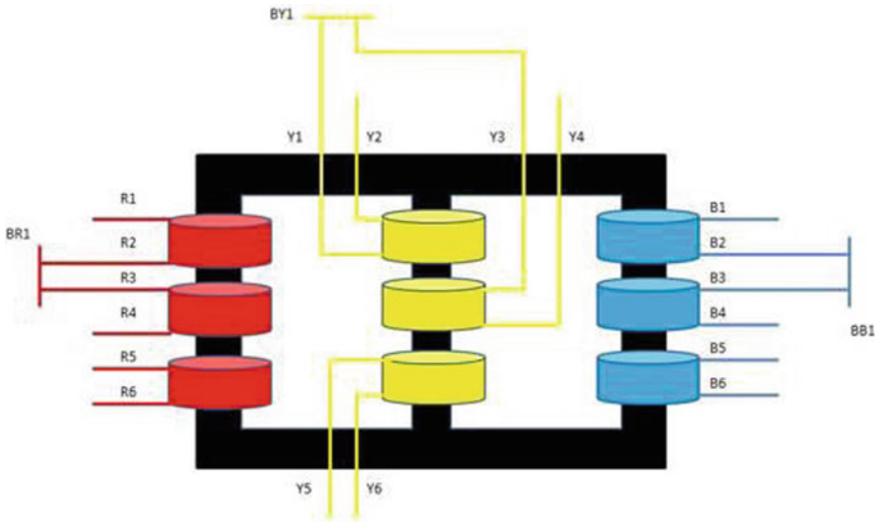

Fig. 4 New internal winding terminations of HT side

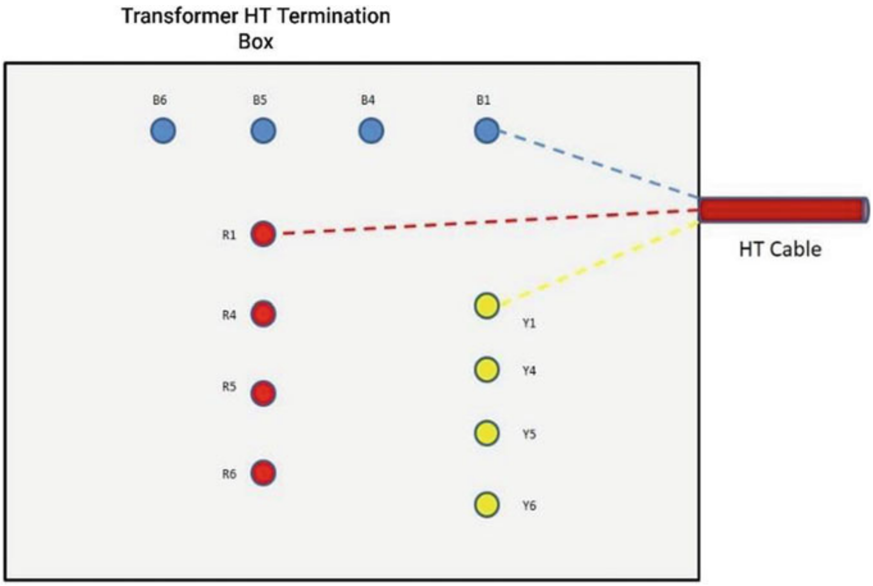

Fig. 5 New HT termination box

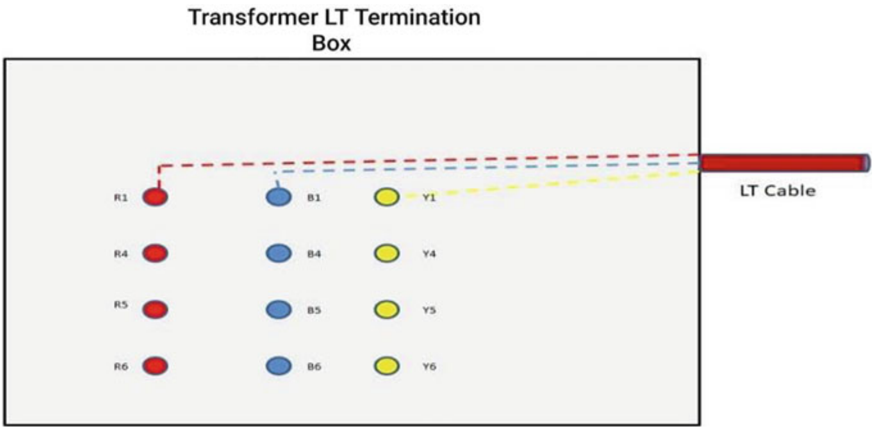

Fig. 6 New LT termination box

6 Conclusion

If by using our method we reduce number of windings turns to half (Keeping turns ratio constant), thus new winding resistance (R') will be R/2.

Thus, Full load Copper loss Now will be

$$P'c = \left(\frac{1}{2}\right)Pc$$

And, our transformer capacity now will be 1/2 of earlier. Now, we will get Maximum efficiency at loading X' (Considering earlier maximum efficiency (X) occurred at 70% loading)

$$X' = \sqrt{\frac{pi}{(\frac{1}{2})Pc}} = X * \sqrt{\frac{1}{2}} = 0.98$$

So, we get our maximum efficiency at 98% of Loading of our 1/2 rated Transformer. Let us understand this with an example.

If our transformer is 990KVA,

Loading for Maximum efficiency (X) = 693KVA

Winter loading of Transformer be 45% of Rated = 445 KVA New reduced KVA = 990*1/2 = 495KVA.

New Loading for Maximum efficiency (X') = 0.98*495 =
485KVA

Thus, by using this we can operate our transformer to loading near to its maximum efficiency.

Also, by reducing the number of turns here we reduce the occurring copper loss in transformer by 50%. At full load guaranteed copper loss of 990KVA NUCON Transformer is 6400 W.

Thus under present scenario at 45% loading the load losses are 2880 W, and by using this methodology which can be brought down to 1440 W which is 1.44KWH, this saves. 138.24 units monthly (As per DERC Supply Code LDHF for Domestic load).

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Experimental Study on Improvement of Power Generation in Building Integrated PV

Lakshmi Santhanam and Balaji Lakshmikanth Bangolae

Abstract Building integrated Photovoltaic (BIPV) is emerging as a promising pathway for green zero energy buildings where it can replace traditional construction material and generate electricity at the same time. Though BIPV is at 1% of solar installations globally, with the right incentives and regulations in place it can quickly accelerate. We know that a solar panel is known to perform the best when it is south facing and is latitude tilted (it produces 1500 Kwh/Kwp). However, in a BIPV system an East or West facing building facade obtains sunshine for only one half of the day and gives a yield of only 800 Kwh/kwp (Won Jun Choi, Hong Jin Joo, Jae-Wan Park, Sang-kyun Kim, Jae-Bum Lee, Power Generation Performance of Building-Integrated Photovoltaic Systems in a Zero Energy Building, Energies 2019, 12, 2471; doi:10.3390/en12132471). The primary challenge in BIPV is that the panels have high capture losses due to the sub-optimal orientation of the panels and thermal related losses due to the lack of air spaces. At Renkube we intend to solve the challenge of improving the energy production in a vertically mounted panel. We have developed an innovative PV panel design that can increase the energy production of BIPV modules by upto 20% for different wall orientations. Our panel uses patented geometric patterns created on the top surface of the glass to better capture more sunlight coming at an oblique angle of incidence and redirect it to the solar cell. We provide detailed simulation studies conducted for different building wall orientations of our BIPV panels and for different locations from Singapore to Laddak. We also highlight the annual performance and seasonal gains of our panels. This technology has potential to further reduce the installation prices of the BIPV system.

Keywords Solar PV · Optical solar tracking · BIPV · Wall mounted · Optical tracking · Motion free optical tracking

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1 Introduction

Solar energy is the most promising renewable energy and has made rapid strides in deployments in the past 20 years. Worldwide we have today about 630 GW installed so far. Yet, the integration of solar with building known as Building Integrated PV is a meagre 1% of the installation. The primarily growth inhibitors are the cost and performance consideration.

There is no definite consensus on the definition for Building Integrated PV "*one that acts as both a building material and a device that generates electricity*" [2]. There is a broad spectrum of BIPV products suited for slanted rooftop on mounted configuration or as an integral structure like a shingle, façade, glazes, tiles etc. Figure 1 shows various possibilities in the integration of a BIPV panel with the building architecture as published in [2]. Till 2017, BIPV markets existed in the US and Europe; but is slowly picking up in India by leading building developers and solar installers like Onyx Solar. India with its dense urban population and high-rise building has a huge potential for adoption with the right push from the Indian government.

There are several design choices with improving efficiency in BIPV glazed façade. One focus area is to reduce the thermal losses in BIPV system with a natural or forced air circulation in the ventilated air gap as in a double ventilated façade [3, 4]. Another research [5] talks about the extraction of heat underneath panel by liquid heat transfer media and supply it to heat the buildings. These research in literature claim an improvement in the overall efficiency of PV module by about 2–5% with air or water-based cooling.

Renkube has developed an innovative solar glass with complex geometric patterns created on its surface to collect more sunlight. As capability of tracking the sunlight is enabled in the solar glass, we call this as Motion free technique called as Motion Free Optical Tracking (MFOT) technology. It operates just a like physical and mechanical trackers that keeps following the sunlight. But the same is achieved in a stationary manner with a complex geometric glass design. Another important aspect of our MFOT is that it is the only light redirection technology available for traditional solar cells with can tolerate only 1 sun illumination or 1000 W/m^2 illumination.

Fig. 1 Integration of BIPV panel in a residential rooftop *Source* Building energy 2011, DOE 2011 [1]

In this study we analyze a BIPV panel with MFOT technology over a plain BIPV system across various performance metrics:

Including (i) Annual gain, (ii) Seasonal gain for different orientation of the building façade. The east and west facing façade have similar behavior where in MFOT gives 20% gain over a traditional BIPV panel. These results are presented and discussed for four geographic location namely Singapore, Bangalore, New Delhi, and Laddak.

2 System Design

A solar panel generates peak rating of the power only when the sunlight is incident on it at normal (perpendicular) incidence. A traditional rack mounted fixed tilt system has an energy generation pattern like a bell curve as shown in Fig. 2; wherein it generates peak power at noon with only 50% energy generated at early morning (9am) or late afternoon (3 pm).

However, in case of a BIPV system, when the panel is mounted on the building façade, the incidence angle on the panel is determined by the orientation of the building. Incase of an east or west facing wall, the panel generates power only for one half of the day as seen in Figs. 3 and 4. As seen in Fig. 3, the East facing BIPV panel in Singapore (Latitude—1.35^0 N) on January 21st generates peak power 7 AM in the morning and the energy generation tapers down to zero by noon as no sunlight falls on the solar panel due to the vertical mounting. Similarly, Fig. 4 shows the energy generation in East facing BIPV panel in Laddak (Latitude—34.2^0 N).

In Fig. 5, we also show how much the performance of an east facing panel drops wrt a south facing rack mounted panel for location Singapore. We consider various

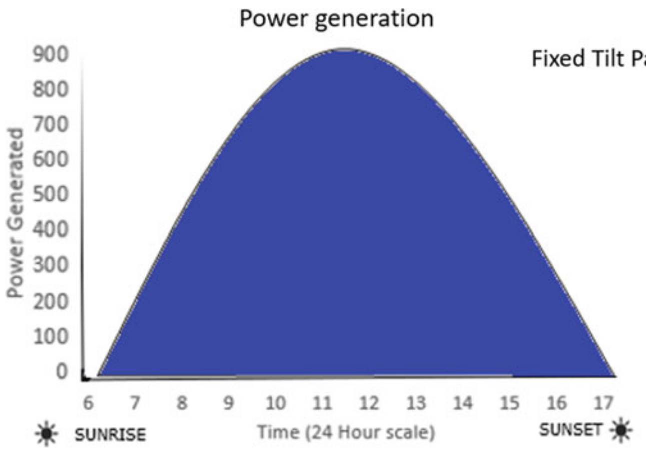

Fig. 2 Energy generation in fixed tilt panels

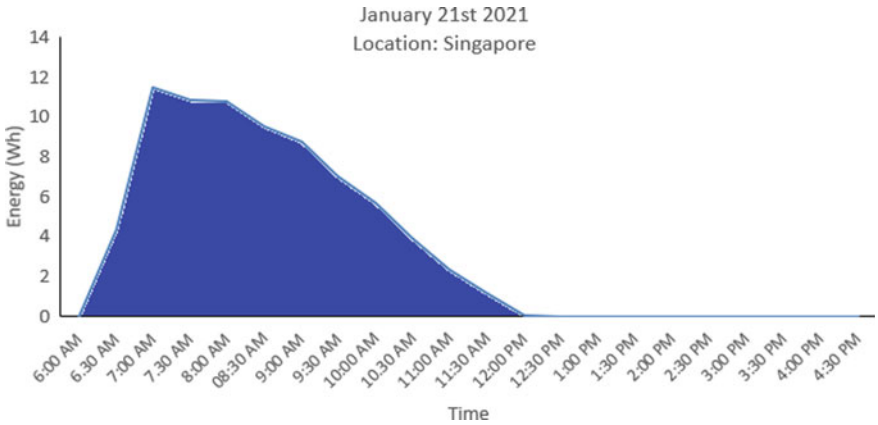

Fig. 3 Energy generation in East/West facing panel on January 21st (Singapore)

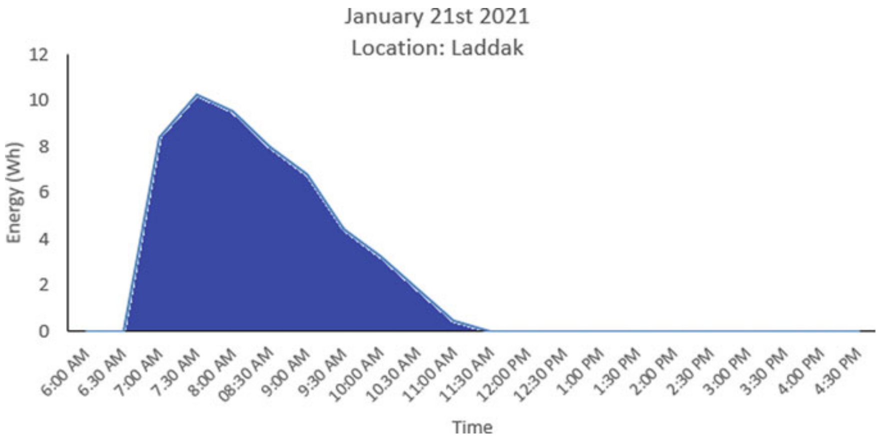

Fig. 4 Energy generation in East/West facing panel on January 21st (Laddak)

possible tilt angles of the East roof on which the BIPV panel is placed. These tilt angles are representative of the slope of a roof in the building on which the BIPV panel is mounted as shown in the last image in Fig. 1. As seen from Fig. 5, there is a steady drop in the panel performance when tilt in the east is varied from 10 to 90°. The performance of the BIPV panel steadily drops upto 56% for a vertically mounted BIPV panel on window façade where in the tilt would be 90° wrt the ground.

Table 1 captures % loss in efficiency with the traditional BIPV panels for different geographies for various type of mounting. We compare the performance of a traditional BIPV panel mounted on east building façade over a solar panel that is south facing at latitude tilt. We consider various types of installation for the BIPV solar panel like a BIPV panel vertically mounted on a wall in which case the tilt is 90° wrt ground plane, a BIPV panel integrated on the building roof which is east facing

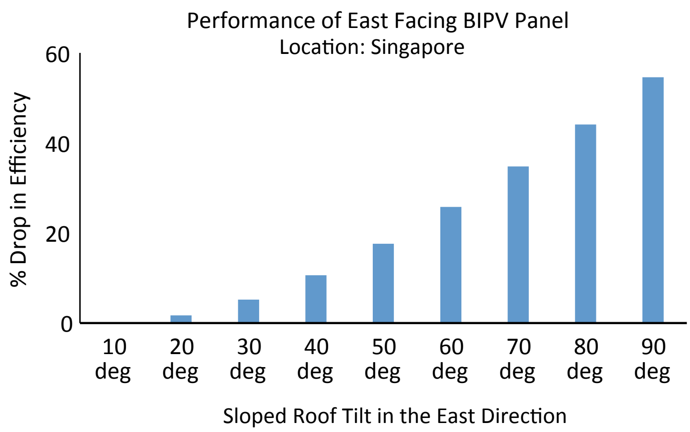

Fig. 5 Performance of East verses South facing panel for different roof tilt angle in the East

Table 1 % Loss in efficiency with BIPV

	% Loss in efficiency		
Place	East/West facing—vertical mounting (%)	East/West facing—10 deg tilt on roof (%)	East/West facing—40 deg tilt on roof (%)
Singapore (1.35^0 N)	−54.6	−0.1	−10.6
Bangalore (12.98^0 N)	−56	−3.2	−15
New Delhi (28.6^0 N)	−57.6	−14	−22.6
Laddak (34.2^0 N)	−59.7	−19.2	−27

and roof is inclined at 10° and a BIPV panel integrated on a building roof which is east facing and the roof is inclined at 40°. As seen in Table 1, across all geographies there is a consistent drop in performance of about 55–60% in a vertically mounted BIPV panel vs a south facing rack mounted fixed tilt panel. Incase of an inclined roof which is east facing there is considerably lesser drop when compared to vertically mounted panel. For a 10° inclined roof there is a drop of up to 20% till the latitude 34°. For Singapore, as it is located in the equator a slightly inclined east roof of 10° doesn't result in any loss. And the losses steadily increase to 10.6% for a 40-degree tilted roof. Also, higher the latitude of a geographic location more is the loss in performance of a BIPV panel mounted on a tilted roof.

2.1 MFOT Design and Topology

The MFOT is a light harvesting glass that has complex geometric pattern (6a) etched on it as shown in the top view in Fig. 6. 6b is solar cell area.

The Fig. 7 shows how the MFOT panel handles the equinox sunshine with the light redirecting units 7a and 7b. The outer units redirect the equinox sunshine towards the solar cell and thereby increase the efficiency of the panel.

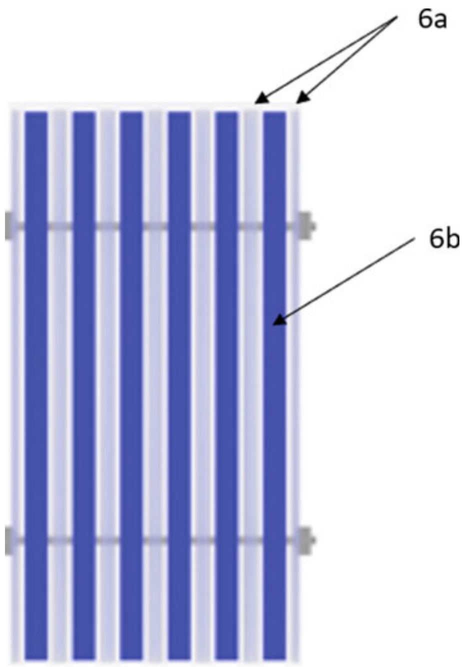

Fig. 6 MFOT panel with light harvesting units

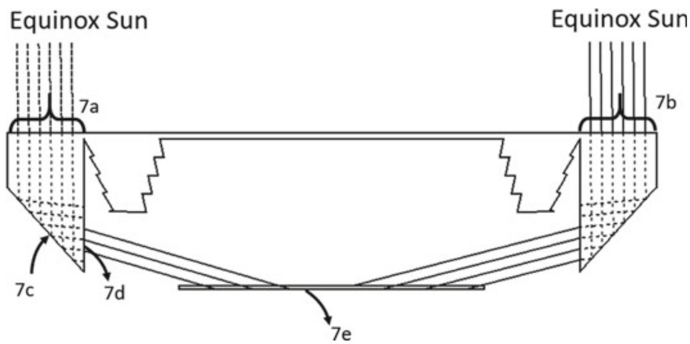

Fig. 7 MFOT panel redirecting equinox sun

3 Peroformance Analysis

We conduct all our solar simulations using Tracepro which is the industry's only ray tracing tool for simulating sunlight on 3D objects.

In this section we show the performance comparison of MFOT BIPV panel in East orientation over traditional BIPV panel.

Figure 8 shows the energy gain of East facing MFOT based BIPV panel over traditional BIPV panel for the location of Bangalore. The average annual energy gain with MFOT based BIPV panel is about 19.3% more than a traditional BIPV panel on a wall with east orientation. Figure 9 shows the performance based on MFOT based BIPV over a traditional BIPV on a west orientation of building wall for the location Bangalore. Here also we get an annual average energy gain of 19.6% with MFOT based BIPV system.

Figure 10 shows the energy gain with MFOT based BIPV over traditional BIPV for an east facing wall that's tested in different geographic locations.

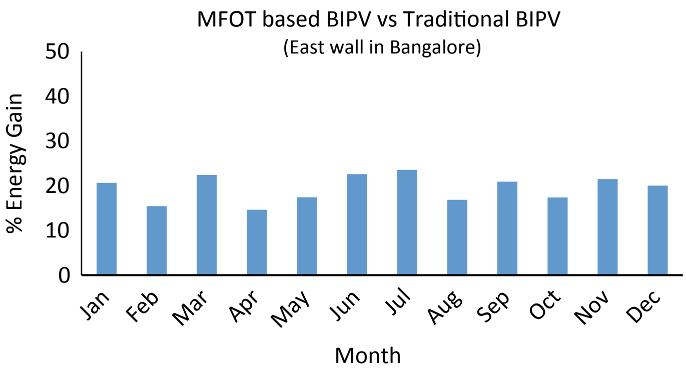

Fig. 8 Performance gain with MFOT based BIPV panel on East wall

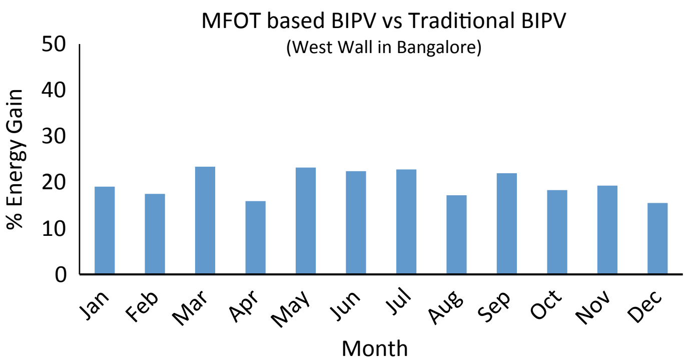

Fig. 9 Performance gain with MFOT based BIPV panel on West wall

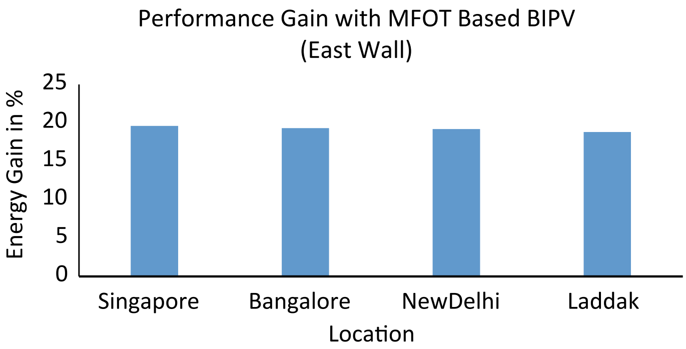

Fig. 10 Performance gain across different geographies for East Wall

4 Conclusion

In this paper we presented a detailed study of performance losses that occur on a vertically mounted traditional BIPV panel and inclined roof mounted east facing BIPV panel.

We presented the idea of MFOT based BIPV panel which can be mounted on building façade to significantly improve the performance by harvesting more sunlight. We presented detailed simulation results for the location of Bangalore for mainly east and west orientations of the building wall on which BIPV panel is mounted. While extensive simulation study has been done for different geographic locations, a pilot of 1 KW prototype testing will be done in the future. And as future work, we intend to enable similar energy gains of 20% on South and North facing wall orientation with our MFOT based designs.

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Unconventional Operation of Power Transformer Through Reverse Feeding Process

Lalit Wasan, Vishal Panchal, and Nishant Singh

Abstract In parlance of India's electrical power sector, all general-purpose transformers are generally used for stepping down the voltage for furthering the flow of electrical power from generation to distribution till end consumers. Though, a transformer is electrically designed as a bidirectional device which translates to that same transformer may be operated for stepping-down or stepping-up the voltage however, practically operating a transformer for stepping-up the voltage is quite uncommon and unconventional as rarely any such need arises which would require attempting such 'reverse' operation. This report puts forth, at length, details of once such operation of a step-down transformer in step-up mode.

Keywords Transformer · Reverse operation · Unconventional

1 Introduction

In April 20, a critical section was to be taken out-of-network for emergency maintenance. However, despite exhaustive load and network analysis, no sufficient margin could be arranged to meet the overall load requirement. Thereupon, the only feasible and sufficing option which evolved out, required two power transformers to be operated unconventionally through reverse feeding that is in step up mode components, incorporating the applicable criteria that follow.

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2 Canvas of TATA Power-DDL Distribution Network

TATA Power-DDL, incorporated in 2002, operating in 510 square kilometres of area, covers the north and north-west portion of the national capital. It evacuates power through transmission circuits, running across hundreds of circuit kilometres, deployed by government run Transmission Company that is Delhi Transco Limited (DTL). Accordingly, TATA Power-DDL has put in place approximately 15,130 circuit kilometres of network with 10,000 megawatt of power evacuation capacity at combined 66/33/11 kV voltage levels for the company to ultimately deliver the power to its approximately 1.78 million consumers.

3 Objective Behind Reverse Feeding of Power Transformer

In April 20, DTL informed that one of its 160MVA power transformer at its 220 kV Gopalpur grid which had developed a critical hotspot, was required to be attended on emergency basis and thus TATA Power-DDL was requested to transfer its load running on said power transformer elsewhere. However, since four of the associated circuits were already out-of-service due to ongoing project work and delayed due to nationwide lockdown, there was no redundancy left in the network to transfer the load.

4 Historic Load Analysis and Its Outcome

Since, the reverse feeding operation was scheduled for a Sunday so, historic load trends of last two Sundays and previous day were considered to paint a wholesome picture before taking final decision. It emerged that said PTR was serving 800 amperes at 66 kV voltage level whereas the only circuit available for load transferring had loading limit of 480 amperes at 66 kV voltage level.

5 Foreseeable Workarounds for Catering Load Requirement

Consequently, cancelling or deferring the emergency outage request surfaced as the only conventionally possible alternatives, however, opting this might have led to untoward breakdown of said PTR and thus affecting more than 2.5 lakh consumers for multiple hours. Accordingly, reverse feeding operations were opted.

6 Reverse Feeding the PTR

6.1 Sequence of Events

- Two 50MVA step-down PTRs were decided to be reverse fed at TATA Power-DDL's 'Jahangirpuri' grid one day prior to the outage.
- Sufficient load margin was created on the circuit which was to be used to reverse feed said two 50MVA PTRs.
- Time slot for subject outage was chosen to be from wee hours till early morning (4:30 am—08:30 am) based on historic load analysis.
- Both 50MVA PTRs were made parallel after considering phase sequencing, percentage impedance and voltage to turn ratio. However, to some technical issues, circulating current of 150 amperes, started flowing between PTRs and thus option of paralleling was dropped.
- Eventually, only one PTR was used to serve the entire load while another was kept idle for network redundancy.
- Inverse definite minimum time (IDMT) relay setting was modified from 3000 amperes to 4000 amperes while its Time Multiplier Setting (TMS) was changed from 0.075 s to 0.1 s.
- At another substation—'Dheerpur', directionality feature of the relay was turned off and non-directionali1ty feature was activated. Moreover, its high set current was changed to 2250 amperes and time delay setting of 200 ms.

6.2 Precautionary Measures for Contingency

- Out of two available PTRs, only one was taken in to load service to keep second PTR as backup in case of any untoward exigency.
- All TATA Power-DDL grid substations are remotely controlled however, considering this unprecedented move, sufficient manpower was stationed at 'Jahangirpuri' grid substation to perform any operation, in case of equipment malfunction, communication failure etc.

7 Theoretical Impacts on Electrical Parameters Due to 'Reverse Feeding' of PTR

7.1 Higher Inrush Current

- For a specified input voltage and VA rating, inrush current for reverse fed step-down transformer will be greater than the inrush current for a transformer specifically designed as step-up transformer. This occurs because the low impedance winding, originally intended to be secondary winding, now serving as primary winding and thus due to lower impedance, higher magnetizing inrush current flows.

7.2 Reversed Tap Changing Operations

- Standard step-down transformer contains taps on high voltage side (generally the primary side). Lowering down the taps on primary side, reduces the voltage on secondary side. However, in case of reverse feeding, wherein the low voltage side is now primary side, these operations get overturned and lowering the tap on high voltage side (now secondary side) increases the voltage at low voltage side (now primary side) and then vice-versa.

8 Challenges Overcame During the Arrangement

8.1 Establishing Percentage Impedance of PTR

- Percentage impedance of both PTRs was established at such short notice to rule out the possibilities of unbalance loading due to indifferent percentage impedance.

8.2 Unnecessary Circulating Current Between the PTRs

- Moving forth without addressing the issue of circulating current would have led to unequal induced electromagnetic force and thus flow of circulating current much greater than the normal no-load current.

9 Major Benefits Gained

Averting potential supply failure and financial loss as had said emergency outage not been arranged, approximately 2.6 lakh consumers would have suffered power outage leading to financial loss of approximately 0.092 million units considering the duration of the outage (4 h) and approximately Rs. 6 lakh assuming an average power purchase price of Rs. 6.5 per unit.

10 Risks Perceived

Such reverse operation was being carried out for the first time in TATA Power-DDL. This birthed risk perceptions related to health of the PTR. Any unforeseen exigency could have led to failure of assets costing millions in India currency.

11 Future Potential

The process of reverse feeding a PTR requires great level of efforts for drafting a comprehensive implementation plan. However, observing its success in this reported case, the arrangement can always be restored to if no alternative is available at disposal.

Cyber Physical Security of the Critical Infrastructure

N. S. Sodha and M. L. Sachdeva

Abstract Power Sector, a critical electrical infrastructure in India, is at risk due to increasing cyber incidences. The electrical infrastructure depends on electronic control systems for its operation which are Cyber physical IT systems. Cyber threats to system can take many forms e.g. failure of a system/element to act/react in designed way due to virus, software bugs, intrusion and congestion in the underlying/supervising system and it may lead the misguidance to the operating engineers and there by taking false decision in real time operation. Non availability of ICT systems is also a form of Cyber Security vulnerability. Cyber intrusions are costly to Power Sector and many are preventable following safe design and Cyber Security Standards. The effect of vulnerabilities in centralized systems e.g. SCADA/Automation etc. used in Transmission and Distribution sector is wider and has potential impact on the synchronous operation of entire Power System, leading to Grid collapse. As far as Distribution sector is concerned where bulk of Smart Grid activities are visible, the impact of compromise of a centralized SCADA/DMS can lead to disruption of services to critical customers like Hospitals, Metro Rail etc. which is critical for the units/Services involved but at the same time not global and widespread. The impact of cyber vulnerabilities is proportional to the criticality of the functions and systems being impacted. The paper details the Cyber threats and prevention techniques involving IoT sensors, communication protocols, cloud architecture and predictive data analytics.

Keywords Power sector · Cyber security · Automation · SCADA · Cyber threat

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1 Introduction

Indian Power System is currently witnessing high growth rate with Generation and Transmission EPUs adopting all Digital Automation and IoT Technology for efficient management. Power System operations and control was initially local, including automated isolation and concentrating on continuity/reliability of the system and of the supply. However, with the introduction of Information and Communication Technology (ICT) based control systems, efficiency, reliability and operational flexibility of Power System has increased many folds. These control systems can be operated in isolation and also in connected mode with corporate network as well as internet. The result is exposure of the Power Systems controls to cyber space and thus becoming vulnerable to Cyber-attacks. Cyber-attacks can be perpetrated both by outsiders as well as insiders and may be caused by design faults, employee errors, firewall misconfigurations, tardy software updates and circumvention of existing security elements. Such attacks can have far–reaching and detrimental effects on power systems controls and could lead to the destabilization of the supply capabilities of the energy sector and lead to cascading effect on the national economy itself.

2 Consequences of Cyber Security Failures

At National level there can be major/temporary loss of National property, Grid collapse causing all round economical loss, Disruption of essential services which may lead to loss of life and/or property, Important data may get stolen from the organization which could turn into major commercial losses and credibility of product/company is affected.

The Government of India enacted the Disaster Management Act in 2005 and adopted as National Policy on Disaster Management in 2009.National Disaster Management Plan (NDMP) was adopted in May, 2016 by National Disaster Management Authority, New Delhi which takes into account the Global Trends in disaster management.

3 Challenges

Increasingly integrated nature of Power System covering Generation, Transmission and Distribution makes them more vulnerable to large scale cyberattacks and hence damages. Renewable Energy and Distributed Generation getting integrated into the Grid and controlled by Smart Grid Application. Moving to open standards such as Ethernet, TCP/IP, and web technologies leading to improvements and increased vulnerabilities simultaneously.

4 Objectives of Cyber Security

Securing the IT infrastructure for Secured Grid control leading to Reliable Power Infrastructure No single point of failure/attack should cause multiple/wider area power system getting compromised. The security level of a system indicates the severity of damage that might be done on penetration. IT and applications (SCADA Systems) controlling Power system, Cyber connectivity of Operation Technology Solution and Communication Systems needs to be secured. It can be secured by Firewalls, IPS, DMZ, Better monitoring and Deployment Practices and Continuous audit.

5 Cyber Security Threats

The attackers can be classified as: **Internal disgruntled employees**-Can be handled by adopting Biometric access control, CCTV systems, Password authorizations etc. **Cyber-Hackers**-They pose a more serious threat and can attack using the following mechanisms: **Targeted Cyberattacks**: Sniffing packets at an ISP and manipulating the packets in network to achieve expected results **Flood based Cyberattacks**: Denial of Service (DOS) mechanisms and others that spread through viruses and worms—cause traffic avalanche in short duration and hence bring down system **Communications hijacking (or man-in-the-middle):** False messages are sent to the operator, and could take the form of a false negative or a false positive.

6 Sources of Cyber Security Threats

Bot-network operators, Criminal Groups, Foreign intelligence services, Insiders, Phishers, Spammers, Spyware/malware authors, Terrorists, Industrial spies. Implementing Cyber Security for Power System Components can be broadly divided into two dimensions. (a) Organization level and (b) System Level.

7 Cyber Security Tools and Methodology

(a) Measures at **Organization level**: Identifying the Critical cyber assets**,** Making vulnerability assessment in each area of operation**,** Creating a plan for implementation at the system level**,** Defining the user roles and access management authentication for each user, Creating awareness and training to all the personnel concerned with Cyber assets, Creating back up control and back data storage options, Creating incident response and disaster recovery plans in case of a cyber incident on SCADA networks, Cyber asset auditing on regular basis by reputed agencies and implementing the audit suggestions and Vendor development to comply with standards.

(b) Measures at the **System level**: Restricted Physical access to Utility Systems with continuous monitoring, Implementing the Segmented Network architecture, Device configuration should be accurate—Deny by default—White listing, Hardware and OS hardening latest Standards, Logging of all control command operations, Restricted User access to servers and applications based on the functional responsibility, Periodic Patch management and Passwords Change, Systems Personnel Training and Make people responsible for Cyber incidents

8 Network Architecture

Firewalls**,** Routers, Intrusion Detection Systems (IDS)**,** Intrusion Prevention Systems (IPS)**,** VPN/IPSec**,** DMZ etc.-All these network architecture components have to be compliant with updated CERT-In Guidelines to enhance the Security Posture of the systems.

DMZ—In computer networks, a DMZ (demilitarized zone) is a physical or logical sub-network that separates an internal local area network (LAN) from other untrusted/less trusted networks**,** A DMZ is sometimes called a "Perimeter network"**,** A DMZ is a step towards defence in depth because it adds an extra layer of security beyond that of a single perimeter.

Perimeter Network.

A network perimeter is the boundary between the private and locally managed-and-owned side of a network and the public network. Perimeter security comprises those preventive control devices that perform the functions of "deter, detect, delay and deny". These are designed to sort the "good guys" from the "bad guys" in today's highly techno-savvy society and to grant access only to those who are authorized to have it and who can prove that they are authorized to have it.

Perimeter Security: To secure Perimeter following may be included: Firewalls**,** IDS**,** IPS**. Boarder Routers**:

Firewalls: A firewall is a software or hardware-based barrier against unauthorized access to your network. Firewalls inspect all the traffic going through them. "Legitimate" traffic is let through, while "malicious" traffic is rejected. **Firewalls Protect: Data,** Proprietary corporate information**,** Financial information**,** Sensitive employee or customer data**, Resources-**Computing resources**, Reputation-**Loss of confidence in an organization**.**

Network Management System (NMS).

9 Present Preparedness of Cyber Security in Indian Transmission Sector

All SCADA/EMS Systems have Identity management system. Now a days all the SCADA/EMS systems implement Network Segmentation/DMZ. To check any vulnerability, practice of annual audit from CERT-In certified auditors introduced.

10 Top 10 Vulnerabilities

1. Inadequate policies, procedures, and culture that govern Protection and Control security
2. Protection and Control design does not consider cyber security defense-in-depth mechanisms
3. Remote access to the control system without appropriate access control
4. System administration mechanisms and software are not adequately scrutinized or maintained
5. Use of inadequately secured WiFi wireless communication. Use of a non-dedicated communications channel for command and control and/or inappropriate use of control system network bandwidth for non-control purposes
6. Insufficient application of tools to detect and report on anomalous or inappropriate activity
7. Use of Unauthorized or inappropriate applications or devices
8. Control systems command and control data not authenticated
9. Inadequately managed, designed, or implemented critical support infrastructure

11 Conclusion

Cyber-attacks may not be as easily identified and many of the attacks may go unnoticed even to the Power companies for long periods of time. Even though the resources and tools for cyber-attacks are becoming more common place and readily available, companies that own and operate or make up the critical infrastructures are often unaware of the problem and may have poor Cyber Security designs and weak protection.

Cybersecurity challenges in India and globally are soaring, as the cyber world gets more complex with increasing interconnected devices that expose enterprise data to the external world. Experts say the traditional approach to security will not keep pace with the advancement and there is a need to move beyond breach prevention and reaction.

There is a need to re-think the overall approach to Cyber Security and to build a resilient cyber defence that can help resist, respond to and recover from new threats.

Building a cyber-resilience is truly a top business priority. One of the ways to achieve this is automation. However, automation alone cannot help and we need various other methodologies on priority to build and strengthen India's Cyber defence capability**.** Collaboration between public and private sectors is necessary to build a resilient Cyber Secured Power Sector.

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Review of Charging Infrastructure Pilot Projects: Global Scenario and Lessons Learnt

Mahena Mahmood, M. Saad Alam, Sanchari Deb, and Yasser Rafat

Abstract With the tremendous advancement in technology we have vehicle running of electrical energy. For the success of this invention various other arrangements are made which includes the establishment of charging infrastructure. The establishment of charging infrastructure imposes great effects on grid stability, loading scenarios and economic conditions. To point out the various positive and negative aspects of charging infrastructure Pilot projects are run. Here various charging infrastructure pilot projects are reviewed and the lessons learnt from them are mentioned. The global scenario of Electric vehicle charging station optimization is also stated. Pilot projects are run to resolve real-world deployment issues and to run improvement programmes for charging stations. Areas of working of various pilot projects are cost management, grid reliability and load optimisation, solar power incorporation, etc. Mostly pilot projects aim the improvement of smart-charging infrastructure. The benefits of smart-charging includes: lower generation costs and carbon intensity, lower upgrade costs for grid infrastructure, increased grid reliability, etc. The further areas of research are also mentioned.

Keywords Electric vehicle · Charging infrastructure · Pilot projects · Smart-charging

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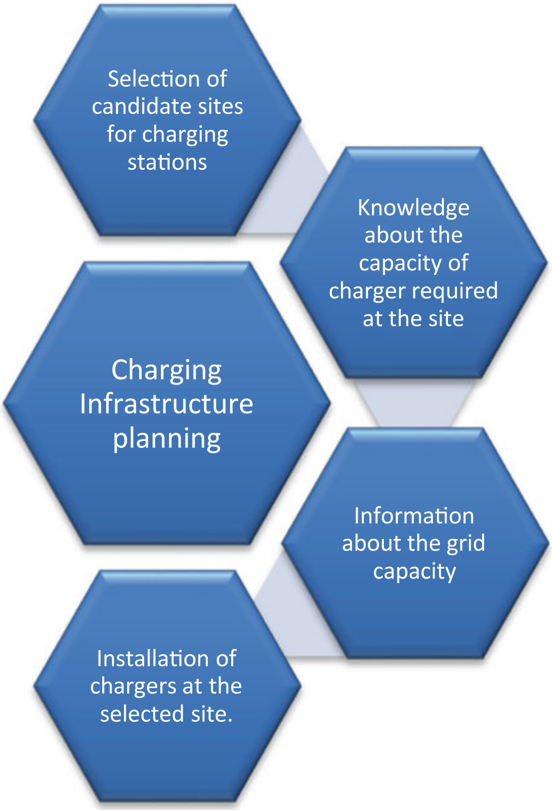
1 Introduction

Transportation sector contributes about 28% of U.S. Greenhouse gas emissions which is the greatest contribution from any sector [1]. The burning of fossil fuels leads to the emission of Carbon dioxide in the environment. The start of the era of electrification of transportation marks some of the greatest technology boosts. The Internal Combustion Engines are now replaced by rechargeable batteries which lowers the dependence of transportation sector on the fossil fuels for the energy requirement [2]. The sale of Electric Vehicles (EVs) is rising in every coming year, 2019 marked around 2.1 million EV sales globally [3]. With this hype in the EV usage the stakeholders are also concerned for a proper and reliable charging infrastructure for hassle-free charging. The installation of charging infrastructure poses certain challenges to the grid and power supply systems [4]. To chalk out these challenges and to build up a reliable charging infrastructure various pilot projects are conducted globally. With the findings of these projects, we will be able to come out with some great solutions to the problems in the path of hassle-free charging.

2 Overview of Charging Infrastructure Planning

Charging infrastructure plays the key role in widespread usage of EVs. The deployment of charging infrastructure requires optimal planning through competitive techniques in a stepwise propagating method, which includes the selection of candidate sites for charging stations, knowledge about the capacity of charger required at the site, information about the grid capacity and the final stage of installation of chargers at the selected site, Fig. 1 shows the schematic representation of charging infrastructure planning. The optimal planning of charging stations is done concerning different aspects in different research links like, power grid characteristics, traffic network, EV owner's behavior, power losses, total infrastructure and maintenance cost, etc. Once the candidate sites are chosen the optimization process is started in which the capacity of each charger and the respective grid are considered. In Wang et al. [5] proposed a plan of EV charging station which aims at reducing power losses and voltage deviations of the distribution systems to maximize the EV traffic flow. Also, in Islam et al. [6] a plan of rapid charging station deployment is made out by considering the costs of travellingloss, build-up loss and substation energy loss cost. S. Micari et al. in [7] used the technique to calculate the sites and number of chargers by taking into account the EV technology, EV flow and charger technology. Hall and Lutsey [8] states the feasibility of placing the chargers at home and workplaces as they are the most favored site of charging engaged by EV drivers.

Fig. 1 Schematic representation of charging



3 Global Scenario

According to [9] around 5.1 million EVs were on road across the globe till 2018 and china being the top contributor of 45% followed by Europe accounted for 24 and 22% by the United States [10]. In 2018 the global stock of electric busses increased by 25 percentage in 2017, China being the marketplace for 99% of Electric buses [9]. By 2026 India government has asked the taxi services like Ola and Uber to start electrification of taxis to about 40% [11]. Approximately 5.2 million charging points worldwide were estimated at the end of 2018, accounting an increase of 44% from the previous year. Private charging points accounts for more than 90% of 1.6 million installations [10]. In 2030 China will maintain its world lead with 57% share of the EV market, followed by Europe (26%) and Japan (21%), over 30% in Canada and the United States, 29% in India, and 22% in aggregate of all other countries. Presently India has only 164 public EV chargers [12] while US has over 20 thousand and china ranging up to 770 thousand EV charging stations [11]. According to battery prices have fallen to approx. 250 USD in 2017 and reach 74USD/KWhr by 2030 [9]. [13] states that different standardizations are made by different countries for the battery systems, like In Europe the EV charging equipment used is mostly CCS Combo. US and Korean industries are using CCS, while China follows GB/T standards and Japan follows CHAdeMO. Figure 2 shows the number of active EV charging stations per state in EU till 2019 according to [14]. Figure 3 shows the number of active EV charging stations per state in USA till 2019 as per [15].

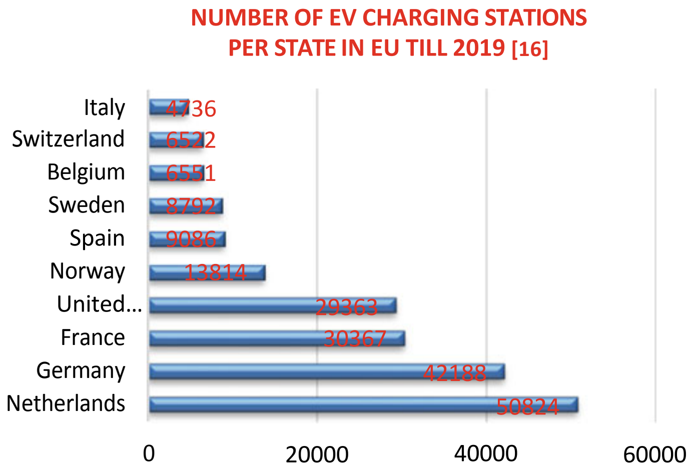


Fig. 2 Number of EV charging stations per state in EU till 2019

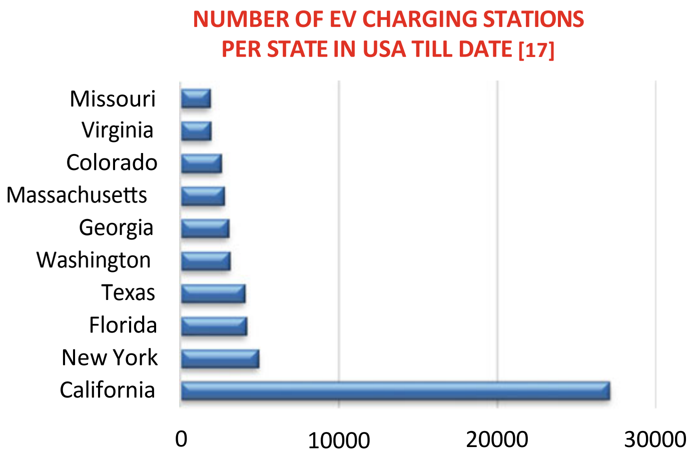


Fig. 3 Number of EV charging stations per state in USA till 2019

4 Pilot Projects Executed Globally

Various pilot projects are carried out across the globe for the rectification of problems in which the charging stations are hung up in. A review of such pilot projects is done in this section classifying them according to their regions of implication.

4.1 India

4.1.1 Proposal for A Quick Pilot on EV Charging Infrastructure [13]

NITI Aayog in collaboration with AC2SG launched a quick pilot project in September 2017, to gain an insight about the EV charging infrastructure deployment for Gurgaon-IGI-South Delhi-Noida Corridor and later for the whole country. The Five-stepped planning process includes; preparation of guidelines of infrastructure, short-listing ideal sites for the charging stations by AC2SG, estimation of timeline for each site, Documentation and final check of the plan and finally feedback.

The plan included 55 locations with 135 charging stations including 46 DC quick charging stations and 89 slow AC charging stations. The planning process was done using a planning tool developed by AC2SG.

The traffic in Delhi is usually slow-moving facing congestions all around so a density of 3 km radius was fixed for the quick charge station whereas 1 km radius for the slow charge station. The estimated charging sessions by a vehicle in Delhi are taken to be as 2 sessions per day as the approximate distance covered by a vehicle ranges up to 100 km in a day. The facility for residential charger is also provided under this project where the charging should be done in the night. Figure 4 shows the position of charging stations installed in first wave of the project.

About ten organisations including, NITI Aayog, Indian government at North and South Block, Nirman Bhawan, Udyog Bhawan, some Government companies, IGI airport, DLF Mall, National Highway Authority of India, Airports Authority of India housed the charging stations at the office premises in the first wave of the plan

4.1.2 Beyond Nagpur: The Promise of Electric Mobility [16]

This pilot project was inaugurated in May 2017, the main target was to make industry and government stakeholders realize the potential for electrification of transport. Under the pilot, battery charging and battery swapping infrastructure was setup in Nagpur by Ola. This pilot was conducted to learn about the operational issues that include the impact of temperature on charging and battery life, and of integrating renewables with the charging infrastructure, customer charging behavior, vehicle performance. The project was a steppingstone for the mission Electric 2018 through which Ola determined to bring 1 million EVs on road till 2022. Ola in Nagpur had

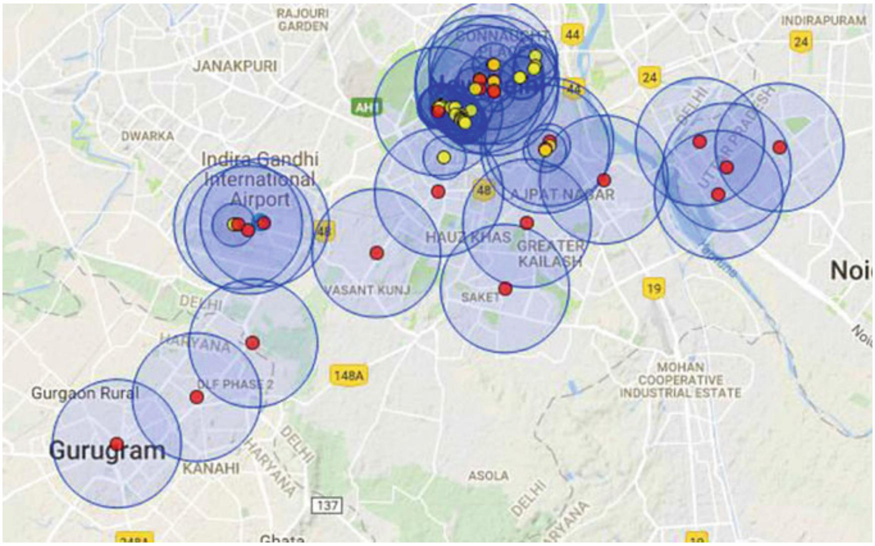


Fig. 4 Geographical representation of first wave network [13]

served over 350,000 customers, covering over 7.5 million clean KM, saving over 5.7 lakh LITRES of fossil fuel and reduced CO2 emission by over 1,230 tons. ola fleet included E-rickshaws and E-cars manufactured by Mahindra and Kinetic

Ola also established charging stations across Nagpur by collaborating with Municipal Corporation of Nagpur, Indian Oil Corporation Limited and Hindustan Petroleum Corporation Limited. There were around 22 charging points including both fast and slow. Battery swapping was also taken up by Ola which came out as a revolutionizing idea as it increased the running time of vehicles and reduced the idle time significantly.

4.1.3 Hero Electric and EV Motors India Partenership for Rapid Charging E-Bikes [17]

Hero Electric in collaboration with EV Motors India is about to launch a successful solution of EV adoption in the form of e-bikes. EV motors claim that the bikes will be supercharged in less than 30 minutes with the help of their hi-tech batteries. The three main issues haunting the EV users namely; range anxiety, high battery replacement costs and high acquisition prices will be nullified through this venture. EV Motors also aim to provide rapid charging station network 'PlugNgo' at some strategic locations and at the Hero Dealerships to facilitate the EV users. An approximate range of 130–140 km daily travel will be guaranteed with this rapid charging solution. For this project a pilot will be launched of 10,000 bikes in few cities for an interval of 12 months before the nationwide launch of vehicle. This venture is basically designed for aiding the delivery service businesses.

4.2 The United States of America

4.2.1 Electric Vehicle Charging Station Pilot in Maryland [18]

Maryland Public Service Commission has approved a pilot project by Potomac Edison, a subsidiary of FirstEnergy Corp., under which Electric Vehicle (EV) charging stations will be installed in Maryland and rebates will be offered to both residential and non-residential charger installations. Its aim is to reduce the auto emissions to help improve the state's environment. The project is approved by the concerning authorities and is prevailing across Maryland territory.

It is a five-year pilot program, under which Potomac Edison will install more than 50 charging stations, (including nine "fast charging" stations), across Maryland. Rebates of up to US$300 will be provided to residential customers for the installation of EV charging stations at their home. The goal is to reach 300,000 zero-emission vehicles on the road by 2025. Through this pilot Maryland utilities intend to evaluate the benefits of EV charging while being cost-effective. Also, the "range anxiety" of EV owners will be reduced by the installation of some public charge stations under this project.

4.2.2 Pilot Project to Expand EV Infrastructure in Vermont [19]

Delta Clime VT, a climate economy business accelerator, in collaboration with EVmatch, a California based start-up initiated two pilot projects with Green Mountain Power and The Burlington Electric Department in 2019, aiming the expansion of EV infrastructure of Vermont.

Major goal was to increase the adoption of EVs and to lower the harmful emissions from vehicles by easing the charging process and setting up charging stations. The EVmatch offered solutions like, publicizing private chargers through a peer-to-peer sharing app which allows reservation and payment for the charging online. This method was cost- effective and user friendly.

This project was initiated to meet the goal of 2025, 50,000 EVs on the road of Vermont. Burlington Electric Department had 15 charging stations and 27 ports in the Burlington area. The pilot project with EVmatch was directed to bring 16 new charging stations by 2020.

4.3 The European Union

4.3.1 eCharge4Drivers Project [20]

eCharge4Drivers is a four year project under the banner of the Low Carbon Green Vehicles program ‘User-centric charging infrastructure’—a European Commission initiative which supports the development of smarter and convenient electric vehicle charging infrastructure. The budget of €18.8 million has been approved for the project, co-finance of €14 million euros by the European Union under the Horizon 2020 Programme. The enlistment of demo sites for EV charging will start from the summer of 2021 and the pilot demonstrations will start in the second half of 2021. The basic idea is to understand consumer perspectives by organizing demonstrations across EU states. The projects is flagged by 32 stakeholders including ABB alongside companies such as Volvo, Fiat, Bosch, BMW and several European educational institutions. ABB aims at testing the new DC charge stations on EU standards. The project focusses on ten regions across Europe, including metropolitan areas and Trans-European Transport Network (TEN-T) corridors.

The chargers for the demonstration sites will be provided by ABB called “easy-to-use, scalable EV chargers” they will have large digital displays and plug and charge according to ISO 15118. Also, the ABB’s Dynamic DC sharing technology will be used under this project which allows the sharing of power across multiple charging points.

4.3.2 ‘Plug and Charge’ [21]

Plug and charge pilot is an initiative taken by Virta, Charging-platform provider, Efacec, charge-point provider, the Departmental Energy Association of Yonne (SDEY) and Hubject in France to be launched in 2020. The major aim is to sell the last ICE car in France by 2040. This will lead to France becoming the home for the best charging facilities in EU. Plug and charge’ (P&C) solutions use digital certificates to communicate between the vehicle and the grid following the ISO 15118 standard. The requirement of RFID card or the smartphone app will be crossed out, only the plug in is required for the charging process to initiate, the encrypted data from the car is automatically transferred to the grid, while processing the payment in background. Virta platform will connect the charging station to the Hubject network.

Firstly, six Efacec HV160 P&C-compatible charging stations will be installed in the Yonne region of France by SDEY.

5 Charging Standards

Various worldwide organizations are setup to form a particular range of EV charging standards to be followed everywhere. The absence of these standards leads to limited usability of products and usually results in increased power losses. Separate EV charging standards are made for each type of charging system namely; Conductive, Inductive and Battery Swapping.

5.1 Conductive Charging

Various Conductive charging standards and their brief descriptions [22] are listed in Table 1.

5.2 Inductive Charging

Various Inductive charging standards and their brief descriptions [22] are listed in Table 2.

5.3 Battery Swapping

Various Battery Swapping standards and their brief descriptions [22] are listed in Table 3.

6 Lessons Learnt

Pilot projects contribute largely to the planning and optimization of EV charge stations. Various issues faced by the charging technology are highlighted by the functioning of pilot projects and then it becomes easy to rectify those problems. Pilot projects reviewed in the previous sections were based on diversified objectives, but their sole objective remained same, i.e. making EVs user friendly by streamlining the charging technology. The extensive diffusion of EVs depends on the omnipresence of the charging stations. The problems faced by the EV diffusion primarily are the high upfront costs, inefficient charging infrastructure, unreliable behavior of EVs, etc.

Table 1 Conductive charging standards

Title	Description
IEC 61851-1 Ed. 3.0	General requirements
IEC 61851-21-1 Ed 1.0	Electric vehicle on-board charger EMC requirements for conductive connection to A.C /D.C. supply
IEC 61851-21-2 Ed 1.0	EMC requirements for off-board electric vehicle charging systems
IEC 61851-22 Ed 2.01.0	A.C. electric vehicle charging station
IEC 61851-23 Ed 1.0	D.C. electric vehicle charging station
IEC 61851-23 Ed 2.0	D.C. electric vehicle charging station
IEC 62982 Ed. 1.0	Bidirectional D.C. charging station
IEC 62196-1 Ed. 3.0b:2014	General requirement
IEC 62196-2 Ed. 1.0b:2011	Dimensional compatibility and interchangeability requirements for A.C. pin and contact-tube accessories
IEC 62196-2 Ed 2.0	Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories
IEC 62196-3 Ed. 1.0b:2014	Dimensional compatibility and interchangeability requirements for D.C. and A.C./D.C. pin and contact-tube vehicle couplers
IEC/TS 62196-4 Ed. 1.0	Dimensional compatibility and interchangeability requirements for a.c., d.c. and a.c./ d.c. vehicle couplers for Class II or Class III light electric vehicles (LEV)
PNW 69-405 Ed 1.0	D.C. Charging with an automatic connection system
PNW 69-177 Ed 1.0	Control communication protocol between a.c/d.c supply hybrid charging system and electric vehicle
PNW 69-183 Ed 1.0	General technical requirements for off-board charging and discharging equipment
J1772 (RIP)	Electric vehicle and plug in hybrid electric vehicle conductive charge coupler
P2690	Standard for charging network management protocol for electric vehicle charging systems
2030.1.1-2015	IEEE standard technical specifications of a DC quick charger for use with electric vehicles
IEEE SA - WGP2030.1.1	Working group for creating technical specifications of quick charger for electric vehicles
UL2202	Standard for electric vehicle (EV) charging system equipment
UL2251	Standard for plugs, receptacles, and couplers for electric vehicles
UL2734	Outline for connectors and service plugs for use with on-board electrical vehicle (EV) charging systems
UL2871	Outline of investigation for electric vehicle (EV) service and production chargers
UL9741	Outline of investigation for bidirectional electric vehicle (EV) charging system equipment
EN 61851-1	General requirements

(continued)

Table 1 (continued)

Title	Description
EN 61851-21	Electric vehicle requirements for conductive connection to an A.C. /D.C. supply
EN 61851-22	AC electric vehicle charging station
CLC/TS 50457- 1:2008	D.C. charging station
CLC/TS 50457- 2:2008	Communication protocol between off board charger and electric vehicle
GB/T 18487.2- 2001	Electric vehicle conductive charging system - general requirements
GB/T 18487.3- 2001	Electric vehicle with AC/D.C power supply connection requirements
GB/T 20234.1- 2011	Electric vehicle AC/D.C. charger (station)
GB/T 20234.2- 2011	General requirements
GB/T 20234.3-2011	AC charging coupler
QC/T 895-2011	D.C charging coupler
QC/T 841-2010	On-board conductive charger for electric vehicles
G105-1993	Connectors applicable to quick charging system at Eco-Station for EVs

Table 2 Inductive charging standards

Title	Description
IEC 61980-1 Ed.1.0	General requirements
IEC 61980-1 Ed.2.0	General requirements
IEC 61980-1am1Ed. 1.0	General requirements
IEC/TS 61980-2Ed. 1.0	specific requirements for communication between electric road vehicle (EV) and infrastructure with respect to wireless power transfer (WPT) systems
IEC/TS 61980-3Ed. 1.0	specific requirements for the magnetic field power transfer systems
J1773	Electric vehicle inductively coupled charging
J2954	Wireless charging of electric and plug-in hybrid vehicles
G106:2000	EV inductive charging system: general requirements
G107:2000	EV inductive charging system: manual Connection
G108:2001	EV inductive charging system: software Interface
G109:2001	EV inductive charging system: general requirements

Table 3 Battery swapping standards

Title	Description
IEC 62840-2 Ed.1.0	Safety requirements
IEC/TS 62840 1Ed. 1.0	System description and general requirements

- Pilot project stated in section IV, A., 1, establishes the fact that major charging stations are to be located in the center or the most populous areas of cities for the ease and efficient usage by the customers.
- Pilot project by Ola made the significance of battery swapping and integration of renewables very clear. Battery swapping comes out to be the best way through the problem of idle time for the EVs during charging. More emphasis should be given to the battery swapping infrastructure as it helps in increasing the ease of driving by maintaining the driving time. The integration of renewables with the charging infrastructure comes out to be the game changer as it not only helps in reducing the total cost but also plays a great role in greening the EV infrastructure. Ola chose to start a fleet of public two and three-wheelers rather than encouraging private EVs at first. The publicizing of EVs led to the easy diffusion of technology all over the area. Public vehicles cover more kilometers than private vehicles which makes in highly penetrable in making a good economy out of the EVs.
- Hero Electric's and EV Motors' joint venture of rapid charging of e-bikes opens the avenue of hassle free EV adoption by various delivery service businesses. Through the hi-tech battery system, a charge of less than 30 min ensures smooth working of e-bike for 130–140 km.
- The Maryland Project highlighted the evasion of "range anxiety" among EV users, which is the most serious issue faced presently. The establishment of charging stations in a close radius will help in nullifying the "range anxiety" among users.
- The project by EVmatch in Vermont mainly focuses on installing user friendly charging stations where just by the peer-to-peer sharing app users can reserve and pay for the charging and this also enables the owner to lend the charger for public use when it is free.
- The basic finding from the eCharge4Drivers pilot is that the chargers for the demonstration sites will have large digital displays and plug & charge according to ISO 15118. Also, the ABB's Dynamic DC sharing technology will be used under this project which allows the sharing of power across multiple charging points.
- Plug and charge pilot in France broadcasted the use of digital certificates to communicate between the vehicle and the grid following the ISO 15118 standard. The requirement of RFID card or the smartphone app will be crossed out, only the plug in is required for the charging process to initiate, the encrypted data from the car is automatically transferred to the grid, while processing the payment in background.

7 Way Ahead

As EVs are the future of the worlds transportation sector, their proper and efficient diffusion in the day-to-day life is of vital importance. Through this study it can be said that the widespread deployment of charging stations is the key to the EV adoption. While the installation of charging stations some major points should be kept in mind like the feasibility of stakeholders, convenience of users, protection of EV technology, etc. Till now battery swapping comes out to be the best way through the charging problem of EVs. Battery swapping eases the use of EVs and increases the running time of vehicles which makes EV more user friendly. Battery swapping technology uses a lot less land then the conventional EV charging. Also, these batteries can be put to use for domestic loads during blackouts and grid failures [23]. A major thought should be given to establishing more battery swapping stations at the moment.

The integration of charging infrastructure with the renewable also comes out to be of great importance as not only it will reduce the dependency of Energy sector on fossil fuels but also will help making the charging infrastructure greener.

8 Conclusion

Pilot projects play a very important role in the extensive diffusion of EVs around the globe. By the help of streamlined pilot projects, it becomes easier to mark out the concerning issues of the charging and other EV related sector. In this paper various pilot projects are reviewed which aims at bringing major revolutions in the charging sectors. The ideology of battery swapping, integration of renewables to the grid, usage of user-friendly chargers, peer-to-peer sharing apps which enable hassle free charging and sharing of free chargers are the key findings of this paper. These upcoming technologies aim at the establishment of more convenient and a quick way of charging EVs. These pilot studies provided knowledge about the EV user interface which is of utmost importance.

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Solar—Wind Hybrid System for Optimized Planning and Coordination of Hybrid Renewable Energy

Manan Pathak and Rohan Gupta

Abstract It is well known fact that the rate of industrial growth of any country is a function of the amount of energy available in that country and the extent to which this energy is utilized. Energy plays an indispensable role in modern society. Besides energy independence the devasting impact of climate change has become an issue of critical consideration. The burning of fossil fuels to generate energy is a dirty process. Greenhouse gas (GHG) emissions result when fossil fuels are produced and consumed and these emissions contribute to climate change. Hence, transition towards a low carbon energy economy is the real solution for the mitigating the impact of climate change. Recommendations for the integration of renewable energy sources beyond other measures have been offered, especially with reference to the salient environmental benefits that accrue to it. A wind turbine upon which solar (PV) panels are placed supplementary which is ideal hybrid concept. Solar panels are attached to the structure of the turbine thus maximizing the power output of the device for its given size. Thus integration of the two renewable energy sources will help in maximizing the power output of a domestic-size, and improve the system's economics. Installing a hybrid system, instead of a pure solar or wind device, could assist in maximizing energy output from a given area and hence improve the economics of renewable energy.

Keywords Hybrid Renewable Energy · Solar and Wind energy · Greenhouse Gas · Environment · Climate Change

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1 Introduction

Renewable Energy Resources are best practices possible today to stand against increasingly risk of climate changes and global warming of the world and the most important sources of such types of resources of energies can be Wind and Solar energies which are most the efficient relatively. These clean power resources are used as in Distributed Generation (DGs) units technology to be defined as newer sources of power, which are in direct relation with the use of micro and smaller in capacity power generating units that are installed in distribution part of each power combined system or all the possible locations that loads and energy consumers are concentrated. Hybrid systems are of different states [1]. One of the practices possible to provide these hybrids is combination of grid connected wind turbines and solar photovoltaic generators that together each could sit instead of the other one in a grid connection state when one of them cannot generate the required electricity for consumption by load properly. Moreover, Solar cells can generate the electricity required in the day while wind turbines can compensate the needs in the night by wind energy. This is exclusively where solar cells have gained more important effects in electricity generation of the world. They are consisting of a sort of assembly of different cells together to form a flat photovoltaic system to absorb the photons and generate electricity by electrons energized in the circuit. On the other hand, Systems for conversion of energy of wind use Permanent Magnet Synchronous Generators that are usually installed to generate electricity. Recently, wind turbines are even improved to VSD drives from constant speed generators which provides the machine the ability of generation based on cases that rotational speed varies with changes in speed of wind and that means better contributions for flexibility. These simplified hybrid systems are provided and Simulations are done to confirm expectation outcomes of this—connection.

With increasing concern of global warming and the depletion of fossil fuel reserves, solutions to preserve the earth for the future generations are undertaken. Renewable energy sources such as solar energy and wind energy have been, inexhaustible, unlimited, and environmental friendly [2, 3].

However, all renewable energy sources have drawbacks. The one that is common to wind and solar sources is their dependence on unpredictable factors such as weather and climatic conditions. Alone, wind energy is capable of supplying large amounts of power but its presence is highly unpredictable as it can be here one moment and gone in another [4].

A system that brings together solar and wind sources of energy is called a hybrid system. By combining these two intermittent sources the system's power transfer efficiency and reliability can be improved significantly. When a source is unavailable or insufficient in meeting the load demands, the other energy source can compensate for the difference.

2 Morden Hybrid Systems

In the current economic climate domestic-sized solar energy systems are expensive. To develop enough energy to power a domestic residence, many panels are required, which accounts to a large amount of space. The wind power is intermittent in nature. And a stand-alone wind power system that supplies all demand is exceeded the storage capacity. This will increase the initial cost of the plant [].

The potential to address these issues lies in the use of a hybrid wind/solar system. A hybrid PV-wind system is expected to perform more reliably than a stand-alone wind system or solar system, when appropriately designed; however its overall performance strongly depends on the local resources.

For Hybrid Power Systems, areas without electricity supply from integrated networks but demand for electrification can be identified as potential markets. Large potential for rural electrification especially with renewable energy sources can be found in developing countries.

Hybrid solar-wind power generating system is suitable for industries and also domestic areas. The topic of hybrid solar wind energy system has been looked upon by many researchers all around the globe. The brief literature review helped for completion of this thesis is presented [5].

Solar-Wind Hybrid system can be used by any domestic user at a place where wind speeds are not predictable some of the loads may run through solar. It will charge the inverter battery even when there is no grid power. The switching action is provided from the microcontroller to the battery charging system based on the power received from solar photovoltaic panel and wind generators. It ensures the optimum utilization of resources and hence improves the efficiency as compared with their individual mode of generation. Also it increases the reliability and reduces the dependence on one single source.

A. *Hybrid Solar Wind System*

A stand-alone wind system with solar photovoltaic system is the best hybrid combination of all renewable energy systems and is suitable for most of the applications, taking care of seasonal changes. They also complement each other during lean periods, for example, during winter when the solar is dull, wind takes over. The hybrid solar wind power system is as shown in Fig. 1. With the use of renewable energy based system the emission of carbon and other harmful gases are reduced to approximately 80–90% in environments. Initial cost for solar-wind hybrid power system is high, but it produces electricity at least cost.

The Wind Energy Conversion System consists of a wind turbine coupled to a PMSG. The three-phase diode bridge is used to rectify the generated ac voltage which is then connected to boost converter. Similarly photovoltaic panel which generates dc voltage is connected with boost converter to step up the dc voltage [6, 7].

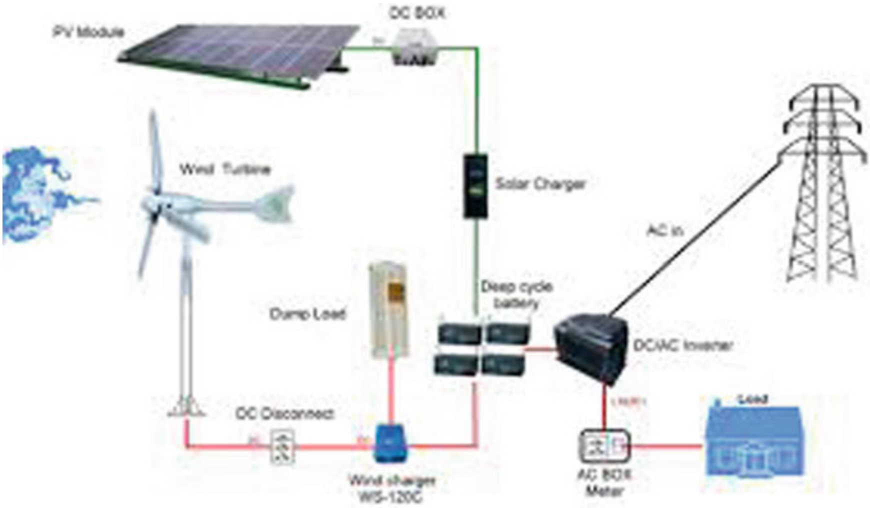
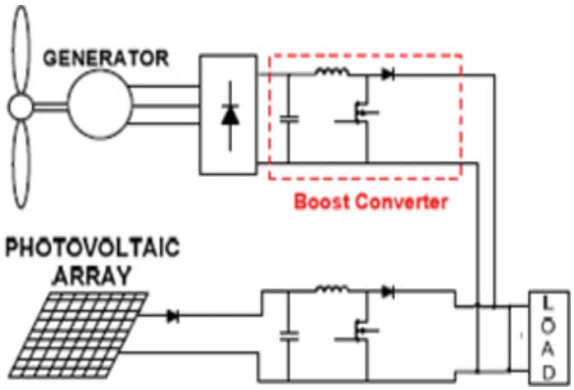


Fig. 1 Solar-wind hybrid power system

Fig. 2 Hybrid wind/PV system with multi-connected boost converter [2]



Fluctuating power is generated from solar and wind which varies voltage and frequency with variation in wind and solar radiation. The boost converter consisting of the inductor, the diode, and the switch will be current controlled to track the MPP and boost the voltage across the load resistor. Simulation is carried out using boost converter and MPPT techniques (Fig. 2) for power generation as shown in Fig. 3.

3 Modelling of Different Systems

B. *Modelling of Solar Energy System*

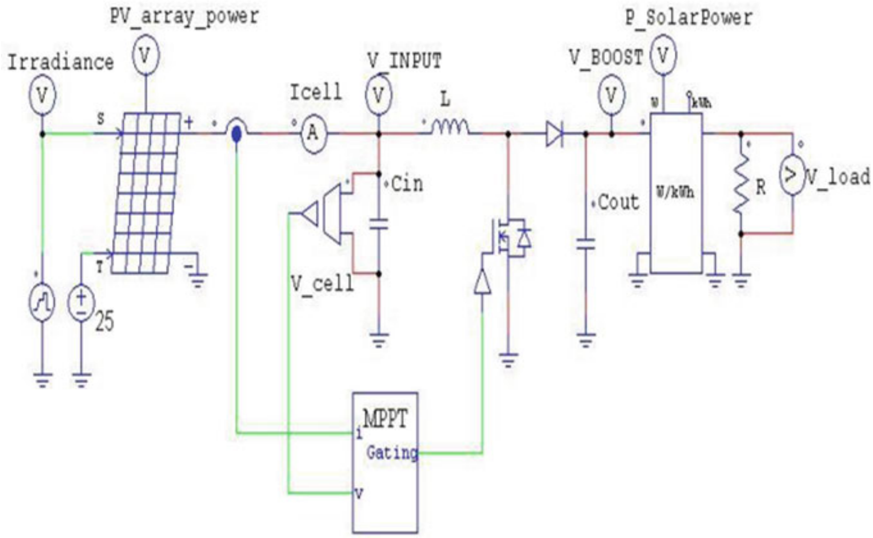


Fig. 3 Solar array with boost converter and P&O MPPT technique

Solar energy is a renewable energy resource which can be converted into the electrical power using PV cells. There are two factors-radiations and temperature which can affect the output of PV panels. If irradiance increases then current increases but variation in voltage is very less. If temperature increases, open circuit voltage decreases while if intensity of solar radiation increases, short circuit current increases. Thus I-V and P-V curve changes with change in temperature and irradiance, which also changes maximum power point. The power output from a solar photovoltaic system mainly depends on the nature of the connected load because of non-linear I-V characteristics. The schematic diagram of solar system to which MPPT technique will be applied is shown in Fig. 1. When PV panel is directly connected to the varying load its voltage keeps on fluctuating and thus voltage and current must be tracked continuously to achieve maximum power using MPPT technique. MPPT technique is used with boost converter to track maximum power and by extracting maximum power from the PV array using MPPT technique efficiency of the system can be increased.

III. Modeling of Wind Energy System

The maximum value of C p is 0.48 at $\beta = 0$ and $\lambda = 0.16$. So we cannot convert all the wind energy into electrical energy; we can only convert 48%, according to Betz limit. The schematic of the wind energy system to which the MPPT applied is shown in Fig. 4. Generator used is of permanent magnet synchronous generator type which is directly coupled to turbine due to its advantages like no need of gear box, small size, very less maintenance cost, no requirement of excitation current [8]. Instead of using three-phase controlled

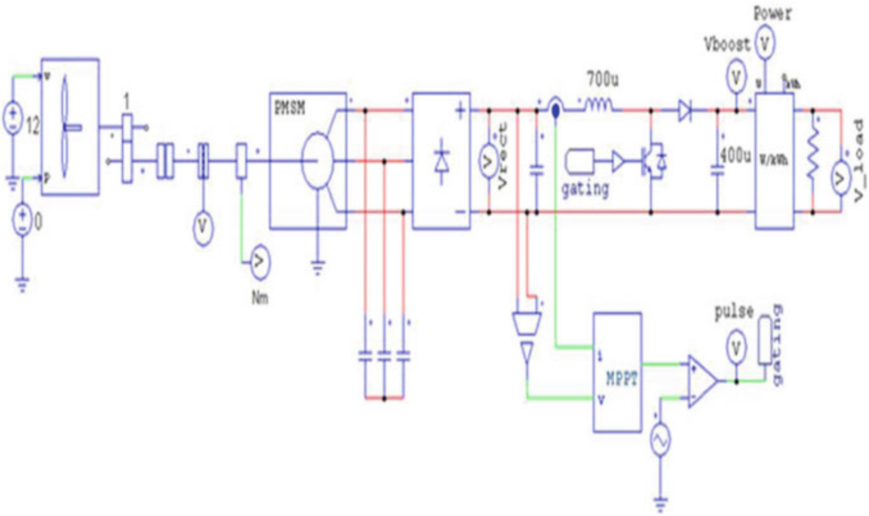


Fig. 4 Wind generator with MPPT technique

rectifier, diode bridge rectifier is used which converts the AC to a DC by rectifying voltage at constant level using boost converter.

IV. Hybrid Power System Installation

Solar Wind Hybrid Power System has been installed at many places. Out of which some are listed in Table 1. Some of them are installed and working while some power plants are under construction.

Table 1 List of Installation of solar wind hybrid energy system [9]

Location	*Project Capacity*	*Year of Installation*
Suzlon, Energy [Corporate Campus, Hadapsur, Pune]	155 kW Wind-solar hybrid system [4.75 kW Wind energy system and 55.89 kW Solar PV]	Installation complete and initial trials runs successful
Shree Jagadamba Devi Saravajanik Trust, Ahmednagar	10 kW Wind-solar system	2004 2007
Shree MartandDevSansthan, Pune	10 kW Wind solar system	2002 2005
Gujarat Energy Development Agency, Karai, Gandhinagar	10 kW Wind solar hybrid systems	2006
Reserve Bank of India, Pune	1.75 kW Wind solar hybrid system	2002
Dolat Capital Market pvt. Ltd, Mumbai	2 kW Hybrid system	2005

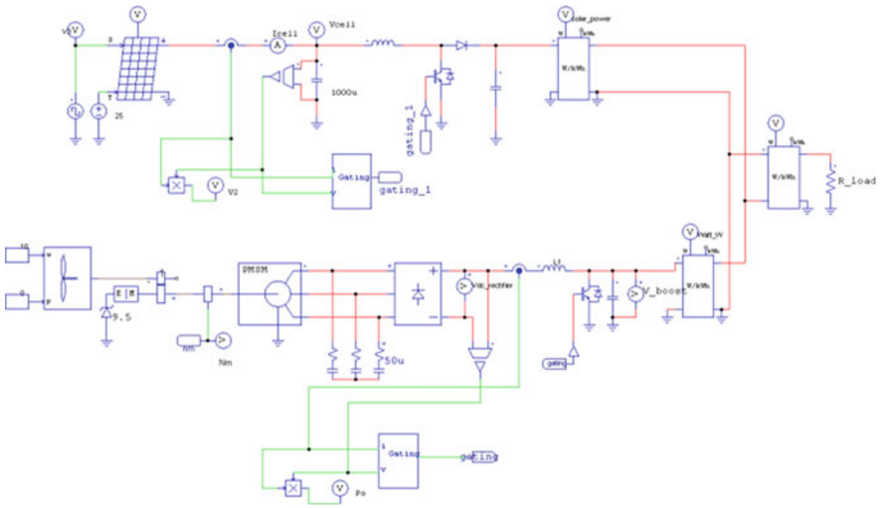


Fig. 5 Hybrid solar-wind system for battery charging application

E. Applications of Solar Wind Hybrid System

Applications of Solar-Wind Hybrid Power System are listed below [2]:

- Remote and rural village electrification.
- Ideal for cell phone recipient stations,
- Residential colonies and apartments for general lighting.
- Street lighting.
- Telecommunications.

F. *Hybrid Solar Wind Generation:*

The output from both these individual sources (which is DC after the rectification of wind generator output) is combined and it is used to drive DC loads. MPPT techniques are used to increase the efficiency of the system. Also by combining both the system, load of higher value can be used as energy generated by both the system when combined gets double (Fig. 5).

Here load value selected was 15 Ω. When solar energy system and Wind energy system were simulated individually, maximum load value obtained was 30 Ω. So by doubling load in hybrid energy system, i.e. decreasing resistance value by half obtained was 15 Ω.

4 Simulation Results

By combining solar energy system and wind energy system with MPPT techniques, results obtained are shown in Fig. 6 Both the systems are of different capacity. With load 15 Ω, power consumed is nearly 10.43 kW out of which wind energy system is

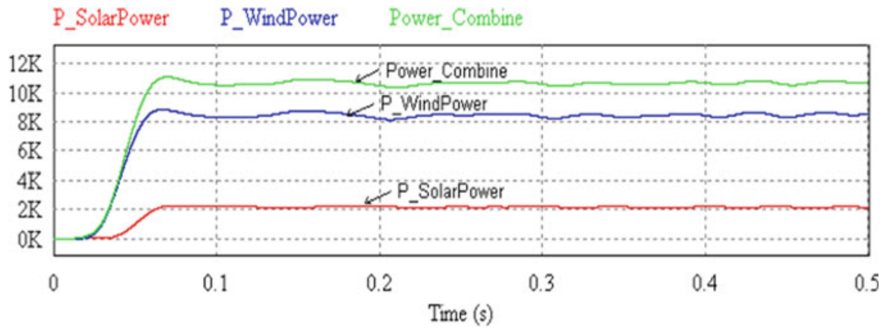


Fig. 6 Power in hybrid energy system with constant load 15 Ω

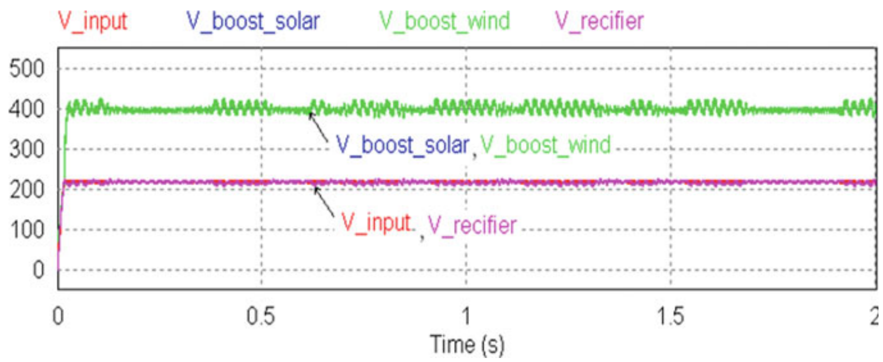


Fig. 7 Output of boost converter for hybrid system

generating 8.2 kW and Solar Energy System is generating 2.1 kW. Output of boost converter, when both sources are combined, is shown in Fig. 6. From input 210 V it is boosted to higher level of 400 V using boost converter (Fig. 7).

Conventional top-down and bottom-up models have inherent weaknesses which limited their usefulness to police-makers in energy and climate policy analysis. Accordingly, policy modelers have explored the development of a new generation of hybrid energy-environment economy models which contains both technological foundation of bottom-up models and the economic richness of top-down general equilibrium models. In this paper we have introduced a hybrid modeling approach for energy and climate policy analysis. It is a static, multi-sectoral, applied hybrid top-down/bottom-up CGE model formulated as a mixed complementarity problem designed to assess the effects of alternative energy and climate policies in a small open economy. The costs of these policies can be substantially reduced if an assessment is made of the most efficient policy instruments and technological options. Such impacts can be properly captured by using this type of modeling tool [10–14]. The practical suitability of the model is illustrated by an empirical application for the Portuguese economy to evaluate the economic and environmental effects of the current feed-in tariffs (FITs) policy to promote electricity from renewable energy sources. This is a significant contribution of this study which is, to our knowledge, the first attempt in the Portuguese empirical literature. Results from our simulation show that the promotion of RES electricity through the feed-in tariffs instrument requires relatively modest adjustment economic costs. From an environmental perspective, the increase of the share of RES-E in overall electricity production with carbon-free power generation technologies replacing partly high-carbon fossil fuels technologies represents environmental benefits with emphasis on CO2 emissions reduction.

5 Conclusion

Energy challenges of today include increasing energy dependency, growing energy consumption, ensuring security of energy supply, reaching for sustainable development and tackling environmental concerns, most importantly climate change. Bangladesh is one of the low energy consuming countries of the world. Still the national grid can so far cover 49% of the total population. Renewable energy sources offer considerable opportunities to respond to growing energy crisis and have multiple advantages over conventional energy sources. In Bangladesh most of the electricity generation is by non-renewable energy sources like furnace oil, natural gas etc. But the reserves for these non-renewable sources are limited and will be exhausted soon. Therefore, searching alternative sources is the only option to solve the problem of electricity shortage. In order to meet sustained load demands during varying natural conditions, different renewable energy sources need to be integrated with each other like solar, wind, ocean, geothermal, biomass, wave energy, fuel cell technologies and hydro. Biogas technology combined with solar technology can have a huge positive impact on the present power sector of Bangladesh. This paper will discuss on design of a cost-effective biogas-solar hybrid power generation system and also feasibility analysis of that system considering different types of sensitivity and environmental aspects.

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Global Product in Local Need—Impact of Environment Over Smart Grid IED/Electronic Equipment

Deepak Kumar Agrawal and Mani Bhushan Prasad

Abstract Intelligent electronic devices (IEDs)/Relays are considered as brain of any electrical networks or power system and its healthiness ensure protection of electrical equipment's. Pre-mature failure of IEDs in Delhi's polluted environment leading to disruption of major chunk of healthy network along with faulty section. Need for global IEDs in local condition is recognized after environmental gaseous analysis and corrosion study. Also, regulator is being pursued for review of IED's life assessment. We would like to share our experience gained through the whole journey.

Keywords IED · SAIDI · SAIFI · AT&C

1 Introduction

Tata Power-DDL is witnessing a critical issue with respect to frequent IED/relay failure due to which protection and automation system is getting bypassed and safety of equipment also compromised. This problem aggravated in last 3–4 years due to which it has become major challenge for us to ensure protection all feeder/electrical equipment by 24*7.

Main purpose of the Efficient and healthy IEDs facilitates optimum utilization of these large number of IED's network which has improved the Operational Efficiencies in Distribution Grid with better SAIDI and SAIFI reliability indices and reduction in AT&C losses. About 35% of total tripping's on account of protection occurred due to relay failure during FY 2017-18. Moreover, healthy IED's ensures safety of all electrical equipment's with living being's safety. Being custodian of IEDs, all facets of IED's failure is conducted which we would discussed.

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2 Methodology Adopted

2.1 Root Cause Analysis of IED's Failure

We have done detail analysis at our end w.r.t type of electronic card failure, location of IED installed, useful life a relay already lived etc. and taken up with OEM's for root cause identification. They have carried detailed analysis on the failed relay at *their* laboratory and submitted failure analysis report which stated that Delhi's environment at few of the location is harsh in nature which is impacting relay useful life and leading premature failure of its PCB. Also, OEM's elaborated the testing procedures with standards they follows on PCB (printed circuit board) cards at factory.

Environmental testing standard followed by all OEMs are as follows.

1. IEC 60068-2-60: Environment Testing: Flowing mixed gas corrosion test
2. ISA 71.04: Environment Conditions for Process measurement and Control System: Airborne Contaminants

2.2 Conducting Environment Study

As per OEM's findings and rising pollution in Delhi, we at TPPDL also conducted a study on environmental gas analysis and corrosion analysis in 2019 with third party at 5 different critical locations under our licensee area.

The objectives of the study were as under:

- To find the rate of corrosion in the indoor environment by using different types of Corrosion coupons (Copper, Silver and Brass).
- To analyze the indoor air quality of the Power Sub-Stns.

The gas analysis carried out after studying all factory testing procedures and main gaseous components to be focused upon like Sulfur dioxide, Nitrogen Dioxide, Hydrogen Sulfide, chlorine, Formaldehyde, Carbon dioxide, Carbon mono oxide, Particulate matter and Volatile Organic Compounds. Gaseous components collected on weekly basis in different times as shown in Fig. 1.

Apart from harmful gases present in Delhi's environment, corrosion of several metallic strips also considered which is kept for 30 days to analyze level of weight loss on those metallic standard specimens (in Fig. 2) by using ISO 118544:2.

Following Procedure adopted for conducting environment study:

- The indoor air quality of the grid/Sub-stations was also analysed at interval of one week for one month.
- Three specimens (Copper, Brass and Silver) were placed at five selected area and analysis of corrosion was carried out for minimum one month by determining the degree of change in the mass of the metal strips.

Fig. 1 Gas analysis kit

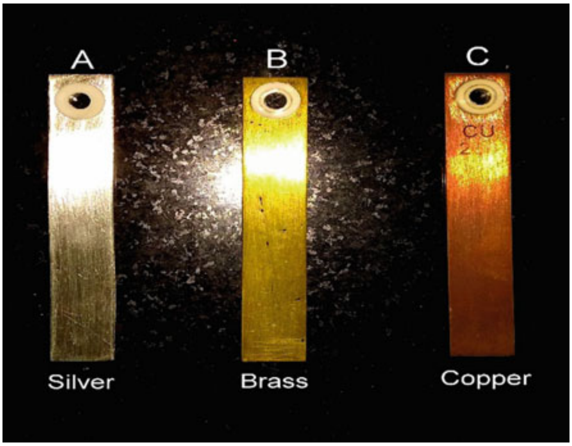

Fig. 2 Corrosion coupon (Silver, Brass, Copper)

- The indoor gaseous contents taken 4 samples for each site and compared with values mentioned in IEC 60068-2-60:2015, Test method-4.
- For conducting corrosive study ISO 11844-2:2006 is followed which specifies methods for determination of corrosion rate with standard specimens of metals in indoor atmospheres with low corrosivity.
- The values obtained from the measurements are used as classification criteria for the determination of indoor atmospheric corrosivity.

During study, few challenges faced like no prior reference of such study, methodologies to be adopted while carrying out study, strategic location selection, applicable standards and many more.

3 Results of Environmental Studies and Impact

After carrying out the analysis by OEMs and our internal study, it was emerged that few gases like SO2 and NO2 available were available in the environment beyond permissible limit defined in the relevant standard at some of the grid location causing damage to the PCB failure of relays.

Corrosion report analysis has shown that the corrosiveness of indoor atmosphere of all five Grids cross the corrosively category IC5 (Very High). Silver, Brass and Copper corrosion result is hundreds folds more than the prescribed limits. Such level of high corrosiveness may have potential to impact PCB cards of IEDs which can lead to pre-mature failure of IEDs. These locations also have to meet the cleanliness level of ISO 14644-1: 1999 Class 8, in which the minimum metals corrosion occurs and filters shall be used to make indoor air clean.

4 Conclusions and Way Forward

Moving ahead, there is more clarity on our requirement keeping in view of poor environment condition which shall enable us to frame our product specification and simultaneously recommendation is being made to all OEMs to design their product as per the Delhi environment.

Considering harsh environment prevailing in Delhi, action plans taken up for future IEDs are.

1. Designing our product in local need i.e. revision of specification as per environmental condition so that IEDs may sustain for longer period and avoid premature failure. Conformal coatings has been made mandatory for all kind of IEDs. Further deliberations are on with OEM's with respect to environmental studies and to design products as per prevailing environment.
2. Policy advocacy with our regulator to consider IED under IT asset category (useful life 8 years) in place of keeping the same at par with switchgear equipment. All kind of IEDs with PCB cards needs to be covered under revised useful life. Relevant representation is made with regulator.

This paper explicitly describe about the methodologies, challenges and aligning standards during our gaseous analysis and corrosion study and also the need of re-designed product with respect to present scenarios.

On this platform, we would also like to request our manufacturer and honorable regulator to come out with useful life of relays in line with prevailing environmental condition to maintain the reliability of protection and automation system with optimum utilization of OPEX allocated to utilities.

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A System Design Using IoT, IEC61508, IEC61850, and IEEE C37.X to Improve Reliability of Smart Grid

Moreshwar Salpekar

Abstract This paper presents a system design and protocol are presented in this paper for improving the reliability of the Smart Grid using IEC 61850, IEC C37.x, and IEC 61508-x protocols. It starts with a brief introduction of IEC 61850, IEC C37.x, and IEC 61508-x. Then, it gives the block diagram of the proposed system and the proposed protocol. The design incorporates redundancy to recover faster from failure. The protocol allows the transmission of data, alerts, or a combination of data and alerts over the network. It also allows substation or master station to explicitly request data from a sensor or any subsystem in the hierarchy. It defines time synchronization protocol across the system to help detect duplicate packets. It also adds a layer of authentication and optional encryption of data from the field. The paper concludes with the constraints of the proposed system and protocol and the scope for future work.

Keywords Smart grid · Reliability · Redundancy · Protocol · Monitoring · Time synchronization

1 Introduction

A Smart Grid is an electricity network that integrates the actions of all users connected to it to efficiently deliver a sustainable, economic, and secure supply of electricity. It performs monitoring and control of generation and supply of electricity using communication and feedback. This allows it to optimize the operation of the system and provide the consumers with more information.

There are multiple standards to govern the operation of the smart grid. The paper discusses only a few of them as the list is long.

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2 The Relevant Standards

IEC has developed the core standards for the Smart Grid. The main standards in the context of the paper are:

- IEC 61850 is a multipart international standard under the general title Communication networks and systems for power utility automation [1]. It defines the communication between substations and the communication between field equipment and substations. It aids the possibility to build Power Utility Automation Systems (PUAS).
- IEC 61508 is a multipart standard for functional safety of electrical/electronic/programmable electronic safety-related systems. It aims to [2]:

  a. provide a technically sound, system-based approach, with sufficient flexibility for the future.
  b. provide a risk-based approach for determining the required performance of safety-related systems.

The relevant **IEEE** standards are:

IEEE Std 1588-2019 (the 2008 version is the same as IEEE/IEC 61588 Ed.2) defines a protocol that provides precise synchronization of clocks in packet-based networked systems. The Precision Time Protocol (PTP) generates a master-slave relationship among the PTP Instances in the system. The clocks in all PTP Instances ultimately derive their time from a clock known as the "Grandmaster Clock" [3].

The IEEE C37 series of standards (except C37.1) apply to individual devices, e.g., switchgear used in relay devices for the electric system. They specify the design requirements of the devices covered under the series [4].

IEEE C37.1 applies to systems used for monitoring, switching, and controlling electric apparatus in unattended or attended stations, generating stations, and power utilization and conversion facilities. It does not apply to equipment designed for the automatic protection of power system apparatus or switching of communication circuits [4].

There are other important standards for the smart grid are IEC 61968 [5], IEC 61970 [6], IEC 62351 [7], and IEC 62056 [8] from IEC.

The IEEE standards include IEEE 1815 [9] and IEEE 1815.1 [10].

The prominent **IoT** standards include IEEE Std 2413, ITU Y 4000 series.

ETSI develops and maintains the standards for the radio layer in 3GPP (LTE-M, NB-IoT, and EC-GSM-IoT), and at service layer in oneM2M [11].

3 Improving the Reliability of the Smart Grid

The above standards specify the design of the generation and the transmission system and the communication mechanism. They also help to increase the reliability of the smart grids, e.g., the C37.x set of standards specifies the design of the electric, electrical and electronic components for the smart grid.

3.1 The System Design

3.1.1 Consideration as Components

Each of the system constituents is either a component or is decomposable into components, e.g., Remote Terminal Units (RTUs), Sensors, etc. Each component performs a pre-defined task. Its design is based on functional safety as defined in IEC 61508. Each component has a Safety Integrity Level (SIL) is assigned to it as per IEC 61508 parts 2, 3, and 7 [12–14]. It is used in the system only after it passes the tests for the assigned SIL.

The proposed design assigns a pre-assigned identifier to each component in the system. The identifier.

a. identifies device type.
b. identifies device capability.
c. has a unique number that differentiates it from other devices.

3.1.2 The Top Level Design

For this paper, the top-level electricity system is composed of:

- Primary Generation System (PGS) that generates electricity.
- Transmission paths consisting of wiring.
- Distribution and Rerouting Substations (DRS). Each DRS is connected to one Monitoring Station.
- Monitoring Substations (MS) that monitor and control the state of the system under each of them.
- Advanced Metering Infrastructure for feedback from the consumer end.
- IoT based sensors for measuring data such as current, voltage, temperature, and humidity.

The generation system and the distribution paths have lightning arresters and air-break switches to prevent damage.

The following ensure generation and transmission redundancy:

1. Redundant Generation system (RGS) that can take over the generation in case the PGS fails. It may be a large battery array that stores surplus power that the PGS generates. Alternatively, it may be a full-fledged electricity generating system.

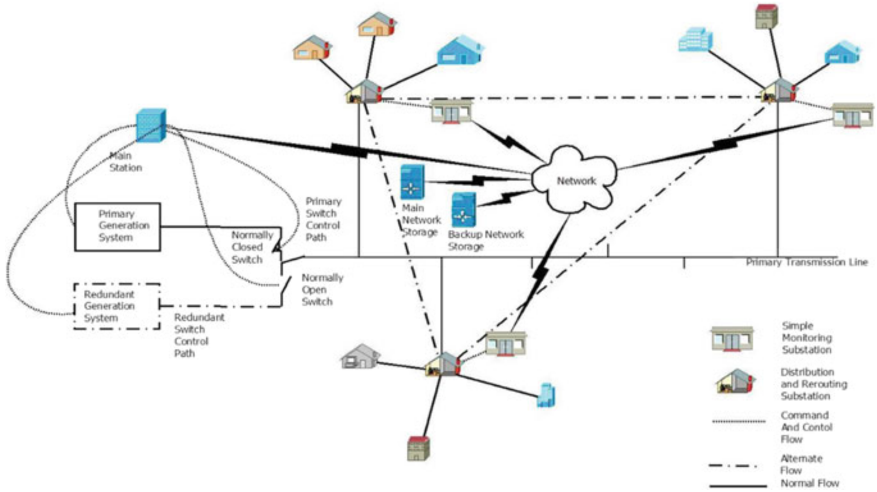

Fig. 1 Proposed electricity network

2. Alternate transmission paths for re-routing the transmission in case the primary transmission path fails. The DRS control the transmission paths, and in turn, MS monitors them.

Figure 1 gives the simplified top-level system that shows only a few DRS and MS for brevity.

3.1.3 Monitoring Station Design

The monitoring stations have:

1. A Local Network Server responsible for the local network. It does not connect to an external network.
2. A Data Reception and Sending System (DRSS) that receives the messages from RTUs and IoT sensors. It decrypts the incoming messages and forwards the data to AS. It is also responsible for sending the local data and status, from the AS, up the hierarchy. It also sends commands to sensors and other stations.
3. An Analysis Subsystem (AS) consisting of

   a. A Data Analysis Subsystem (DASS) that analyses the data and sends a list of actions to the action subsystem. It also sends the status to the DMT.
   b. An Action subsystem that acts on the action list.

4. A Database Server that stores the data received from the AS. The stored data consists of the input data, analysis, and the action taken if any.
5. A Display Map Terminal (DMT) that displays data and the status on the console.

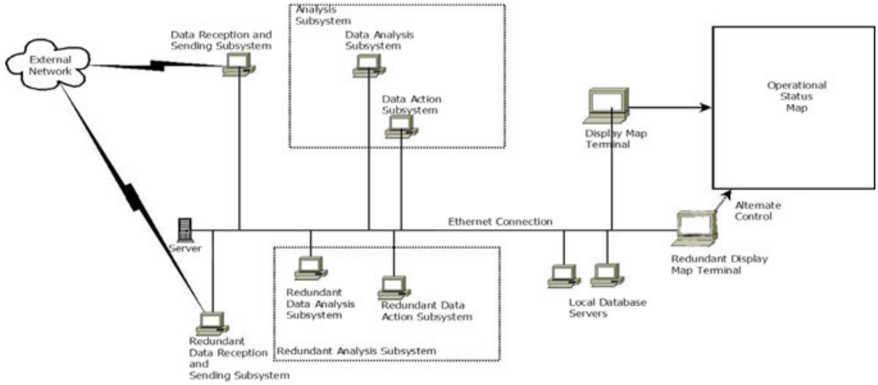

Fig. 2 Proposed monitoring station

6. An Operational Status Map (OSM) that displays the status map of the network under its control.

The MS sends all rerouting requests to the connected DRS because only DRS can reroute the supply.

The simplified network diagram of the MS is given in Fig. 2. This diagram is based on IEEE C37.1 [4].

Each of the MS components has a redundant backup in the hot-standby configuration. All of them connect via a local ethernet connection. This ensures redundancy at the monitoring substation.

The Real-Time Measurement: IoT Sensors and RTUs in Smart Grid Network.

The transmission towers and wires (including wiring inside the stations) have sensors to measure transmission, distribution, and generation parameters. These sensors help in preventing and detecting faults. The sensors use Wi-Fi networks such LoRAWAN or Sigfox for communication with the DRSS of the monitoring station.

The RTU sends the data to the DRSS of the station in the context of this paper.

3.1.4 Communications

The components communicate with each other using messages. Each component in the system at level N can communicate with the master at level N−1 and subcomponent at level N + 1. The sensors have no sub-components, and the master station has no components at level N−1. The RTUs may have more than one sensor.

The Message Packets

Each message sent in the system has the following format:

a. **Sender Identifier**: A pre-defined identifier that identifies the originator of the message.

b. **Message Type**: it may be a key message, request for information, information, warning, alert, or fault.
c. **Data**: this paper does not specify data format except that the recipient must be able to understand the data. The data may consist of keys to be applied, sensor reading, meter reading, RTU data (all to substation), or substation data (to the higher-level station). Each message contains only one type of data. It may comply with IEC 61850, IEC C37.1, or even IEEE 1815.
d. **Timestamp**: time of message formation
e. CRC: CRC of data and timestamp

3.2 The Working

3.2.1 Normal Working of the System

The following steps give the normal operation of the system:

1. The smart meters, RTUs, and IoT sensors send the electricity measurements to the connected MS at regular intervals of time as encrypted messages that contain a timestamp.
2. The DRSS decrypts the messages and sends the data to the AS.
3. The AS analyzes the received data and forwards it to the database for logging.
4. The AS sends analysis status messages to the DMT for display.
5. The analysis and status are sent to level N–1.

The MS may also request RTU or sensor for information. Any request originating from layers other than the local MS must pass through the layers in the hierarchy.

3.2.2 Fault Prevention

Fault prevention relies on detecting conditions that may lead to fault. For example, a steep rise in current reading may be due to faulty wires, or it may be due to electrical breakdown. The AS sends a warning to the DMT when it detects conditions that may lead to a fault. It sends the analysis result up the hierarchy via the DRSS.

3.2.3 Fault Detection

The local MS performs the Fault detection. The following steps happen in this case:

1. The IoT sensor or RTU detects a faulty condition and sends a message to the connected MS.

2. The AS may also detect anomalous data and flag it as a fault after reconfirming it through successive readings.
3. The AS logs the fault in the database and sends an alert to the DMT.
4. The AS waits for a timeout or end-user action whichever earlier.
5. The AS takes the Fault Isolation action immediately upon timeout expiry.
6. If an end-user acknowledges the alert, the AS lets the end-user act. The result of the action is updated on the DSM.

3.2.4 Fault Isolation

The AS performs the fault isolation action if it detects a timeout (automated isolation action). The end-user may also perform the fault isolation (manual fault isolation) action. The actor (AS or user) at the MS performs the following steps:

1. Switch off the faulty line and inform the source.
2. Switch on the alternate path after negotiating with the DRS for the new path, if possible, with the station at layer N in the loop.
3. The AS sends an alert to the DMT showing the updated status and new path.
4. The AS logs the action into the database server.
5. The AS sends a message to the higher-level station in the hierarchy with the substation identifier.
6. The higher-level station receives a message from its substation, and it displays the faulty substation or the line in red color.

If the fault is between the substation and a specific end-user (or group of users), the AS cuts the supply to the affected part and sends an alert to the DMT.

The generation MS cuts off the faulty generation system and switches on the power from the RGS in case of generation fault. In case it unable to switch on the RGS, it requests the higher-level station for.

a new electricity supply source. The higher-level station connects the nearest source to the affected region.

3.2.5 Message and System Security

Message correctness and authenticity are must for accurate analysis and action. The system uses Authenticated Encryption to ensure Message security. Advanced Encryption Standard (AES-128) [15] is used in CTR mode [16] for encryption and decryption of the data. Galois Counter Mode (GCM) [17] is used in data authentication.

All the modules used in the proposed system comply with FIPS-140-3[18]. The sensors use hermetic sealing to prevent tampering.

3.2.6 Key Management

Level N generates the key used at level N+1 using configuration messages. The master station generates and manages its keys. Level N changes the keys of Level N−1 at random intervals to discourage eavesdropping.

As a security measure, the new key is encrypted and authenticated using an existing key. Level N marks the key setting operation, for a given device A, at level N +1 as successful only after receiving an acknowledgment from device A. The acknowledgment message is encrypted and authenticated with the new key.

3.2.7 Time Synchronization

Each RTU and sensor sends data stamped with its local time. The timestamp must be accurate to allow correct logging and actions. Further, if the substation or the master station receives the same data at different times, it might interpret it correctly. A hacker may also send duplicate packets to fake errors or repeat the data to confuse the AS. Timestamping avoids this scenario when used with encryption and authentication. However, the correct functioning of the system requires all the components in the system to be synchronized. The system can synchronize time using either of two options:

a. IEEE 1518 based time synchronization: each component has access to the "Grandmaster clock", such as the GPS, and synchronizes with it using the PTP.
b. Protocol proposed below: This avoids lack of access to the signals, such as GPS, in certain areas.

The proposed protocol for time synchronization involves the following steps:

1. The station at level N−1 sends a packet with its time to all substations at level N.
2. The substation at level N adjusts its clock to the received time.
3. The lowest level substation sends its time to sensors and RTUs.

The level N−1 sends time packets using authenticated encryption and the time synchronization is random to protect against eavesdropping. All packets sent after time update message (allowing for a lag in applying time) must have an updated timestamp corresponding to the new time.

4 The Design Constraints

The design given above has the following constraints:

1. The system uses only those components that pass the functional safety tests. However, the system may not be able to detect and handle all functional failures that are not considered in functional safety design.

2. Redundancy improves the grid reliability, but the primary and redundant components may not be synchronized always. Further, there is a risk that both primary and redundant components fail simultaneously.
3. An incorrect timestamp will result in AS processing stale data or ignoring it as it is out of the acceptable range.
4. The message protection rests on authentication and encryption, therefore, it is necessary to protect the keys. The key changing time must be random for increasing the difficulty in predicting the next key change.

5 Conclusion and Further Research

The Electrical Grid should function reliably always. Functional safety is the starting point for reliability. IoT sensors can be placed on transmission towers and lines for more accurate measurement of operational parameters. The use of functionally safe components in real-time data measurement and analysis enhances the system's reliability further. The presence of redundant components in hot standby configuration aids in the system recovery. The system can continue to operate even in case of failure of some components.

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Know Your Electricity Consumption

Devanjan Dey, Suchit Yeragi, Ruman Maknojia, and Laxmi Patel

Abstract Generally, consumers get to know their electricity consumption & Bill amount only at the end of the month on receipt of bill. Consumption patterns of a consumer can fluctuate widely without explicit knowledge of the consumer. Monthly Electricity Bill can be much more than the consumer's expectations due to higher consumption, consumption crossing over to the next higher tariff slab for residential consumers or penalty imposed on Commercial & Industrial consumers due to poor pf, billing Demand exceeding Contract demand, etc. KYEC is a unique, digital, value added service provided to our consumers through which they get information about their Electricity consumption on daily basis. The in-house developed mobile based software has been enriched based on consumer inputs. The residential consumers can set monthly budget towards bill & monitor/ control their consumption, get slab change alert, consumption alert during non-occupancy, etc. Commercial and Industrial consumers can also receive alert whenever their PF falls below a set value or maximum demand crosses a set value .This service is currently provided to around 23000 consumers who are covered under Automatic Meter Reading system. This "On the Go" service, helps consumer know, monitor & manage consumption, Demand, power factor & eventually earn incentives/reduce penalties. TATA Power Consumers saved Rs.120 million annually under this Value Added Service.

KYEC is a pioneering & unique service in Indian Power Sector. This service is highly appreciated by our consumers. It has also helped in improving consumer's

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consciousness to reduce power consumption and thereby contribute towards energy conservation.

In Mumbai with parallel licensees, Value Added services (VAS) to our Consumers is the key differentiator in service standard. Know Your Electricity Consumption (KYEC) is one such VAS which is offered to Industrial, Commercial and Residential consumers who are covered under Automatic Meter Reading (AMR) system. Presently, the KYEC is enjoyed by all high end Commercial, Industrial and 17,000 residential consumers amounting to 75% of our annual sales. This “On the Go” service, helps consumer know, monitor and manage consumption, demand and power factor and eventually earn incentives/reduce penalties. The residential consumers can set monthly budget towards bill and monitor, control their consumption. TATA Power Consumers saved Rs.120 million annually under this VAS till date.

We have started this Value added services- “Know your electricity consumption” for our customers who are covered under AMR. Through this service customers are informed about their hourly, daily and monthly consumption pattern through sms and e-mail. All information is available in graphical and tabular form.

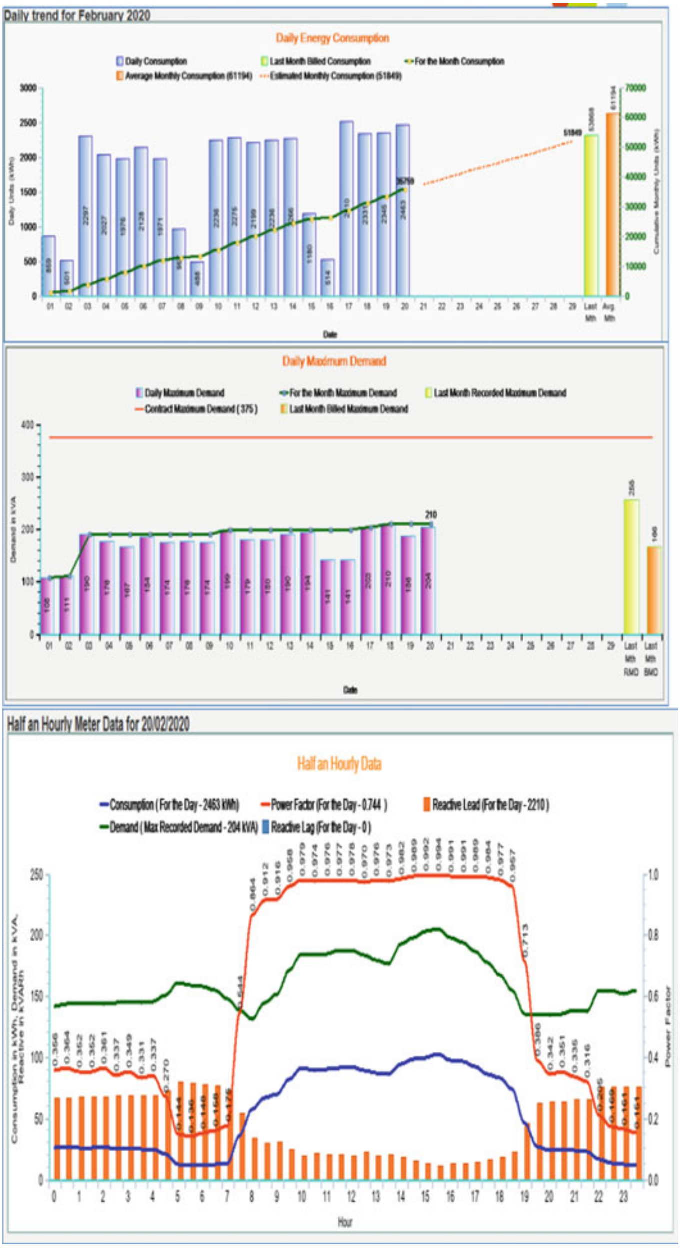
1 KYEC for Commercial and Industrial Consumers

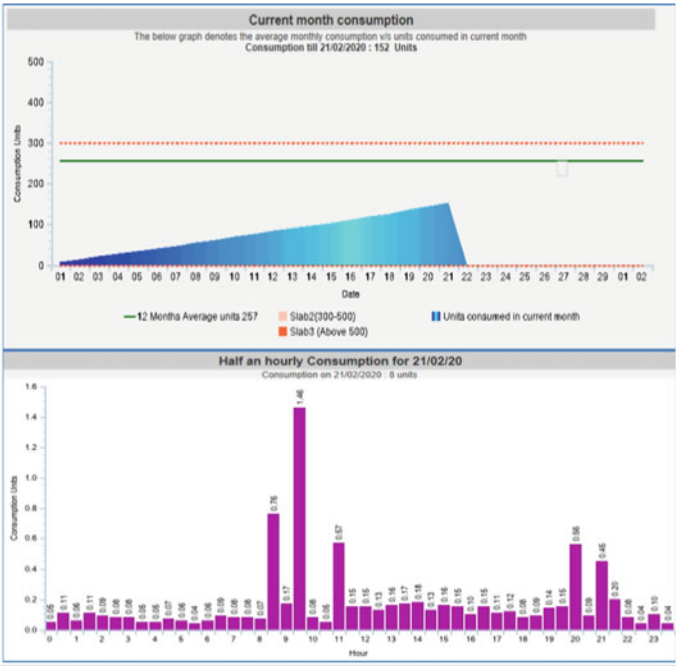
Features available for Commercial and Industrial Consumers:

- (TOD) wise and total consumption for the day and month
- TOD-wise demand values for the day and month
- Power factor for the day and month
- Load factor for the day and month
- Interval-wise consumption details for previous day
- Daily consumption pattern till previous day
- Till date unbilled consumption
- Predicted consumption for current month as against previous month consumption and average monthly consumption
- Daily maximum demand for current month
- Daily PF and for the month PF (lag + lead) against last month PF
- Daily reactive energy consumption (lag & lead)

Additional features and configurable alerts for Commercial and Industrial Consumers:

- Downloading facility for Load profile values
- Alert in case of Demand Crossing set Value
- Alert in case of Power factor Falling below set Value


Daily trend for February 2020
Daily Energy Consumption
Daily Consumption
Last Month Billed Consumption
For the Month Consumption
Average Monthly Consumption (61194)
Estimated Monthly Consumption (51849)
Daily Maximum Demand
Daily Maximum Demand
For the Month Maximum Demand
Last Month Recorded Maximum Demand
Contract Maximum Demand (375)
Last Month Billed Maximum Demand
Half an Hourly Meter Data for 20/02/2020
Half an Hourly Data
Consumption (For the Day - 2463 kWh)
Power Factor (For the Day - 0.744)
Reactive Lead (For the Day - 2210)
Demand (Max Recorded Demand - 204 kVA)
Reactive Lag (For the Day - 0)
Hour



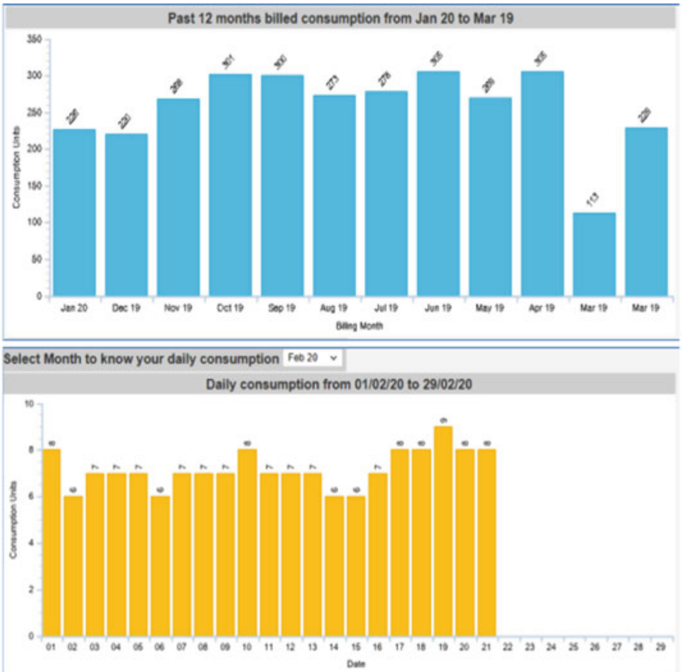
2 KYEC for Residential Customer

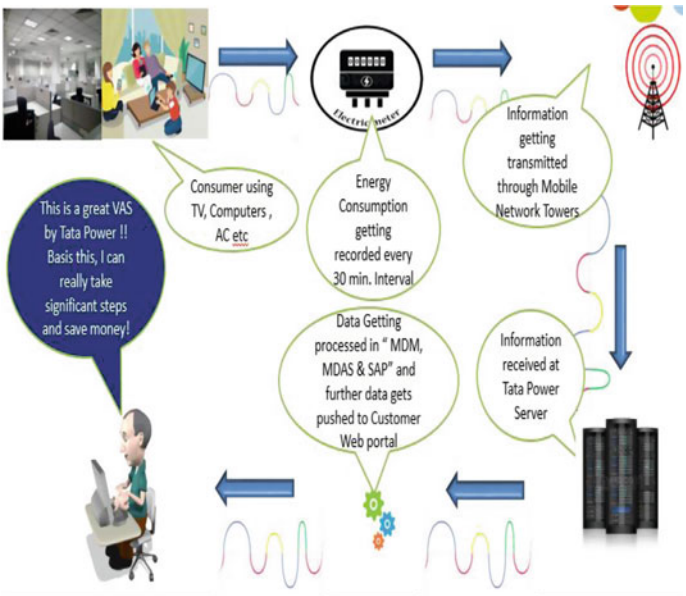
Features available for residential customer:

- Current month unbilled consumption against twelve month average consumption
- Hourly consumption for any selected day
- Day-wise consumption for any selected month

Configurable alerts for residential consumers:

- Alert for usage during non-occupancy
- Alert for slab change (for residential customer)
- Alerts for Exceeding set Budget for the Month


Past 12 months billed consumption from Jan 20 to Mar 19
Consumption Units
350
300
250
200
150
100
50
0
Jan 20
Dec 19
Nov 19
Oct 19
Sep 19
Aug 19
Jul 19
Jun 19
May 19
Apr 19
Mar 19
Mar 19
Billing Month
Select Month to know your daily consumption
Feb 20
Daily consumption from 01/02/20 to 29/02/20
Consumption Units
10
8
6
4
2
0
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Date


Electric meter
Information getting transmitted through Mobile Network Towers
This is a great VAS by Tata Power !! Basis this, I can really take significant steps and save money!
Consumer using TV, Computers, AC etc
Energy Consumption getting recorded every 30 min. Interval
Data Getting processed in " MDM, MDAS & SAP" and further data gets pushed to Customer Web portal
Information received at Tata Power Server

3 What's Unique in KYEC

Generally, consumers get to know their electricity consumption and bill amount only at the end of the month, on receipt of electricity bill. Consumption patterns of a consumer can fluctuate widely without explicit knowledge of the consumer. One can get a tariff shock at the end of the month; in case higher slab is crossed just by few units. KYEC empowers the consumer to monitor, analyse, check trend and manage consumption on daily basis. The in-house developed mobile based software has features like slab change alert, monthly budget setting facility, alert during non-occupancy etc. The product is a perfect fit in the Company's campaign; "Less is more". KYEC is a pioneering and unique service in Indian Power Sector. KYEC service has evolved with the addition of new features and alerts based on inputs from the consumers. Involvement and engagement of the consumers for continuous improvement of KYEC indicates that it has been beneficial to the consumers.

4 How Does KYEC Work

We have, so far covered around 23,000 consumers under AMR. Meter readings and load survey data for these consumers are getting updated in Meter Data Management System (MDMS) on daily basis. This data is pushed into SAP, which is our billing software. In SAP, we have developed various programs to process this meter data and convert it into valuable information and send to consumers on e-mail and SMS as KYEC.

5 Key Challenges Faced

Following are the Key challenges faced by us in extending this service to consumers:

- Non uniform data structure for different types of Existing meters installed at site.
- Modems were initially not programmed to send half hourly consumption data on daily basis.
- Low GPRS signal strength at site resulting into modem communication issues.

To overcome these challenges, following measures were taken:

- Proper data mapping was carried out to tackle non-uniform data structures.
- All the modems were re-programmed to send data on daily basis.
- Normal antennae were replaced by high gain antennae to overcome low signal strength issues.

6 Benefit to Company

We are using KYEC as a VAS to retain customers. This VAS helps the consumer to get an early insight on poor power factor so that corrective actions can be taken. The half hourly consumption data is used for improving accuracy of Load forecasting. KYEC has enabled us to extract Smart meter like functionality from existing meters without any capital expenditure. HT & LT 2 part consumers have lauded the offering and have been taking corrective actions to ensure economic benefits to their organizations. KYEC has resulted in enhanced customer satisfaction.

7 Benefit to Consumers

Generally consumers only come to know about their electricity consumption after getting their monthly electricity bill. Before implementing KYEC facility, they did not have any option to monitor and control their consumption. This is the first of its kind service in India whereby we share daily electricity consumption trend to Commercial, Industrial and Residential consumers. Hourly and Daily trends of key Electrical parameters like kWh, kVA, KVArh, Power Factor can be monitored through KYEC. KYEC help the consumer in better planning and energy bill savings. KVArh trend monitoring helps the consumer to maintain healthy Power Factor to avoid Penalty and gain Incentive. It is seen that commercial and industrial consumers got benefitted to the tune of Rs 120 million in a year by improving their power factor after using this facility. Besides above mentioned benefits customer are also getting huge benefits from some new features of KYEC e.g. low PF alert and high demand alert which are launched recently. Residential consumers are getting benefited from slab change alert, alert for consumption during period of non-occupancy and alert for exceeding set monthly budget.

Self Submission of Meter Readings(MR)

Rohit Shukla, Ankamma Marpu, and Ajay Gulati

Abstract During the crisis of COVID-19, meter-reading services are suspended and all NON AMR consumers are Getting billed on estimation. Thus, a new option of self submission of meter reading(MR) is required that does not require registration and no boundation is imposed on the consumer. Consumers can self-submission reading in simple way and get their bills prepared on actual basis. Thus consumer grievances is reduced recovery of dues gets facilitated. We have implemented 3 different services to consumer to submit their Meter reading. Self-MR submission through SMS, Website and Mobile App.

Keywords Automatic Meter Reading · Meter reading · Short message service · Application

1 Self Meter Reading Submission Introduction

Around 60% of electrical energy consumption in India is from non-Industrial sectors like Residential, Agricultural and commercial. There are robust systems in place for industries to monitor and optimize their energy consumption. But in case of residential and commercial sectors, these systems are not well placed due to n number of reasons like lack of awareness, lack of infrastructure etcetera. But there exists a lot of potential to save energy in these sectors by employing techniques as simple as just analysing their energy bill and optimising their consumption without compromising the comfort. At this juncture, we found a simple mobile application called Bharat Self Meter Reading which was found little interesting as they are trying to empower consumers.

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In Utility sector Billing consumer is vital part in terms of revenue and Service providing. This Process is implemented in three various categories SMS(Short message service),Website, Mobile App. Where consumer can submit his/her Meter reading using any of above said options. We have given this Provision to specific consumers and for a specific time duration in every month. The process is limited to single phase consumers only, wherein only one reading (KWH) is required for billing. After consumer submitting their Reading, End-user will verify the same in actual system, whether it is correct or not. If MR is correct then only NPCL user, consider the same and proceed further. There is some validations before submitting the meter reading like Consumer is valid or not and is part of eligible consumer list or not.

2 Process to Submit Self MR

2.1 Self MR Submission Through Mobile App

We have Developed NPCL Mobile App. Where consumer can down load the same from Play store. After the App. Installation consumer has to complete the Log in formalities by Click on Sign in Option from Below Picture (Fig. 1).

After Completing Sign in Procedure User will select Online Services after that user will navigate to below screen (Fig. 2).

Consumer select Self-meter Reading Option submit his/her Reading by providing Consumer details like Consumer Number, mobile number. Based on data provide by consumer we have performed some basic validation like consumer number is valid or not, Mobile number is registered with consumer or not and Consumer is Live or not. After found Data Okay, we will allow consumer to submit Meter reading. While submitting MR, Consumer can submit meter Reading Image also. Same image we have configured in our SAP data base against that Particular Consumer with Date and time. At last, Consumer will get confirmation Meter reading successfully submitted.

Image while submitting MR (Meter Reading) (Fig. 3).

Once the MR received from the consumer, our End users will verify the reading with actual Database if both values match then only billing will initiated other that reading will be cancelled and send the acknowledgement to consumer your meter reading not considered for the actual billing. Please submit the MR again.

We have maintained log for every attempt of consumer whether submission is correct or incorrect. Log data like consumer, Mobile, Date and time of submission and Image details.

2.2 Self-MR Submission Through NPCL Website

In SAP system we have developed one Interface where outside consumer or everyone can use this facility. Here consumer can submit their meter-reading website. Provided

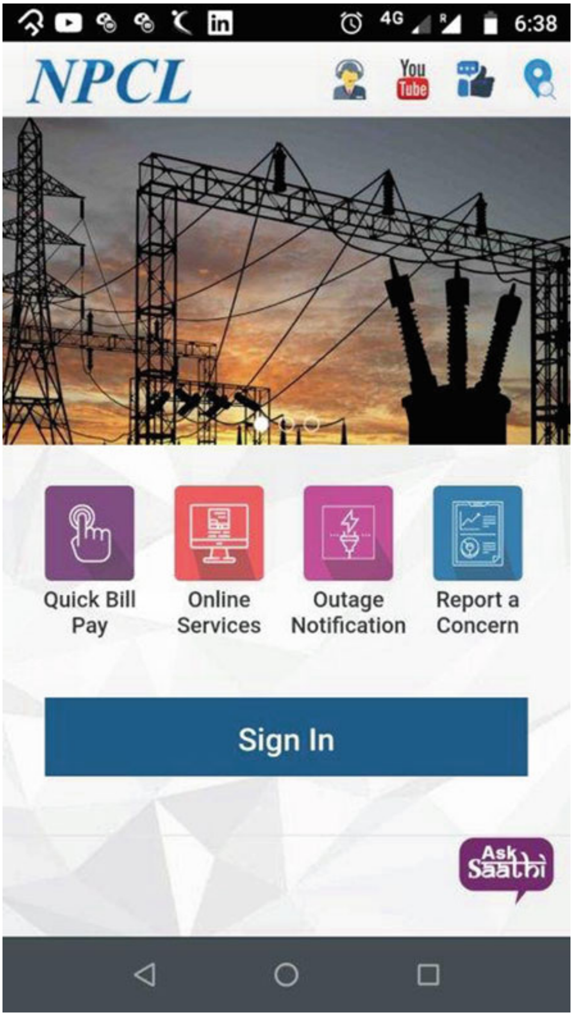


Fig. 1 Sign in

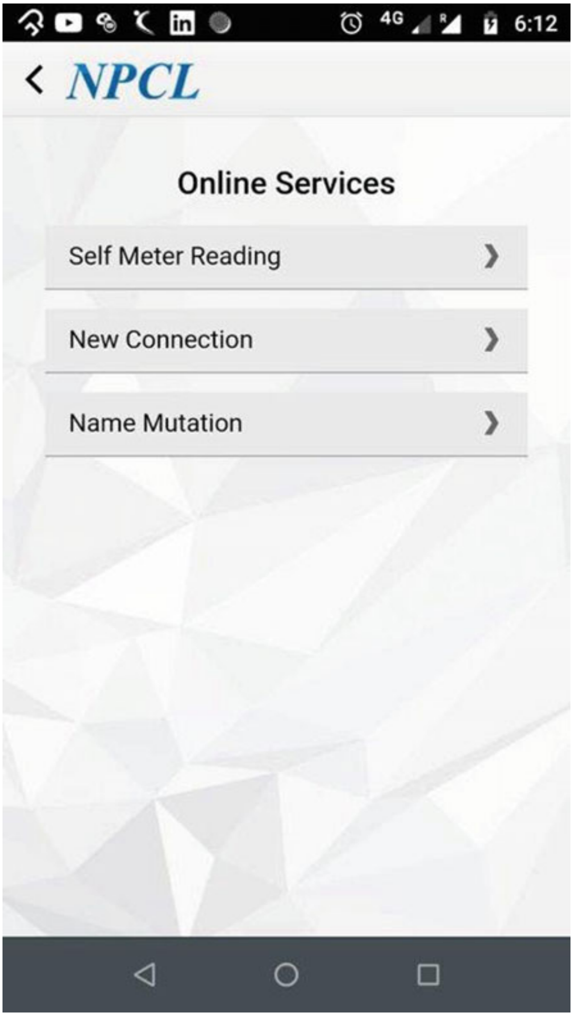
necessary awareness to consumer on website for the same. After visiting NPCL WEBSITE Consumer find the below screen (Fig. 4).

Once Click on SELF-METER READING Option Consumer will navigate into another screen (Fig. 5).

After entering consumer number system will validate consumer is valid or not and LIVE or not if Okay, consumer propmt to enter mobile number (Fig. 6).

After entering mobile number, system will check mobile and consumer number combinations is correct or not. If Both details are correct consumer will navigate to below screen where consumer enter meter reading, reading submission date and MR image (Fig. 7).

Fig. 2 Online services



After entering all details consumer will click on Submit meter reading Option. Meter reading successfully submitted option shown to consumer. Through this Process, we have maintained Consumer data maintained SAP Database as a log. The same we can refer in future also.

3 Self-MR Submission Through SMS(Keyword)

Even though promotional texts are considered spammy by nature, text marketing is, surprisingly, a useful performance marketing tool.

Fig. 3 Meter reading image

Fig. 4 Self meter reading icon

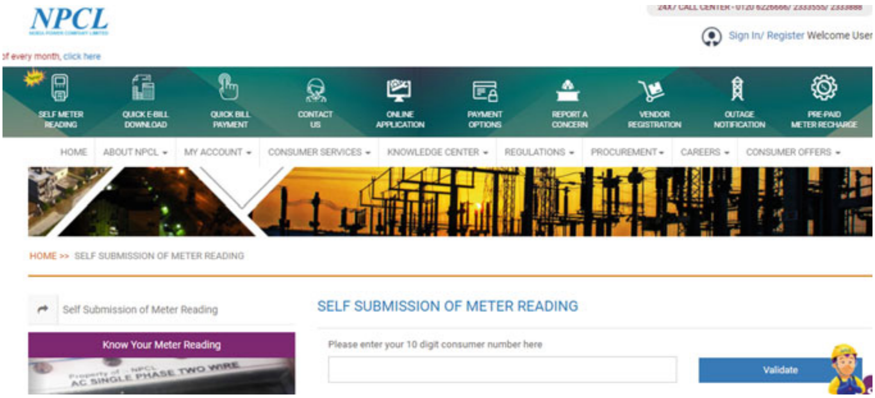


Fig. 5 Input consumer no

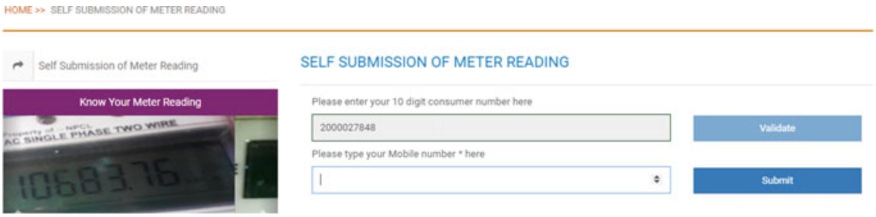


Fig. 6 Input mobile no

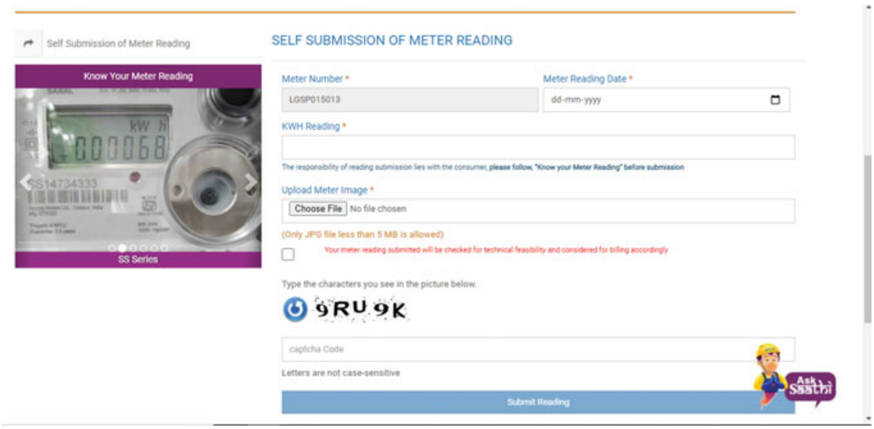
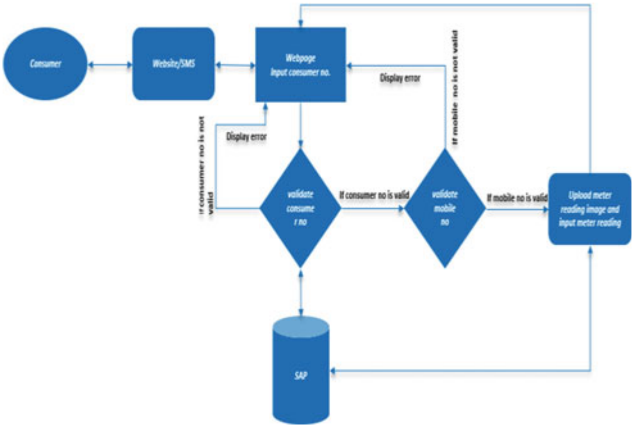


Fig. 7 Upload meter reading image and meter reading

Here we have Provide another option to consumers to provide their Meter reading Through SMS for ease of use to rural are consumers we have introduced this Process. Consumer can use predefined key words to avail the services here we have integrated with Third party vendor for SMS purpose. Vendor will directly receive response from consumer and once Reached in our SAP system we have done some basic validation consumer number is correct or not and Mobile number is matched with consumer or not. We have validated Keyword which is send by consumer.

For predefined key word we have already given much useful information to our customers on NPCL website as well we have informed our customers via SMS.



Self meter reading : Architecture

Keyword information on NPCL website as below.

(Type Short SMS Code <space> your consumer number and send to 7840002288, eg- #NOPOWER 2XXXXXXXXX)

S.No	Short SMS Codes	Purpose
1	#BILLDISPUTE <space> 2XXXXXXXXX	To register billing dispute complaint
2	#DUEAMT <space> 2XXXXXXXXX	To know bill amount, due for payment
3	#DUPBILL <space> 2XXXXXXXXX	To receive the bill on registered E-Mail ID
4	#METERBURNT <space> 2XXXXXXXXX	To register meter burnt complaint
5	#METERDEFECTIVE <space> 2XXXXXXXXX	To register meter defective complaint
6	#NOPOWER <space> 2XXXXXXXXX	To register No supply complaint
7	#SELFREADING <space> 2XXXXXXXXX <space> READING	To provide self meter reading
8	#STATUS <space> 2XXXXXXXXX <space> Complaint number	To know the status of existing complaint
9	#THEFT	To register electricity theft complaint
10	#WRONGREADING <space> 2XXXXXXXXX	To register wrong reading complaint

2XXXXXXXXX is the 10 digit consumer no. printed on the first page of the bill

Process flow for SMS Process:

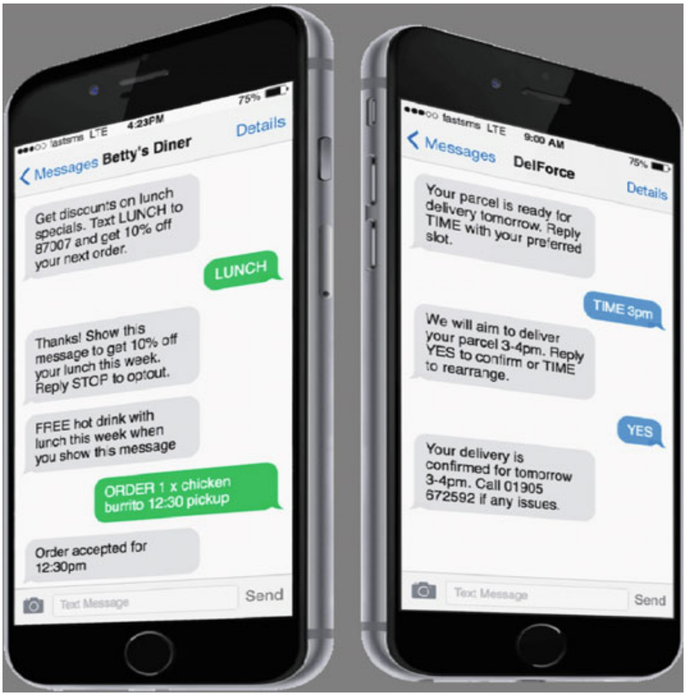


Fig. 8 SMS

- Consumer send predefined keywords using SMS to 78XXXXXX88. These keywords and mobile number (from which the key word is sent) will be captured by SMS vendor and forwarded to us using our (API) We perform internal process flow using these and will send out response SMS back to consumer (using NPCL's own SMS gateway—NPCLCC) (Fig. 8)

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Experience of Battery Energy Storage System by TATA Power DDL

Nilesh Kane, Lalit Wasan, and B. Karunakaran

Abstract The electric grid is a complex machine that is constantly being balanced to account for varying consumer demand and generation supply. An inability to balance these leads to grid instability, brown-outs or even black-outs in extreme situations. These situations happens on account of increase in variability of both supply and demand. With increase in Renewable energy and expected rise in Penetration of EVs which are unpredictable and intermittent in nature can be accommodated easily at low penetration levels but greater Penetration makes increasingly it difficult to maintain grid stability. TATA Power DDL has two Battery energy storage system (BESS) one is Grid integrated 10 MWh system and 150 kWh Community Energy storage System. In this paper we would like to share the TATA Power DDL experience of Battery Energy storage system usage from Distribution Utility perspective where the System has been used extensively for Deviation Settlement Mechanism (DSM/ADSM), Sustained Deviation violation management, Reactive Power Management, Peak Load management, Frequency regulation, Capex deferral and Emergency services by developing various Automated logics to run the system with best of the business potential perspective. In addition to this the paper would describe about potential Battery Energy storage system required for TATA Power DDL to overcome Penalties on account of deviations with respect to various regulations and Power for Emergency services. Initiatives like Pole mounted battery Energy storage system (Zero Foot Print solution) under development to cater the needs of consumers in densely populated areas with space constraints for maintaining voltage regulation within specified limit.

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Keywords Battery Energy storage system · Deviation settlement mechanism · Frequency regulation · Reactive Power Management · Ramp rate · Sustained deviation violation · Central Electricity regulatory commission

1 Introduction

Tata Power Delhi Distribution Ltd. (TATA Power-DDL) formerly known as North Delhi Power Limited, a 51:49 Joint Venture of The Tata Power Company Limited (Tata Power) and the Government of Delhi, was formed on July 1, 2002, as an outcome of the Electricity Reforms Process in Delhi. Tata Power-DDL is authorized to distribute electricity in North and North West part of Delhi having about 17 million registered consumers. Tata Power-DDL is in a regulated business and governed by Indian Electricity Act and regulations issued by DERC (Delhi Electricity Regulatory Commission).

In a short span of 18 years, Tata Power-DDL reduced Aggregated Technical & Commercial (AT&C) losses from 53 to 8% with successfully serving of the peak demand of 2069 MW in North and North West Delhi, show casing one of the few success stories of Public Private Partnership model in power distributions from 137 in 2015 to 29 in 2017.

It has been a front runner in innovating and adopting several world class technologies including SCADA, ADMS, OMS, DMS, Field Force Automation, Integrated GIS, and Advance Metering Infrastructure including Smart Metering and involving the convergence of Information and Operational technologies. Tata Power-DDL is the first Indian utility to be a member of Global Intelligent Utility Network Coalition (GIUNC) which is a coalition of 14 power utilities worldwide and is working towards accelerating the development of common standards, technology solutions and processes for intelligent networks. It has also embarked upon its Solar Journey through the promotion of Distributed Energy resources including Roof Top solar projects, Energy Storage programs, Automated Demand Response and Electric Vehicle charging systems, applicable both in the Urban and rural environment.

This paper will describe the experience of Battery Energy Storage system at Tata Power-DDL by taking various Energy storage initiatives at Grid level and Distribution level to meet the challenges of Distribution utility in terms of Managing Deviation Settlement mechanism, Frequency regulation, Reactive power Management, Peak Load management, Power quality and Distribution Asset deferral.

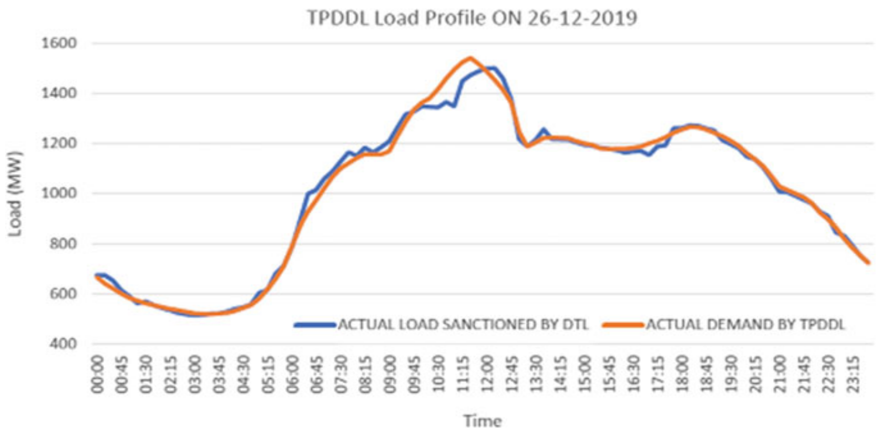

Fig. 1 Load curve with deviation from schedule

2 Challenges for Distribution Utility

2.1 Challenges

The Major challenge in front of Power distribution utility is Peak Load Management, Renewable Power Management, Deviation settlement Mechanisms, Reactive Power Management and Asset Management which are managed currently through Power Purchase Agreement, Real-time Market, Renewable scheduling [1, 2] and through optimum utilisation of Assets. But these challenges can be addressed by implementing battery Energy storage system at utility level at either Grid stations or at Distribution Substations or near the Customer Premises. Below mentioned Fig. 1 depicts a solar eclipse day where there is a sudden increase in heating load after the eclipse due to consumers' behaviour where BESS can address those sudden ramp in load. Through this paper we will explain the various application of BESS through the Installed system.

2.2 Need of BESS for Dsitribution System

To meet the challenges faced by the utilities in managing peak demand, avoid penalty on account of Deviation settlement mechanisms, to support the variable renewable resources [2], to reduce the dependence on Energy market [4, 5], to avoid penalty on reactive power Management, to avoid.

Congestion in distribution network, to defer capital expenditure, to meet high power ramping requirement and to reduce carbon foot print and support sustainable growth in Energy Sector.

3 Journey of BESS

The Journey of BESS started by setting up a Battery test bed at TPDDL where the testing of various chemistries of Batteries like Lead acid, Advanced lead acid, Sodium ion and Lithium ion Batteries were tested for the following parameters like Depth of Discharge, Partial state of charge, Power and Energy Output and Life cycle test. Based on the evaluation of Batteries at various test conditions as per the relevant IS & IEEE standards the Advanced Lead acid and Lithium ion batteries performed satisfactorily in all the tests. Based on the test results we recommended Advanced Lead acid for Microgrids applications as they have C rate slightly more than Lead acid and for Grid storage application where we require high C rate we recommended Lithium Ion batteries. With this continuation of the result we began the journey of grid connected 10MWh Battery Energy storage system at 66 kV Rohini 24 Grid station, Delhi. The Battery energy storage system was built in a foot Print of approximately 625 Sq m area by using Lithium ion NMC (Nickel, manganese and Cobalt oxide batteries) supported with 200 ton of refrigeration to maintain the temperature of Batteries at 24 °C and Bidirectional inverter (Fig. 2).

3.1 Architecture

Basic architecture is where the SMART Inverters are connected through an Isolation transformers and further Batteries are connected to the inverters through a Battery Management system and further integrated with SCADA through Remote terminal unit. Based on the temperature the HVAC is operated to maintain the temperature.

Fig. 2 10 MWH BESS at Rohini sector24

3.2 Array Constrcution

- The 10 MWh system is divided into 4 cores of 2.5 MWh to ensure reliable operations
- Each core has 31 nodes
- Each node has 14 no's of 6.5 kWh batteries connected to them
- Each node has a node controller, UPS, PCS and 80 kVA inverter (Fig. 3).

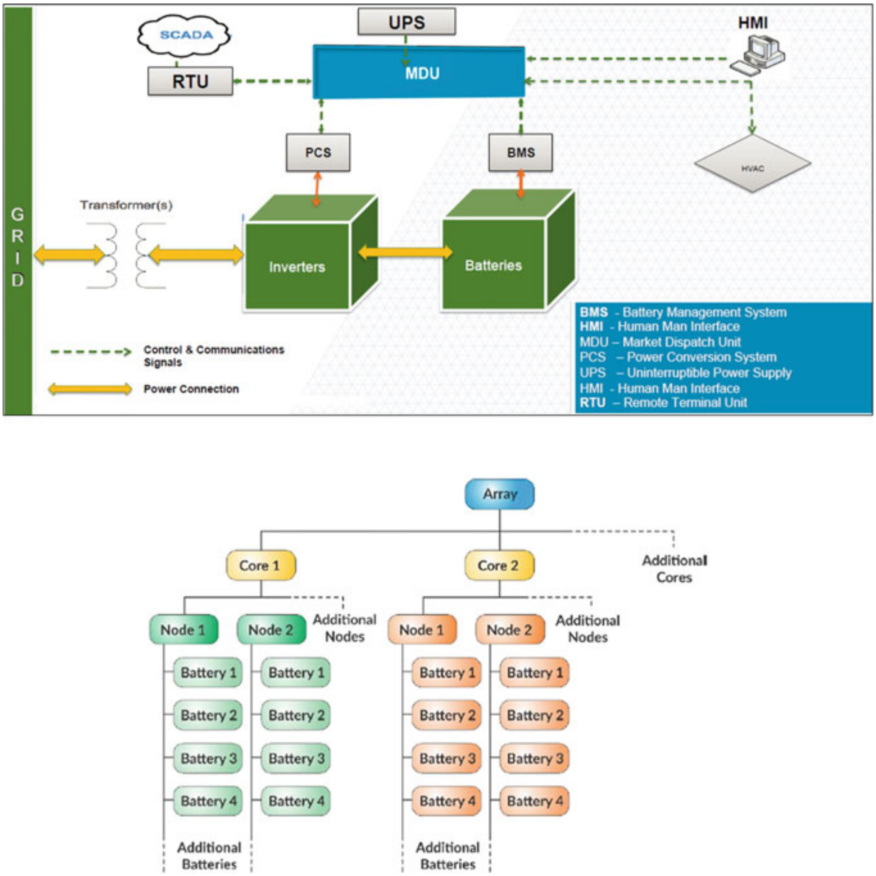

Fig. 3 Architecture and construction

3.3 Safety Aspects

- The Fire Fighting Room—Ensuring the safety of the project, Diesel Generator based Pump has also been installed to ensure the operation in case of fire and non-availability of the auxiliary power.
- Emergency Stop Button—In case of the emergency, Emergency stop button has been installed on every key location to shut down the plant.
- Transformer Fire wall—To reduce the extent of damage of the project equipment, fire wall has been constructed between the adjacent Isolation transformer.
- Fire resistant Wall of the BESS Building—To reduce the extent of damage of the project equipment, fire resistant wall has been used in the BESS building
- Surveillance—To observe the condition inside the battery room remotely, CCTV has been installed on every aisle.

3.4 Human Machine Interface and DAS

- Human Machine Interface (HMI)—Through the platform, end user could get the graphical representation of the BESS architecture at Array, Core and Node level. End user could put action through this platform to change the operational modes, reset, power cycle the nodes. Also user can give manual set point command to charge and discharge the batteries at Array, Cores and Nodal level
- Data Acquisition System (DAS)—Through the platform, user can monitor all the live and recorded parameters of the electrical system, protection system, battery management System, PCS, Control System, BOP equipment. This platform is mainly used to monitor parameters for troubleshooting & record purpose.

4 Application Demonstration

The BESS has been demonstrated for the following applications and the performance is depicted below. To run this application we have developed algorithm based on our regulation and need and implemented them.

4.1 Frequency Regulation

Automatic logic for frequency regulation has been developed in the system and accordingly the BESS was used for Frequency regualtion application.

Logic: Frequency Regulation
Mode: Automatic

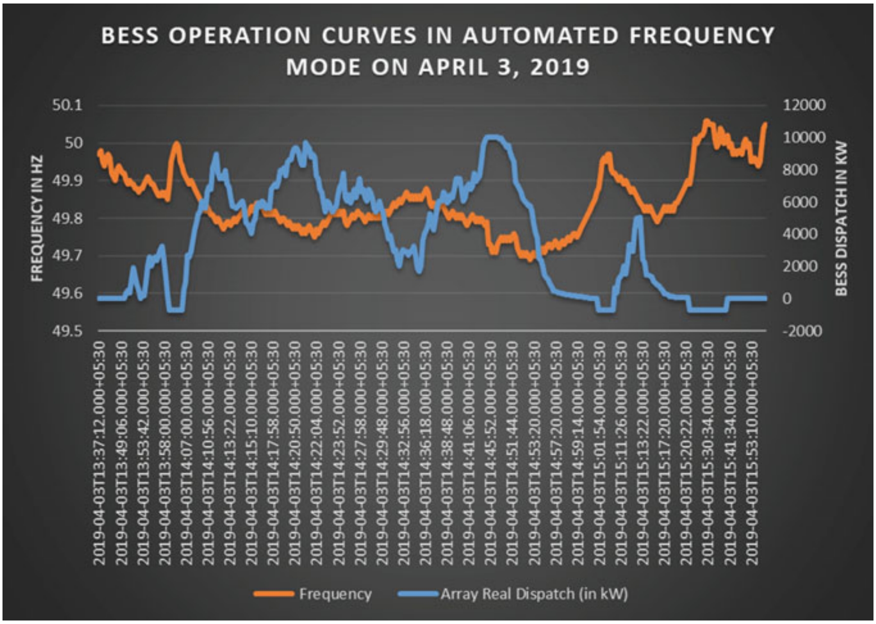

Fig. 4 Typical frequency response

- Ramp rate Slope is (2 MW/0.01) Hz
- Discharge: Between 49.85–49.80 Hz
- Charge: Between 50.05–50.10 Hz.
- Dead Band: 49.85–50.05 Hz (Fig. 4)

The above graph depicts the Automatic BESS repsonse to Frequency regualtion application to support the grid (at 10 MW capacity) sensing the grid frequency from 01:37 to 03:40 PM. This real time graphs showing the BESS capability to support and serve ancillary service.

Similarly during light out event on During the "Lights Out" event on 05'th April 2020, BESS was put into action ramping up and down autonomously to its full available capacity in sync with the change in frequency within milliseconds. Following graph shows the BESS response (Fig. 5).

4.2 Deviation Settlement Mechanism

Logic for DSM:

Continuous checking of Actual OD/UD every 2 min for running time block.

I.e. at 17:28 Hrs. System will check time block from 17:15 to 17:30 Hour for Actual OD/UD.

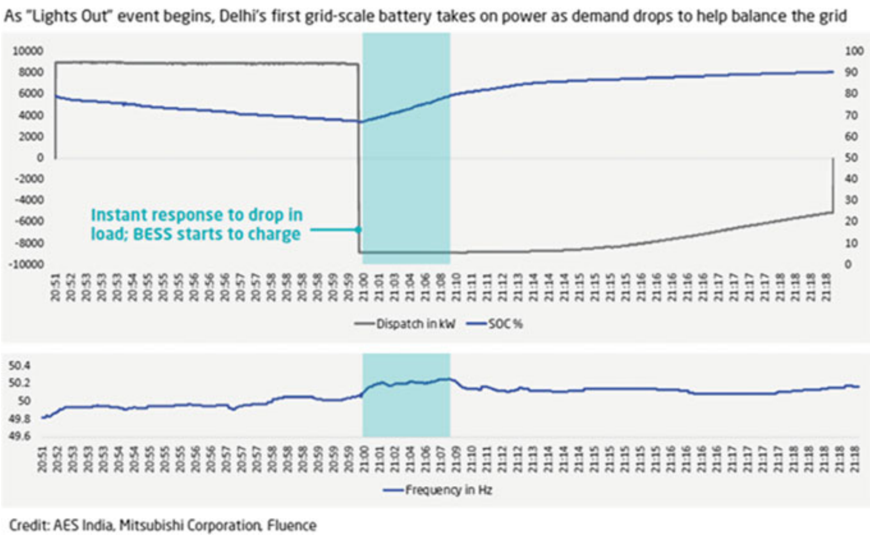

Fig. 5 Response during light out event

Case-1: TPDDL—Overdrawal

If {frequency <49.85

BESS command = "Discharge "

Else freq between 49.86 to 50.04 Hz.

Condition-1 If Actual OD > 38 MW,

BESS command = "Discharge "

Else

No Command

}

Case-2 TPDDL -Underdrawal

If{ frequency >= 50.10 Hz

BESS command = "Charge "

Else frequency < 50.10 Hz

No Command }

The logics has been Prepared by our Power Manager to meet the regulation as well as to ensure the grid discipline.

Typical repsponse of a DSM is appended below:

" − " sign charging and " + " means discharging (Fig. 6).

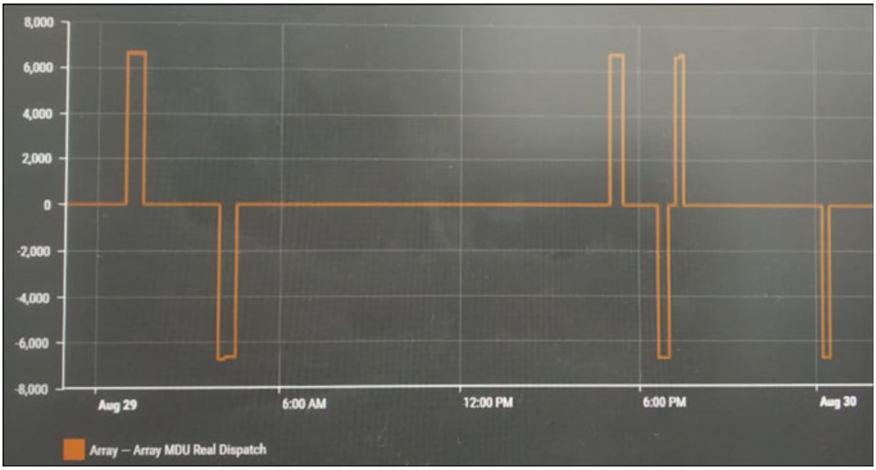

Fig. 6 DSM-charging and discharging

As per the above logics the BESS is used for charging and discharging to maintain the Power within the allotted schedule and ensure grid discipline. Due to recent changes in sustained deviation violation as per the CERC 5th Amendment regulation, sustained deviation after 6th time slot in one direction invites the addition penalty of 20% on and above of deviation penalty for each violation. Amendment has come into effect since Dec-2020. Typical case of 2nd jan-21 where through BESS following savings are obtained. In the typical case of 1st Jan-2020 shown below the overall penalty for the day has been reduced to one instead of two using the BESS.

- With BESS, Sustained Deviation count was one amounting to penalty of Rs. 12,783/-
- Without BESS Sustained Deviation count was two amounting to penalty of Rs.25,693/-.
- Savings: Rs. 12,910/- (Fig. 7)

4.3 Reactive Power Management

It is a common fact that to manage Reactive power, Capacitor bank are installed in the Grid stations and as well as in Distribution Substation to pump in Reactive power into the system. But there is a need in current scenario where the Grid have to absorb reactive power due to the votlage based regulation framed to maintain voltage regulation in the grid. Here BESS can play a vital role in pumping as well as absorbing reactive power through the four quadrant operation of the SMART Inverter. Penalty scenarios is indicated in (Fig. 8).

Typical response obtained through reactive power compensation is depicted below (Fig. 9).

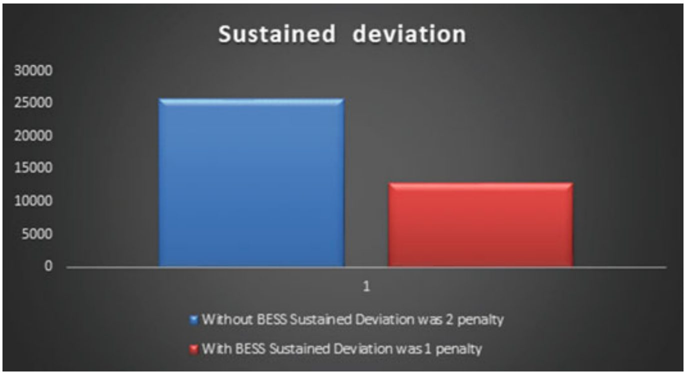

Fig. 7 Sustained deviation case

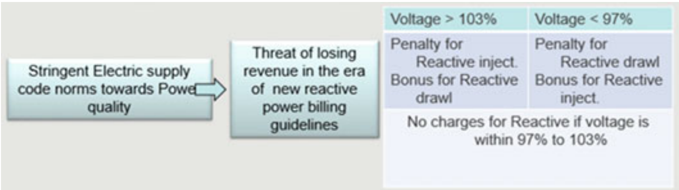

Fig. 8 Regulation for Reactive power penalty

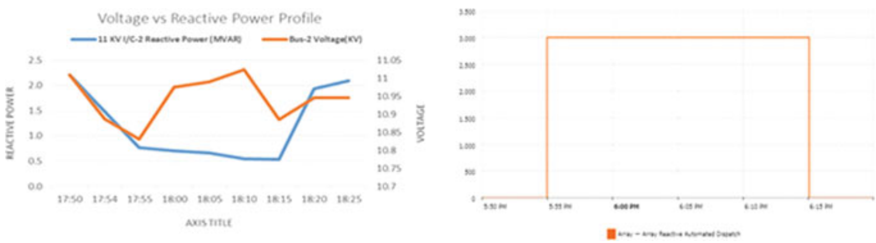

Fig. 9 Reactive power response from BESS

In the above scenario 3MVAR reactive power is pumped at 17:55 h and accordingly the voltage of the system has been improved from 10.85 to 10.95 kV.

4.4 *Operational Performance of BESS*

In the typical 2 years of pilot project we had majorly used the BESS for Frequency regulation, Deviation settlement management, Sustained deviation management and

Reactive Power Management. For this we have used around 285 cycles and the plant availability was about 80% (Fig. 10).

One of the critical component of the BESS is Auxiliary consumption. The main auxiliary consumption of BESS includes the HVAC consumption of the BESS and Lighting load. As per the energy meter data the monthly consumption of the auxiliary unit is depicted below. As the system has 200 Ton refrigeration unit to maintain the Battery temperature at 24 °C ± 3 °C, the Main reason for aux. consumption is HVAC load.

Typical savings obtained from the operation of the BESS in last year is around 30 lacs and we envisage with change in regulation and inclusion of regulation like frequency regulation ancillary services the savings would obviously improve (Fig. 11).

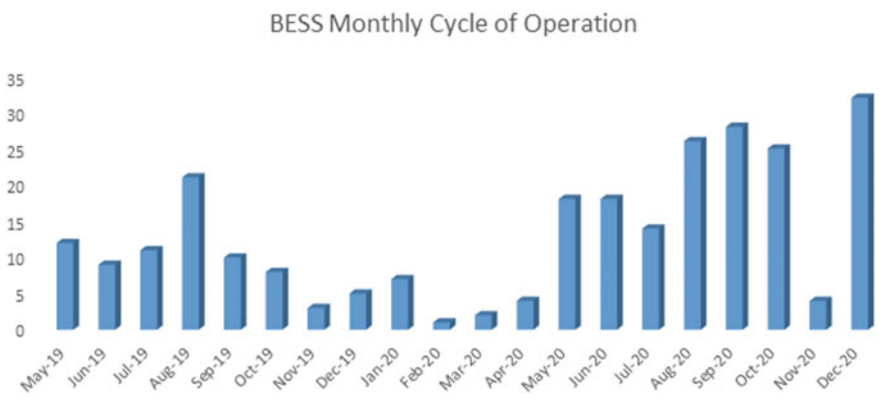

Fig. 10 Cycles operation of BESS

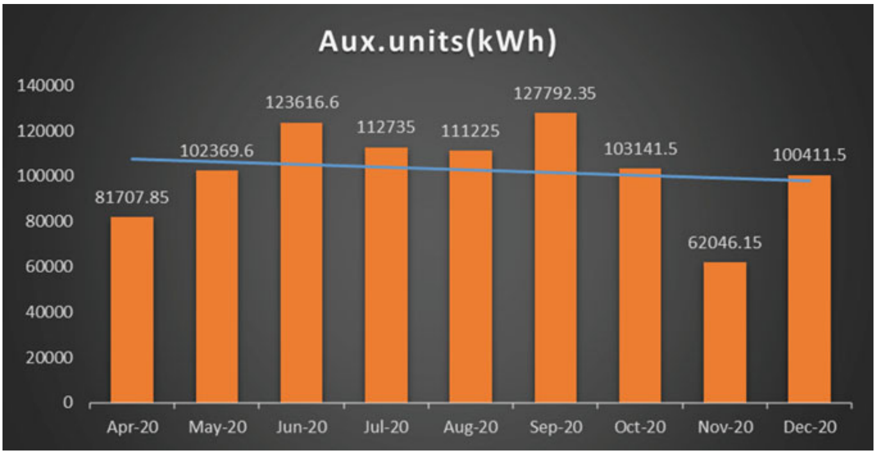

Fig. 11 Auxiliary consumptions

Fig. 12 Community energy storage

4.5 Community Storgae

In cities like Delhi there is a vertical load growth of above 10% and that too the peak load is observed only in summer. But to accommodate the peak load The Distribution assets are augmented to higher capacity and rest of the year the loading of the system is below 50%. To overcome this we initiated a community storage [10, 11] project of 150 KW for 4 h in container based solution where the Battery capacity of 10–15% of the DT capacity is added into them which can cater the additional load without overloading of the assets and ensure reliable power supply. Apart from summer month the system will helps in frequency regulation, Deviation settlement mechanism and voltage regulation through Power factor improvement. The system also have a black start feature where during emergency or any outage the power can be fed to the preferred bus feeder having consumers like hospitals/jalboards (Fig. 12).

5 Conclusions and Wayforward

In today's global scenario Battery energy storage is inevitable as the world is moving towards Electric vehicle concept and the grid is getting decentralized due to infusion of renewables into the system. In future to meet the increase in Renewable penetration the Solar combined with storage will be a combination which would increase the Grid stability. Currently there is no business potential but globally battery price is on the reducing trend and in 2023 the price of the battery would be optimum for getting a suitable business returns. TATA Power DDL has conducted a study with help of IFC to determine the potential BESS requirement and from that study it has been inferred that a capacity of 50 MW/100 MWh Battery energy storage is required for us and which can generate a value stream of 356 MINR per year. Moreover to obtain this we need support from Power ministry and regulatory to include the BESS as a Generator and Policy for using BESS for frequency regulation ancillary services. Only BESS can give a high ramp rate required for immediate addressal of any grid disturbances. We hope that the price of the Battery would drop below $100/kWh by 2023 for the successful penetration of Battery energy storage market [15, 16] and this kind of pilot project would help the utility understand and familiarize the operation and Maintenance of BESS. These pilot projects helps to understand the teething issues of Battery energy storage in Indian climatic conditions and will be ready for implementation during mass scale up in coming future. TATA power DDL are also interested to take forward the Battery energy storage behind the meter by having small Pole mounted solution which can help the utility for Peak load management in future through Automatic demand response program.

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Paperless and Contactless Operations in Distribution Services

Parmanand P. Tendulkar, Devendra H. Santani, Nikhil H. Pujari, Pramod B. Jadhav, and Amit C. Dalvi

Abstract Tata Power Distribution Mumbai, License area of 484 km^2, Serving 7.4 lakh customers, 4700 km of network, 36 Distribution substations, over 1000 Customer substations in the city of Mumbai. During COVID the paperless and contactless operations became a must for operations the various digitization projects has helped in these. Some of these are Dynamic forms (GIS), Digital Shift Handing Over Taking over (HOTO), UVC Sanitizer Box, Samarthya App, RCM—Reliability centered maintenance, CBM, Social Distancing alarm, Daily dashboard/complaint management, Mechanized, Remote site monitoring using camera, Unmanned operations, Automation Using LoRA have been explained in detail in the paper.

Keywords Paperless · Contactless · Digital · Distribution · CBM · RCM · LoRa · Automation

1 Introduction

The various methods for contactless and paperless operation helps in maintaining the network with reduced probability of the infection. These systems in addition to prevention of infection help with other benefits such as digitisation, robust systems,

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savings in cost due to less material consumption, better analytics and reduced manual labour.

2 Various Initiatives

2.1 Dynamic Forms (GIS)

There are various equipment's of a distribution utility which are in pubic. The planned inspection and maintenance of these equipment's will lead to a safer environment. A process of inspection of these was carried out manually in papers in hard format. These copies are maintained for records.

This system has been completely modified and a new system "Dynamic Forms" integrated with GIS (Geographical Information System) has been incorporated with the help of this system. The equipment's in the system have unique Id in the GIS. The system is running on android OS based tablets that have been assigned to service personnel (Figs. 1 and 2).

The data points of the equipment are captured in the tablet. These data points make a history of the equipment's on which analysis and predictions can be run.

The benefits of the these systems are.

a. Reduced usage of Paper and prevention of Spread through Contact points
b. Management Information System readily available

Fig. 1 Technician using tablets for inspection

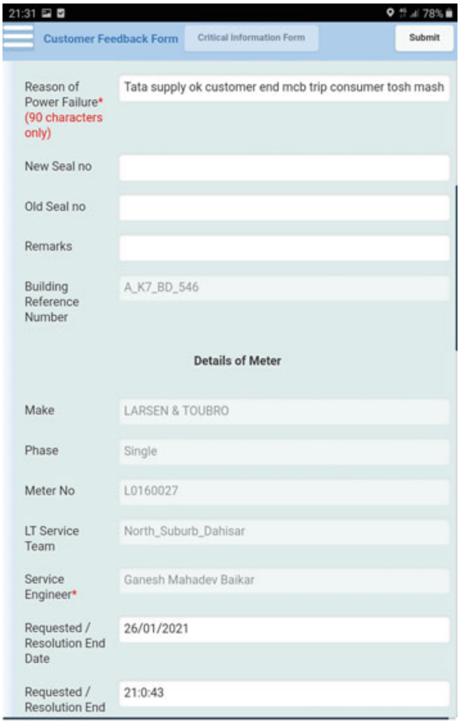


Fig. 2 Sample dynamic forms from tablet

c. Easy pull and push of data for each equipment as opposed to the manual systems of hardcopy.

2.2 Digital Shift Handing Over Take Over

The shift handover and takeover from one operation engineer to another operation engineer is an essential part. This happens in person through verbal conversations and hardcopy in the logbook maintained. This logbook is a statutory document, which is required for all legal purposes. Shift Incharge reads this logbook on daily basis (Fig. 3).

This logbook and process of Handing over and Taking Over was identified as a high potential touch point. To mitigate the risks of this a Digital Logbook was created and access to related individuals is provided. This also help in remote viewing by the Shift Incharge. This system can be accessed by the all the individuals through their personal laptops or cellular devices. To further facilitate Voice notes was also made mandatory so as to have a system continuity with the existing system.

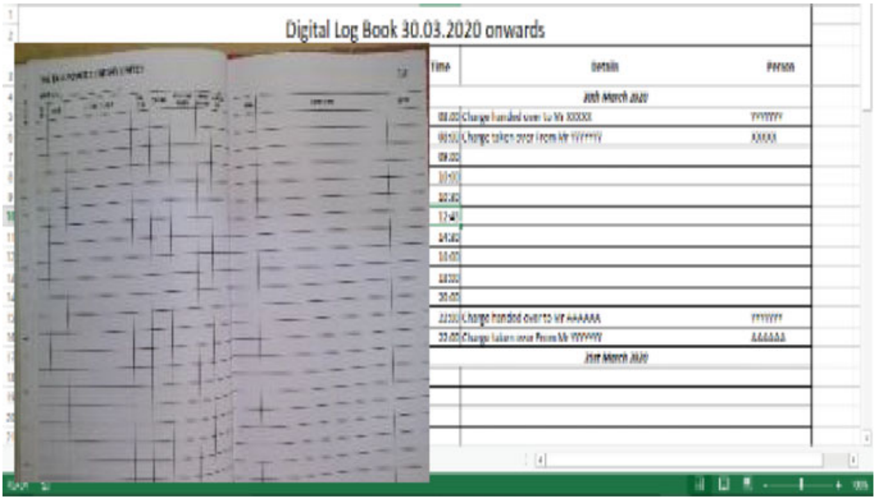


Fig. 3 Old log book versus new digital log book

2.3 UVC Sanitizer Box

The common tools with technicians which are used for the Repair and Maintenance of the equipment's. These tools are a high potential touch points even after team segregation and ROTA, since most of tools are costly. Spares of these equipment's cannot be arranged on a short note (Fig. 4).

The sanitization of these tools can be done via wiping with alcohol solution. To reduce this manual labor of wiping these equipment's. To reduce the time and man hours required for this job. An In-house Ultraviolet C type Sanitization box was developed. In this developed box the tools are to kept for one minute with their contact surfaces exposed. The door has an interlock and timer circuit. The door interlocks stops and resets the time to zero whenever the door is opened when the sanitization was in progress. The timer circuit is developed to stop the circuit and UVC rays from the tube.

This method of sanitization reduces the material requirement and time requirement for the sanitization of the tools.

2.4 Samarthya App

All the equipment's in the zone are mapped in the SAP system with Unique ID. The barcodes for these unique id are generated and attached with equipment. A application was developed for the linkage with backend in SAP. With the help of this application the barcode is scanned. The equipment details are fetched from the

Fig. 4 UVC sanitizer box

backend. The permit and notification can be generated on the equipment on the site itself (Figs. 5 and 6).

The samarthya app reduces the time lag and reduces the risk of exposure. This application can be used for directly creating permits, Job safety analysis, and notification. The complete facility of PM module is extended as per the need and requirements.

Stock Overview can also be obtained from the app displays unrestricted material stock quantities. All materials based on configured material types and plants assigned to the mobile user are displayed. The user can use search function to internally search for specific material (Figs. 7 and 8).

The tab for MIS is also developed in this application which is not available in SAP systems. On this tab pending defects notifications, breakdown statistics are available to the user without the need to login to existing internal network and is independent of the carrier. The application also does not require VPN to access this system.

This reduces the effort to go back to office and access the SAP system and avoid duplication of efforts and further contact with the essential workers in office is also avoided.

2.5 CBM

(1) **Ultrasonic Detection of Partial Discharge**

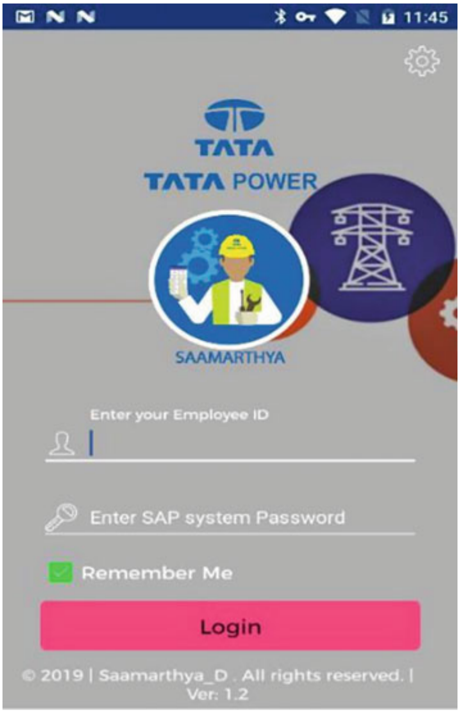


Fig. 5 Samarthaya app. Login page

Ultrasonic detectors are used for detecting the Arcing, Tracking and Corona. The arcing, tracking and corona all these events happening inside the equipment are not audible to human ears easily. Over the long range of time these events cause deterioration of the assets (Fig. 9).

Ultrasonic Detectors are used to detect the chirping sound, hissing or humming sound inside equipment such as Transformer, RMU, cable compartment, breakers, etc. The Ultrasonic detection is carried out periodically for detecting the abnormality like moisture ingress, chirping sound caused by pit marks, ionization etc. and prevent the equipment from flashover.

These tests are nondestructive and non-intrusive in nature and can be performed easily without the requirement of outage.

(2) **Thermovision Scanning**

It is used for detecting high temperature components of different equipments on monthly basis. Thermo vision scanning is carried out periodically for detecting hot spots at all substation equipments i.e. Cable terminations, LT panels, over head lines etc. and necessary actions are taken where hot spots are detected. It helps in Early detection of potential failures and visual identification of problems via non Intrusive procedure.

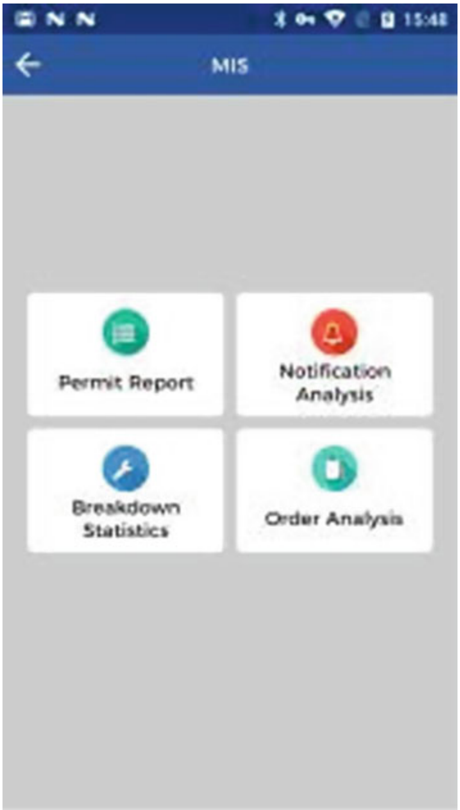


Fig. 6 Samarthaya app. Dashboard

This method of inspection requries minimal contact with the equipments and live part which enhances the safety as well as elminates touchpoints (Fig. 10).

2.6 RCM

Over the past years and a rich experience in Power Sector There is a huge data set available on which Reliability centred maintenance has been implemented from proactive maintenance where breakdown is predicted of the equipment. The software at the backend predicts the failure of the type and the maintenance required. This prevents the effort for the maintaining the equipment's on a planned frequency basis. The equipment's might not require maintenance at that point of time. This reduces the exposure time and contact which is required during maintenance.

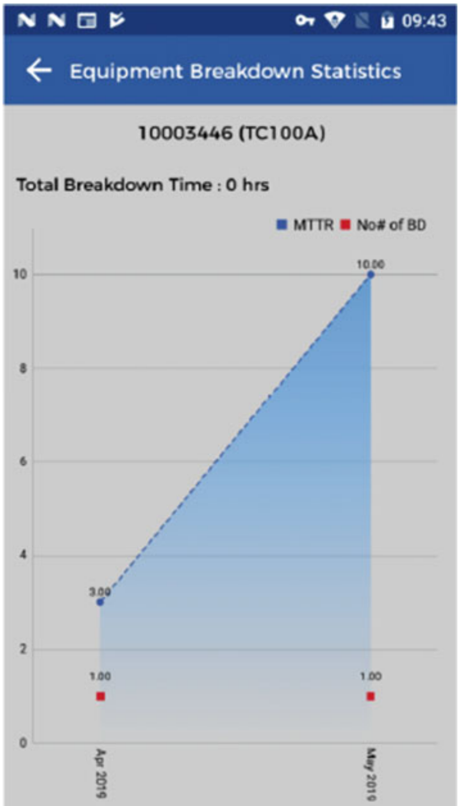


Fig. 7 MIS and analysis. Equipment Breakdown Statistics

2.7 Social Distancing Alarm

Social Distancing alarm was developed In-house which would alert the people in case social distancing norm is continuously on till the social distance is not being made. It works on the principle of Ultrasonic waves transmission and receiving (Fig. 11).

2.8 Daily Dashboard/Complaint Management

The complaint management and tracking is an efficient tool that has been created which updates the utility about the complaints and types on daily basis this has been useful to track the complaints in pandemic times. The dashboard at an instances lists the causes for the complaints in drill down manner with up to 4 causes. These are generated from the backend for all the complaints are received in a day (Fig. 12).

This helps in developing trends in taking proactive action such as certain stations will get heavily loaded and there might be complaints of voltage drops. This can be

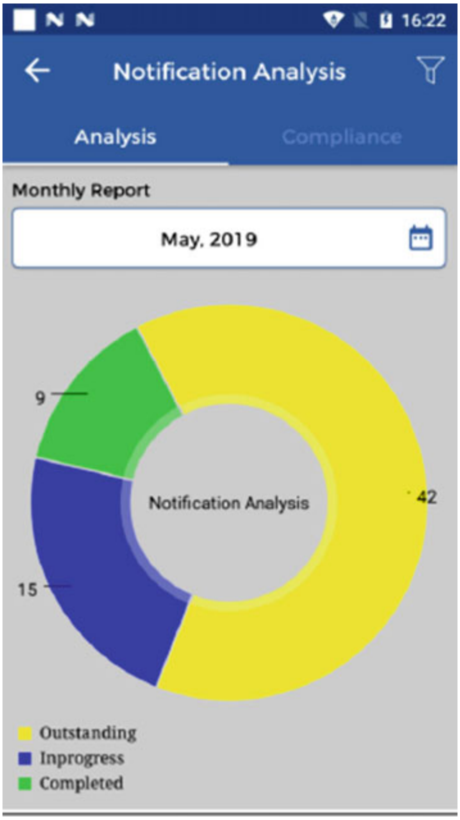


Fig. 8 MIS and analysis. Notification Analysis

identified easily from analyzing the trend of the complaints that are received. Based on these certain actions can be planned without the need to physically be present in office was trend analysis etc.

2.9 Mechanized Winch Machine for Pulling Cables

During Lockdown period there was surge in demand for hospital beds which led to demand for the power supply for these Covid Hospitals. During this period and as specialised measure for contactless cable pulling for the laying activity a winch machine was introduced that is used for cable laying and pulling (Fig. 13).

The benefit of this is reduced contact and less requirement of manpower at site for cable laying activity and maintaining the social distancing norms.

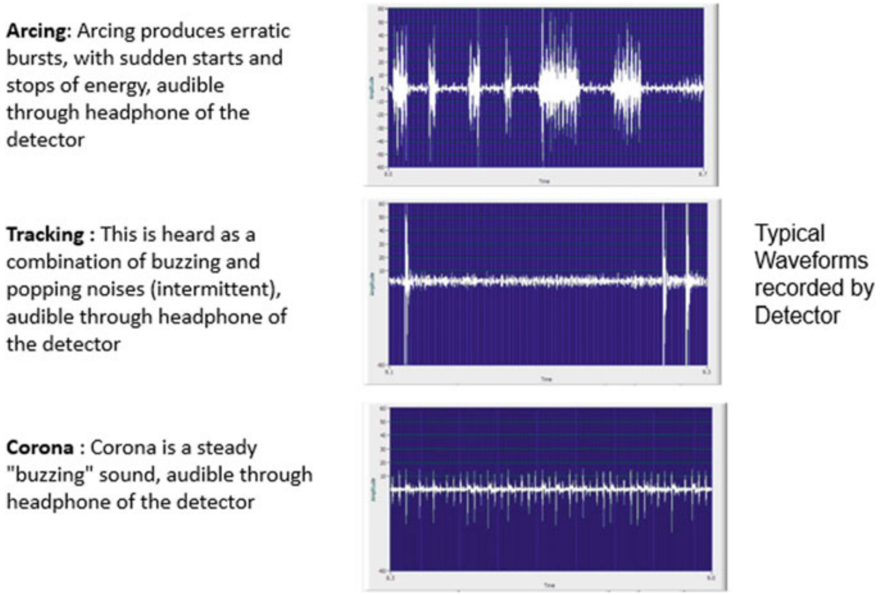


Fig. 9 Ultrasonic analysis

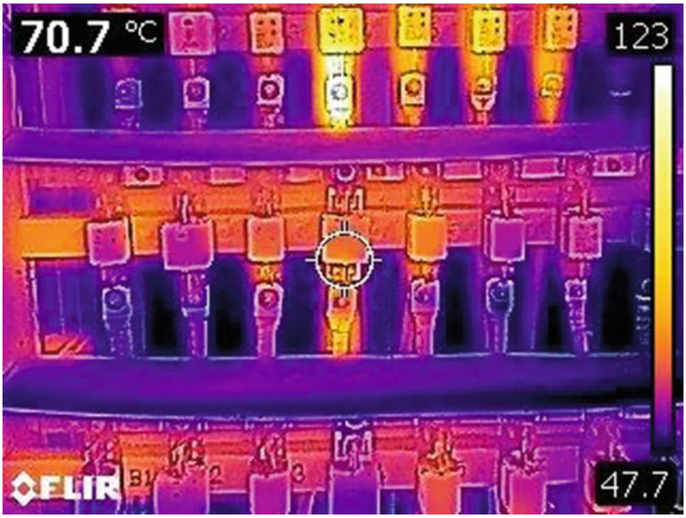


Fig. 10 Thermovision of feeder pillar showing loose contact

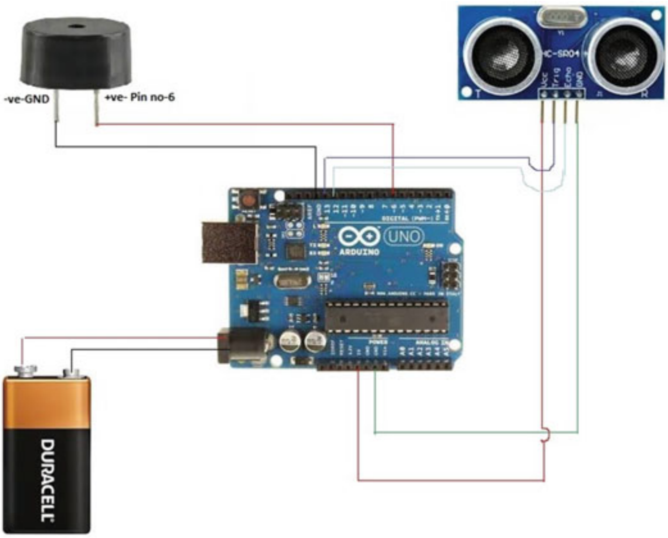
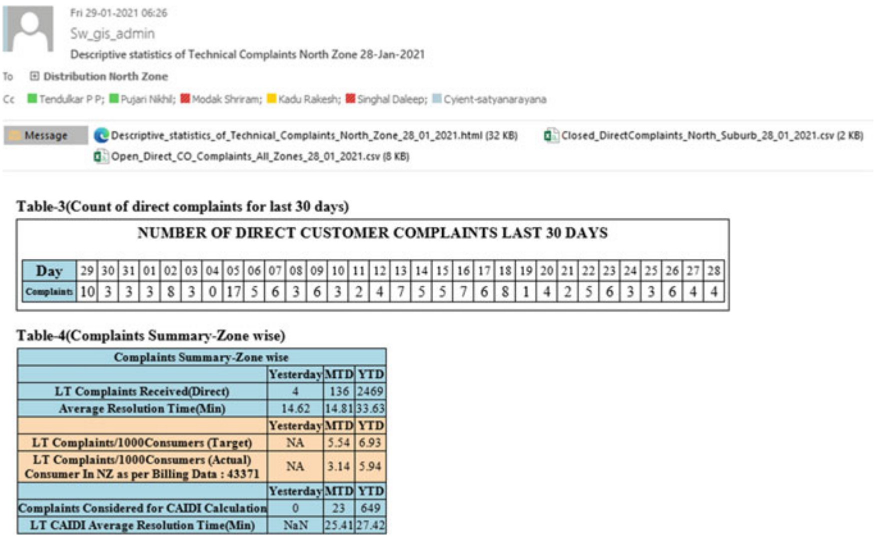


Fig. 11 Social distancing alarm circuit diagram



Fri 29-01-2021 06:26
Sw_gis_admin
Descriptive statistics of Technical Complaints North Zone 28-Jan-2021
To Distribution North Zone
Cc Tendulkar P P; Pujari Nikhil; Modak Shriram; Kadu Rakesh; Singhal Daleep; Cyient-satyanarayana

Message Descriptive_statistics_of_Technical_Complaints_North_Zone_28_01_2021.html (32 KB) Closed_DirectComplaints_North_Suburb_28_01_2021.csv (2 KB)
Open_Direct_CO_Complaints_All_Zones_28_01_2021.csv (8 KB)

Table-3(Count of direct complaints for last 30 days)

NUMBER OF DIRECT CUSTOMER COMPLAINTS LAST 30 DAYS

Day	29	30	31	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Complaints	10	3	3	3	8	3	0	17	5	6	3	6	3	2	4	7	5	5	7	6	8	1	4	2	5	6	3	3	6	4	4

Table-4(Complaints Summary-Zone wise)

Complaints Summary-Zone wise			
	Yesterday	MTD	YTD
LT Complaints Received(Direct)	4	136	2469
Average Resolution Time(Min)	14.62	14.81	33.63
	Yesterday	MTD	YTD
LT Complaints/1000Consumers (Target)	NA	5.54	6.93
LT Complaints/1000Consumers (Actual) Consumer In NZ as per Billing Data : 43371	NA	3.14	5.94
	Yesterday	MTD	YTD
Complaints Considered for CAIDI Calculation	0	23	649
LT CAIDI Average Resolution Time(Min)	NaN	25.41	27.42

Fig. 12 Dashboard

2.10 *Remote Site Monitoring Using Camera on Site*

Some of the works are high risk in nature and require an audit of the tools and tackles, the competiveness of manpower and assessing the site conditions. The critical repairs

Fig. 13 Cable pulling using winch machine

during lockdowns required safety assessment and no business can supersede the safety requirement. Keeping in view the lockdowns imposed the remote audit was carried through video calls and each every point was complied with the requirements.

2.11 Unmanned Operations—Use of PTZ Cameras for Monitoring

The installation of PTZ camera has been started and post stabilization of the network and other infrastructure related issues. The Unmanning of distribution substations has been initiated. This helps in reducing the touchpoint as the said substation will be accessed as and when necessary and the potential carrier, which the security guards could have acted, is prevented (Fig. 14).

2.12 Automation and LoRa

The penetration of the automation and LoRa based technologies has been increased to perform the remote operations and increase the adoption of future technologies of IoT. These LoRa based systems alert the user whenever there is change in the status of the HT breaker, LT breaker, FPI, Transformer status and FPI (Fig. 15).

Whenever the fault in the system happens the FPI glows if the status of all the FPI is known then the faulty section is identified. This reduces the effort required to restore the fault as well as reduces the contact points as it reduces the travel to multiple locations to identify the faults.

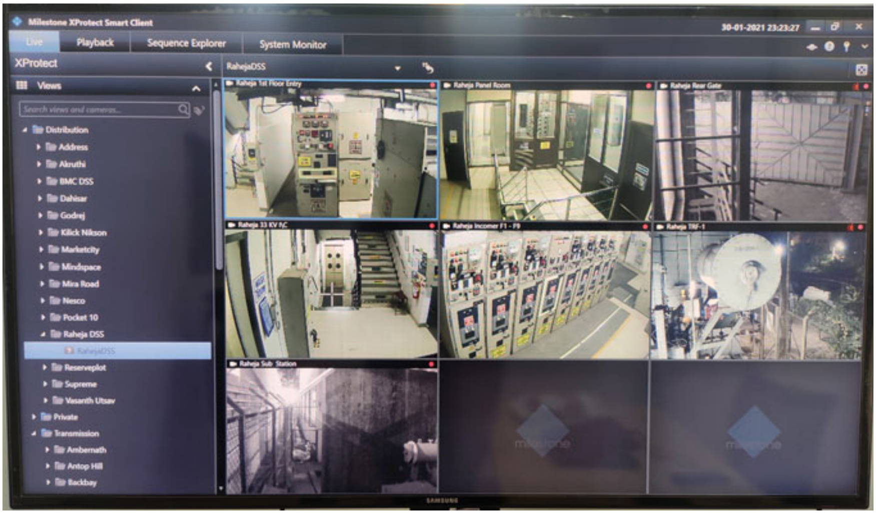


Fig. 14 Unmanned stations

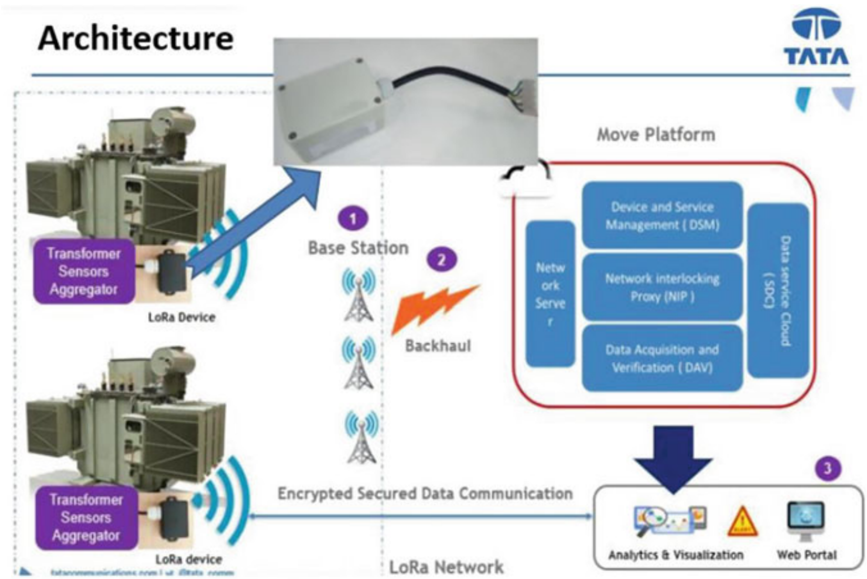


Fig. 15 Architecture of LoRA

3 Conclusions

The smooth and uninterrupted operations of the power utility is an essential requirement where in this era power acts as one of the basic needs of mankind. In the financial capital of India maintain these status quo for the power and powering up the lives of the people working from home is the need. These practices, which have been introduced over the years and few innovative ideas, have helped us throughout.

The maintenance module is now a 100% digitalized process in Tata Power Mumbai—Distribution Operations. There are various benefits of these digitalized operations few key being easy record maintenance, more reliable and robust systems, automatic history, mis and analysis of the data points. These practices if further sustained and progressed over the year will change the way the traditional power distribution business is run and provide a greater customer satisfaction and user experience.

Electric Vehicle Adoption and Penetration in India: Charging Infrastructure and Distribution Grid Upgrades as Vital Goals

Pooran Chandra Pandey

Abstract India is actively implementing policies to roll out a massive electric vehicle (EV) segment. Government's push for clean and renewable energy and incentives for investments offer it a unique opportunity. It, however, needs to put in place robust charging infrastructure, grid upgrade plans and consumer friendly prices for EV markets to expand and sustain.

Keywords Electric vehicles · Charging infrastructure · Grid upgrades · Adoption · Penetration

1 Introduction

India has witnessed a surge of about 20% over the last one decade in registration of vehicles mainly due to high population growth and rapid urbanization. This phenomenon, in turn, has led to serious consequences, among others, on the health of masses due to high prevalence of air pollution in the country.

Indian government has progressively been taking measured to reduce the carbon foot print in conformance with international standards through key policy steps in accelerating the adoption and penetration of electric vehicles (EVs). It also has simultaneously been focusing on twin challenges of commercialization and modernization of distribution grids. These issues however require financial and physical resources, pricing mechanism, technology and cost recovery plans while at the same time requiring upgrades in distribution grids including their optimization to be able to support a large charging infrastructure at all times with EV sales picking up and expected to reach optimal number by 2030.

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https://doi.org/10.1007/978-981-16-8727-3_34

2 Enabling Ecosystem

In order to ramp up various provisions in enabling the strong EVs sales, provisions for charging infrastructure, distribution grid upgrades, India needs to plan out roll out plans with clear policy guidelines to support the sales of the EVs while being able to attract investments—both from national automakers and international manufacturers alike in a time bound manner.

The National Electric Mobility Mission Plan (NEMMP), 2020 launched in 2013 provides for the development of a mission plan and a road map for promoting electric mobility solutions in India [1].

3 India's Strengths and Advantages

In a rapidly transforming mobility paradigm, India has relative strengths and comparative advantages. The country also has a slight advantage of the legacy of resource—blind mobility unlike other economies of the similar nature. Currently, India also has few vehicles per capita than other major economies without carrying much of those nations that were built on the back of private car ownership. This gives India the window of opportunity to create an all new, seamless and seamless mobility ecosystem.

On the technology front, India's strengths lie in information technology, big data, digital payments, and the internet enabled shared economy. These elements are increasingly becoming the drivers of the global future of mobility. In addition, country's renewable energy push would further ensure environmental benefits of electric mobility can be fully realized as India plans to draw 175 Giga Watts (GW) of renewable energy by 2022 [2].

India's efforts on keeping its Paris Climate Treaty (2015) in keeping global temperature to 2 °C continues to stay course and in likelihood may surpass the overall commitments while it continues to maintain its pathway to a 'zero carbon' pathway by 2050 or even earlier.

4 Guidelines on E-Mobility and Infrastructure

Power Ministry issued guidelines in December 2018 in a bid to streamline e-mobility by boosting charging infrastructure in the country to ensure effective roll out of the plans by aggregating policy measures at one single point [3]. Indian government thus approved amendments to guidelines and specifications for charging infrastructure. The revised policy guidelines now subsume all previous guidelines and standards with respect to provisions on making charging infrastructure available in the country for a large scale off take of e-vehicles while incentivizing auto makers besides attracting investments from domestic and foreign investors in the e-mobility sector. The policy envisages a phase-wise installation of a network of charging infrastructure throughout the country to ensure that at least one charging station is available in a grid of 3 km by 3 km in the cities and one charging station at every 25 km on both sides of the highways and roads.

The new policy also addresses the concerns of intercity travels and/or heavy duty EVs such as buses and trucks providing for installations of fast charging stations at every 100 km on each side of the roads and highways. Furthermore, there are provisions for providing highways connected with the megacities with the charging infrastructure.

5 Distribution Grid Upgrades

Introduction of these guidelines by the Ministry of Power, in providing charging infrastructure for EVs portends well both as an incentive for new entrants in this segment and also for the people willing to buy EVs clearly directed at cleaning u pollution and polluted air in cities in a bid to avert and control climate crisis.

Electricity is poised to emerge as the dominant fuel for automotive transformation in the decades ahead. However, in order to meet the demand for the power that the transportation electrification (TE) will create, utilities must perform a tricky balancing act. They need to invest in upgrading the pipeline for that fuel-the transmission and distribution system (or the grid) without triggering excessive upward pressure on the consumer electric rates [4].

6 Commercial Trade Offs

This scenario would bring about trade offs for utilities both in their pricing mechanism and regulatory regime both at the sub-regional and federal levels. According to an estimated modeling scenario involving revenues, costs and retail rate impacts for a "representative" utility with 2–5 million customers, it is likely that the representative utility, depending on the charging patterns, would need to invest anywhere between USD 1,700 and USD 5,800 in grid upgrades per EV through 2030 [5]. As these large invested resources will also likely get translated into deciding the rate base, it is expected to be passed on to the consumers in price sensitive Indian markets.

In majority of scenario, it is likely that there will be rate pressure on customers. It is further estimated that at the high end, the rates could increase 1.4 cents per kilowatt-hour (kWh) or 12%, from an assumed baseline rate of 11 cents per kWh.

7 Conclusion

India has since started its EVs pathway with the hindsight benefit of being a second mover in this segment. It can leapfrog into a leadership zone in the EV segment by quickly innovating and transforming the auto market and allied segments, while attracting investments on the back of its large domestic market and potential to export in the region besides generating millions of green jobs.

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Disruptive Innovation in Utilities

Prakhar Chaudhary, Tanmay Dalal, and Sanjay Singh Rawat

Abstract The power utility business is constantly exposed to regulatory constraints, policy changes, varying economics, technology and customer preferences. In order to exist in this competitive market, utilities need to facilitate uninterrupted power supply with efficient load distribution and minimize downtime with timely maintenance. The rapid growth in IoT, robotics and connected technologies are forcing traditional power utilities and industry participants to adapt, or be outpaced by strong new entrants possessing the benefits by these technological advancements. This paper proposes solutions to utility applications using disruptive technologies by highlighting specific use cases such as transforming customer experience by leveraging power of edge computing, quantum computing, robotics, cost effective maintenance of assets using image analytics, enhancing workforce efficiency by using augmented reality and virtual reality etc.

Keywords Internet of things (IoT) · Compound annual growth rate (CAGR) · Information technology (IT) · Artificial intelligence (AI) · Edge computing · Quantum computing

1 Introduction

Emerging technologies plays a crucial role on power utility industry. Technology that impacts on the electricity system in the future comes in two categories: enabling technologies and disruptive technologies. Technology innovation at the grid edge is disrupting the utility sector, forcing policymakers and utility leaders to explore new regulatory frameworks, and to enable new business and operating models for

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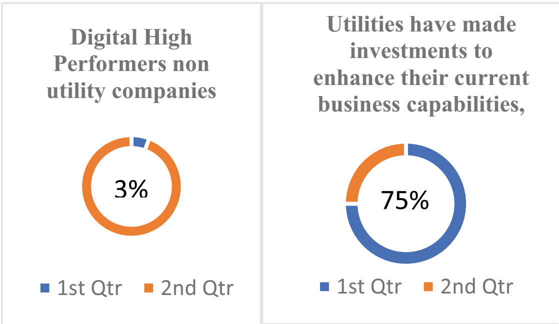
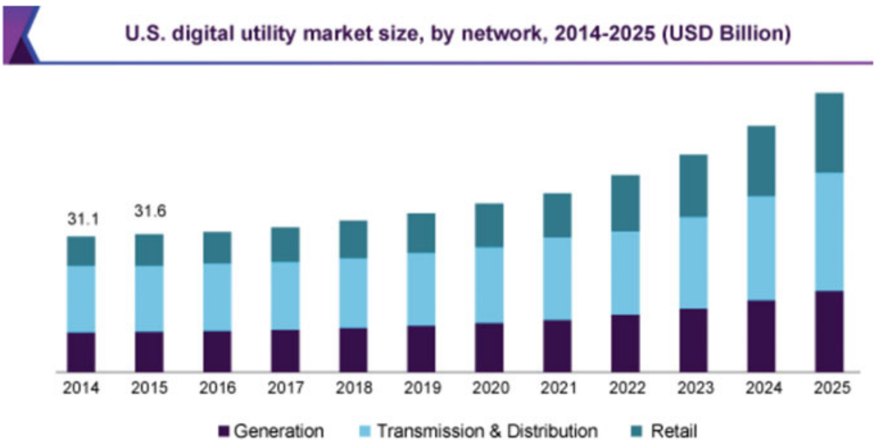
more sustainable energy provisioning. Major technology forces such as the **Edge Computing**, **Quantum Computing**, **Robotics**, **Digital Twin** will impact utilities.

Currently we are in the Fourth Industrial Revolution (4IR) which is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres, collectively referred to as cyber physical systems.

A recent study shows that most companies can use digital technologies to create business efficiencies, but few are currently using them to substantially improve their performance for the long run.



According to a report, the global digital utility market is expected to reach a market size of USD 253 Billion by 2023 at ~12% CAGR.



As per a research report it is projected that utilities will spend $14 Billion per year throughout 2023 to modernize and build smarter infrastructure through digital transformation. Along with the opportunities and benefits of technology, utilities need to overcome major challenges while adopting disruptive innovation. Some of the challenges are described below.

2 Challenges

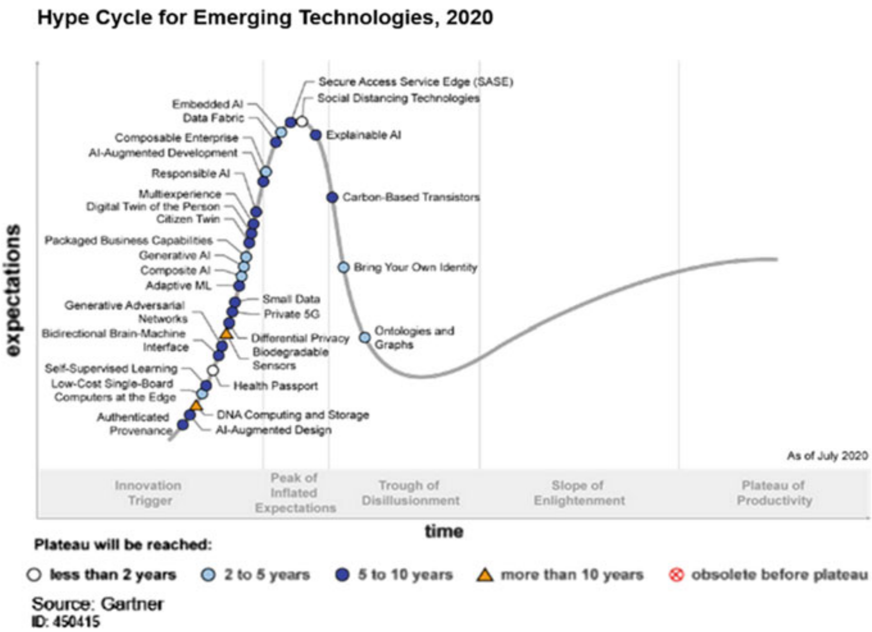
Technological and economical changes are expected to challenge and transform the electric utility industry. Some of the challenges are described below:

- Building a modern and flexible IT infrastructure to foster data driven innovation.
- With the adoption of smart meters and devices, the quantity of data is not usually an issue for utilities, but often the data usability is less.
- Adoption of new technologies both by utilities and their customers will force utilities to form new partnerships both with the end which creates interoperability challenges for utility companies.
- Innovation is often driven by consumer pressure to reduce costs.
- Ensuring cybersecurity.

The challenges in utility firms are diverse. Along with the complexity of the utility value chain and fast-evolving evolutions thinking ahead and grasping the benefits of "new technologies" is key in this extremely competitive and sensitive market with many fluctuations in the broader ecosystems.

3 Purpose of Technologies in Utilities

Digital technologies and innovations including edge computing, quantum computing, robotics, AI, blockchain, cloud, analytics, and IoT are providing utilities with the opportunities to disrupt business models. Technology innovation has become the key to competitive differentiation and is the catalyst for transforming many industries. Breakthrough technologies are continually appearing, challenging even the most innovative to keep up.



Let's look at some of the technological evolutions playing a crucial part in the utilities industry.

4 Edge Computing

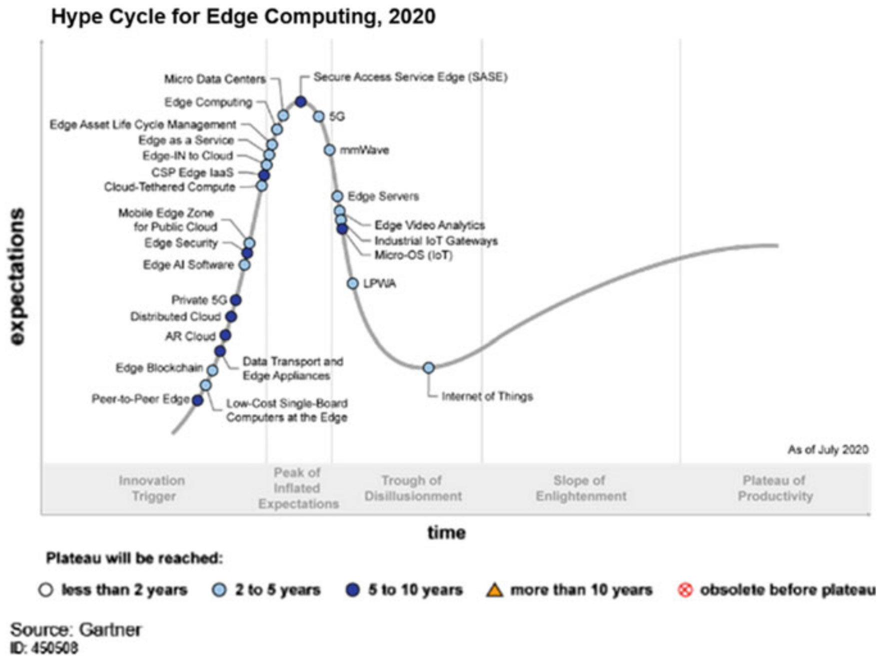
Edge computing allows data to be processed near the physical location of those sensors and devices, serving as a decentralized extension of campus networks, cellular networks, data center networks or the cloud.

Through 2025, the edge hardware infrastructure opportunity will grow to $17 billion but is skewed toward incremental growth of existing applications. IT market players such as IBM, Microsoft, Cisco etc. are doing heavy investment in the Edge Computing technology.

Below hype cycle shows trend and the maturity level of different technologies at present and in near future.

Following are use cases of edge computing identified in energy and utilities.

- Smart meters to prevent theft and reduce expenditures associated with utility meter reading.
- Tracking the condition of equipment to improve maintenance.
- Real-time tracking of worksite safety conditions.
- Augmented Reality based on Edge computing for underground network analysis.
- Virtual Reality based on Edge computing for field force training.

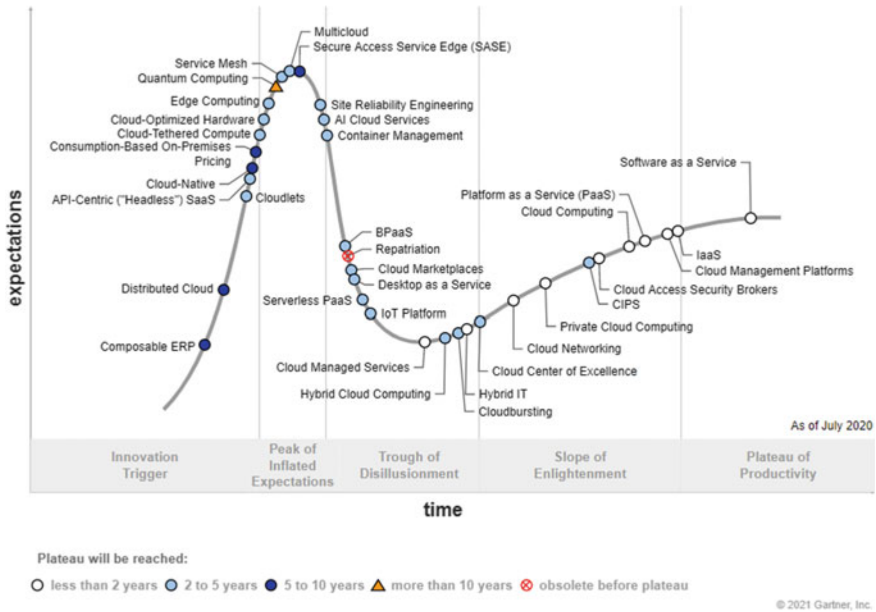


5 Quantum Computing

Quantum computing provides a new paradigm to solve complex optimization problems. A quantum computer processes information differently than a conventional or 'classical' computer in two fundamental aspects.

Below hype cycle showing trend for Edge Computing.

Hype Cycle



Following are use cases of Quantum Computing identified in energy and utilities.

Quantum grid: Advanced technology research has considered using the qubit as a solar cell. A quantum dot is a nanoscale particle of semiconducting material that can be embedded to make quantum batteries.

Grid cybersecurity: Power grid infrastructure in today state is vulnerable towards security breaches. If utilities don't apply quantum encryption to the grid, hackers will be easily able to penetrate it. Adding quantum keys to encryption could make it possible to create hack-resistant algorithms.

Quantum load pattern monitoring: Using quantum computing could help achieve precise knowledge of energy consumption. Quantum calculations can bring almost infinite accuracy to understanding smart meter consumption and event data in developing non-intrusive load monitoring capabilities, as well as providing load analysis and harmonic spectrum analysis to improve the efficiency of power consumption and spot inefficiencies.

Customer analytics: Quantum computing can build on insights by assuming new data sets as well as working on intense number crunching using the data explosion from smart meters, digital channels, and smart homes. Customer analytics will enter a new phase when machine learning on an entire customer analytical record (CAR++) is executed on a quantum computer.

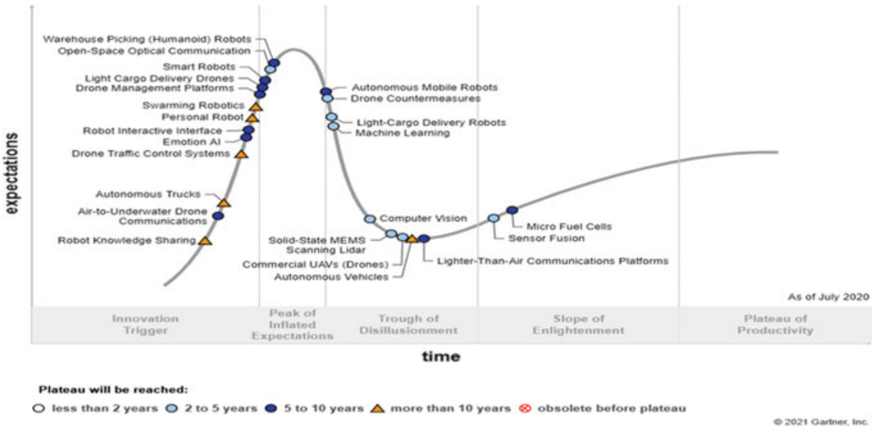
Many companies have started investing heavily in the quantum technology such as GE, IBM etc.

6 Robotics

Robots and drones play a crucial role in the power utilities space as companies are increasingly using robotics to handle the inspection of risky, time-consuming, and hard to reach assets, as well as maintaining the assets and improving their operations.

In current scenario there are three main use cases for robotics in utilities: inspection of assets, automated and remote maintenance, and the handling of nuclear materials.

Hype Cycle



Use cases	Companies developing
Automated cleaning solutions for solar PV panels	Alion Energy
Drone based asset monitoring and inspection	Airpix, Dronitech
Mobile/wheeled unmanned robots to monitor substation equipment	Smprobotics
Visual inspection of the boilers, turbines, and generators, coal stockpile volume calculation, smokestack inspections	Wingtra

In addition to these established use cases, utilities are also likely to be indirectly influenced by a number of developments in the robotics arena in the longer term such as provide a significant source of data for utilities including mapping dangerous or inaccessible parts of utilities' infrastructure that can then support training, planning, and maintenance, installation and setup of technologies such as offshore wind and solar panels, conducting search and rescue in the field independently.

7 Conclusion

The digital developments reshaping the future energy system are socially, environmentally, and commercially game changing. Both the disruptors as well as the Digital High Performers remind us that stronger outcomes (i.e., growth) may be possible from a digitally enabled business model. Yet, many utilities believe the lower-risk approach is to manage more effectively in the current context and pursue changes to the business model at some future point. However, not seizing the current opportunities raises the risk of a low-growth future.

Utilities companies need to create and execute business models that use digital technology both as an enabler and a driver of change in the legacy organization. They need to master the ability to renew and transform their current core business while growing into new businesses. This is only by making a truly digital shift in an organization's business model now that utilities can power a new path to growth.

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GeoUrja—An Innovative GIS Solutions for an Electrical Network

Rohit Patel

Abstract Adoption of the Digital Technologies increasingly allow devices across the Grid to communicate and provide the data useful for the customers and for the grid management and its complex operations. To develop Smart Electrical Grid, Digital information of Grid devices and their location with connectivity is a mandatory requirement. The State Power Utilities do not have accurate data of the Network at their disposal. The asset details whatever are available are a partially digitized information of the Electrical Network and same is not updated, as per the real time changes. To digitize fully the Electrical Network, we require specially designed GPS receivers (Rovers), a Base Station and a GIS software, which are proprietary products of the Venders. But obviously, due to its vulnerability, it cannot match or handle the requirements on a large data scale. Also, it is difficult to develop and manage large Electrical Network of the Government Utilities, with multiple integration, amendments and changes. An innovative platform of GeoUrja is a topology analysis method to establish for a Power Distribution Network model, the connection between electrical equipment can be generated automatically according to the terminal position of the equipment primitives. It is a cross platform and open-source desktop application framework, the topology data is organized and modelled. 'GeoUrja' will extend the range of asset information, data modelling, integration and make analytics for a better Management Decision Support System and the better customer services.

Keywords Distribution network · GPS · Open-source GIS · Spatial database

1 Introduction

GIS (Geographic Information System) has characteristics of intuitive display and supports efficient spatial analysis and topology analysis. The Electricity utilities need to have two types of geographical information: (a) a distribution network containing crucial technical information and (b) geographical locations of the numerous poles,

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lay of the power lines, circuits, transformers, switches, etc., consumers and associated billing information. GIS has emerged as a powerful tool for the development of geo-referenced consumer and network maps for Power Distribution Utilities.

By taking full advantage of the object-oriented technology, each type of equipment is abstracted to the specific primitive object. When user draws the power wiring diagram in the GIS interface, the software will automatically generate the primitive object of the electrical equipment. The connection node object will be generated automatically according to the terminal position of an equipment primitives. It includes the equipment primitives joined together, so the connectivity of the electrical equipments can be generated automatically.

2 Limitations of the Present System?

The DISCOMs or the Power Utilities possess a random asset mapping. Still, major part of the network is not digitally mapped and no location based information of the assets and the network components is available. This entails the random analysis and improper, erroneous results. Besides, the inappropriate lay of the network leads to mislead calculations. Many GIS Programs and traditional Asset Management Programs (primarily asset-class specific tools) have complex system architectures. Therefore, integration and interfaces between them can be very complicated. GIS is often considered a planning function while asset management is considered engineering and/or maintenance function. Organizational alignment and understanding can make it difficult to coordinate. The biggest problem the Power Utilities are facing is storing the historical data and updating on account of the real-time addition, alteration and changes on the field. As the Utilities' work with area vise local server and different proprietor GIS platform, it becomes utmost difficult to manage with the data.

3 Inovative Solution—GeoUrja

An Innovative GeoUrja System is designed with Easy Survey Mobile Application, which simplify the process of mapping, managing and monitoring the overall state of the entire Transmission/Distribution System. Open-source cross-platform of GIS Cloud technologies will help the utilities to manage relevant information about customers, distribution and transmission network with a perfect overview of the entire system, visualized on a Map. Graphic data and Attributed data are stored in uniform by using open-source spatial database PostgreSQL/PostGIS.

Newly developed Easy Survey Android Mobile Application designed for combined GPS tracking and network line drawing methods to achieve maximum time efficiency and accuracy when mapping and managing large areas covered with the electricity distribution and transmission network.

4 Easy Survey Mobile Application

Main functionality of Easy Survey Mobile Application is to collect data because it is inevitable in GIS system. There are two types of data in GIS. The first one is called spatial data which is in relation to spatial location and spatial relationship; the other is called attribute data, which is the non-spatial attribute information of geographic entity. In the traditional applications, the data mentioned above are stored separately. Attribute data is stored in relational database and spatial data is stored as a file because of its particularity. With the development of database technology, it is the direction that GIS software describes and stores spatial data in an object-oriented manner.

Easy Survey Mobile application is used for the GPS survey of an existing electrical network and the consumer locations, by using a User's smart mobile device. The GPS data will be plotted on geo-referencing of area for designing and preparation of the overhead and underground network system. Every feature (locations, attributes, etc.) has to be incorporated accurately with the respective object of the network.

The position of an electrical poles, transformers, switching devices, cable route points etc. shall be marked on the drawing furnished as shown in Fig. 1. According to the characteristics of electrical equipment in a Transmission/Distribution Network, the equipment primitive is designed to meet the requirements of power industry in the aspects of relevant symbols. These symbols attribute such as color, line type, line width and so on are used to represent different segments of the running states and different component types.

As shown in Fig. 2, the same Mobile Application has additional functionality to utilize the point buffer analysis function of GIS development platform, by traversing the bus objects and terminal objects as listed under.

- Feeder network information with HT and LT network over the satellite image
- Consumer basic detail

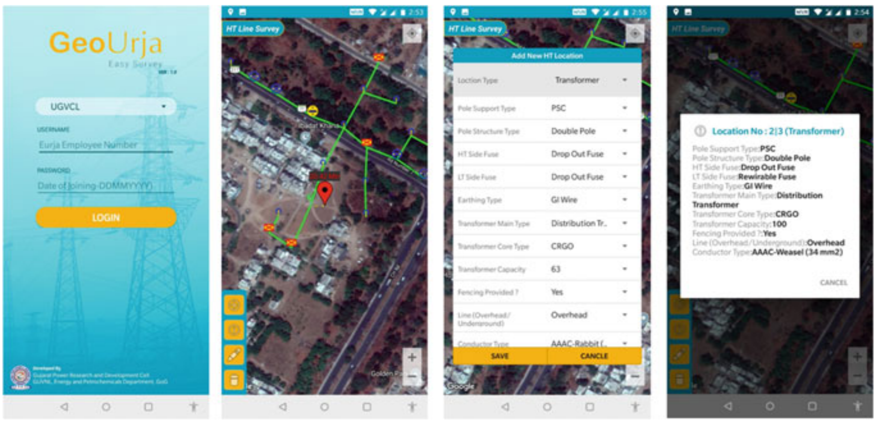

Fig. 1 Easy survey mobile view

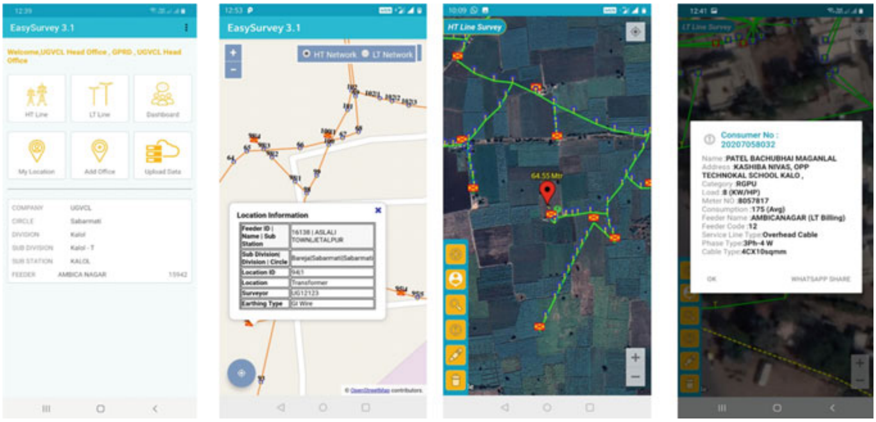

Fig. 2 Mobile application functionality

- Geo Navigation option for consumer and electrical asset search
- Overhead/Underground network information as per the current location of user
- Real time information of power flow from the selected devices

5 GeoUrja—Dashboards

The GeoUrja system, which gives us a digital view of the electrical network over the land base map, this will be helpful for providing information of the assets and the consumers. A User will get the location wise real time information of the Power Network. The asset mapping has made it possible to assess the network in the right perspectives, which, further, improvised the accuracy of the calculations on the network parameters, on actual and real time bases.

The processes related to the network enhancement became easier and faster leading to an accurate re-designing shown in Fig. 3. The use of this tool completely eliminates the human error arriving at a resultant parameters after addition/removal of a load to the existing network. The updating in the network and its parameters is quite an easy task and the trace and the track is quite easy and precise. This helps the field staff to mitigate almost all the issues digitally, which were earlier made manually.

6 Outcome

The asset mapping, inventory in details and the consumer array linkage has always remained at the bay for any of the Utility. For the digitization of all the segments of the Power Sector the GeoUrja is a unique and comprehensive tool, which serves

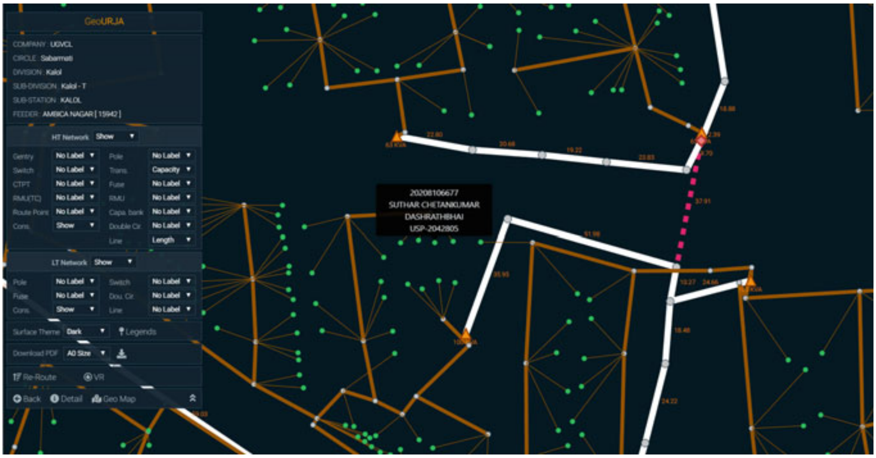

Fig. 3 Vector view of electrical network

almost all the requirements successfully. It shortens the operating and operative time and significantly reduces the effective cost. It effectively deals with and reduces the time consumed for the fault finding, redressing the complaints, restoration of the power supply and enhance the services.

The fault location finding shall be easy and quick, and the power supply restoration time will get reduced. The consumer location search and navigation is possible in mobile for quick redressal of a consumer complaint with the help of this new developed system. Thus, consumer satisfaction level will improved (Fig. 4).

The extensive and continuous GIS surveying of Electrical Network together with the consumer and billing information is providing utility managers with an improved operational and decision-making tools. Before making any kind of decision, utility

Fig. 4 Real time outage information of valuable consumers

Fig. 5 Outage information of electrical network and consumer affected

managers are using the GIS database to answer important spatial questions such as where are the most suitable areas to place a new transmission line or where are the areas with most power outages and various system overloads. The parameters like voltage profile and the anticipated load pattern are made out very precisely (Fig. 5).

The consumer indexing and integration with the billing database as per the Network Topology helps to assess accurate energy accounting of the system.

One of the benefits of the GeoUrja is that, there is no need for extensive education to the Technical Staff/Employees. The solution is implemented in the workflow immediately and it is suitable for even a non GIS users as well as professionals. The option to collect line features in the field with high GPS accuracy and storing them in the database can increase time and cost efficiency of the entire organization as it offers more convenient way to collect the data. The greatest benefit is the real-time coalitions between top management and field operators where maps and layers can be shared with different levels of the access and assess.

7 Result Achieved/Value Delivered to the Beneficiary

To organization: The GeoUrja is a platform which accommodates and demonstrates the tools used to operate the enterprise functioning for the power sector utilities. It acquires the real-time and historical information of the energy data. The Enterprise Solution "GeoUrja" will cover the range of the information about the asset information, data modelling, integration and make analysis for better management Decision Support System for improvised customer services.

To citizen: "Sampark" platform under the GeoUrja is developed for quick information of Electric Network as per the consumer complaint shown in Fig. 6. The complaint addressing and restoration goes faster as the grievances management system and the device operational functionality are well defined.

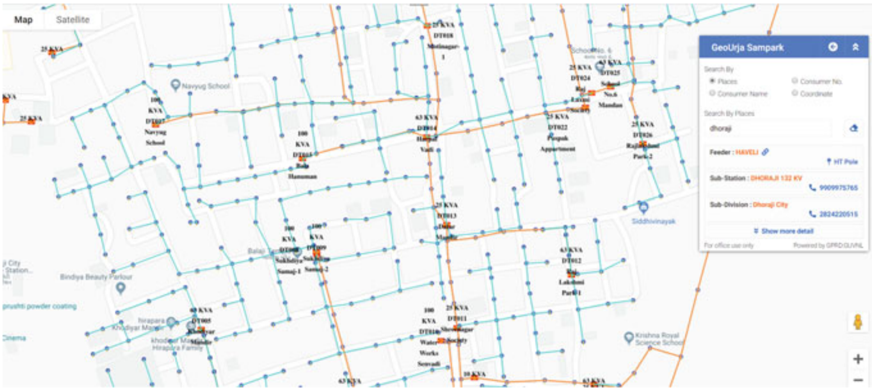

Fig. 6 Network information with maps and other layers

Other stakeholders: The significant reduction on the man-hours leads to relieve the staff in the field, psychologically and physically. This reduces the stress level and thereby, the working environment improve leading to a better organization to work with.

8 Conclusions

There are many asset mapping tools available in the market. Nevertheless, this tools has been developed by the engineers who, actually have worked in the field. But obviously, the related issues are properly taken care of and is made the most user friendly. The required field operations are designed so, neatly that the utility can make the assessment of the system and its parameters at no loss of time and that too, precisely. GIS will provide the geographical organizational aspects of Business Intelligence (BI) and Data Analytics (DA) capabilities. Whether, it is analysis of Networks or display of Key Performance Indicators, the results will come from time-series simulations that much more nearly model real time network performance.

The continuous population growth and the expansion of the cities/urban areas demands for a growth of Electric Distribution Systems. With the GIS Cloud Map Editor, utility managers can create spatial queries based on the information stored in the database. By analyzing various parts of the distribution system, the utility managers can identify areas with aged infrastructure, areas with overload in system components, areas with various system loading conditions and areas with frequent power outages due to the possible electricity theft. The insights from spatial analysis can help planners and engineers to improve the power supply and asset management, in the context of planning the new transmission lines or cables, resolve outages and improve consumer services.

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New Trends in Smart Billing and It's Efficiency for Smart Cities

Ram Avtar

Abstract Smart energy billing system is a humble attempt to eliminate the waste of time in taking meter reading and also to reduce human efforts. Smart meters have brought big revolution in the fields of energy and power measurement. Worldwide at so many places smart meter billing system has been already deployed but in India like in Uttar Pradesh it's just a beginning of smart meter billings deployment. This work describes the key elements in a Smart Meter Billing system and compiles the most employed technologies and standards as well as their main features.

Keywords Android Mobile Billing Application (AMBA) · Central Billing System (CBS) · GSM

1 Introduction

Deployment of advanced metering systems or Smart Metering is one of the basic techniques to reach this goal. At present all over the world smart city development [1] is becoming famous day by day with the upcoming advancement in technologies of smart meter cloud based billing service. In this paper we will discuss about the new trends in smart billings.

1.1 Objectives and Scope of Work

Objectives of new trend in smart billing is to determining the electricity bill generation using efficient android mobile billing application (AMBA) and smart meter technology enables discom/utility to issue paperless electricity bills via SMS, e-mail, whatsapp. Definitely new technologies have a wide scope of work to improve our energy metering, billing, collection and bill distribution system.

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2 Conventional Method Spot Billing Machine (SBM)

The Spot Billing system is a system, in which the meter reader visits the consumer's premises, records the meter reading in SBM and issues bill on the spot using a HHD or SBM. The spot billing process helps in integrating various activities being handled by several people at multiple locations into a single window operation.

Spot billing machine

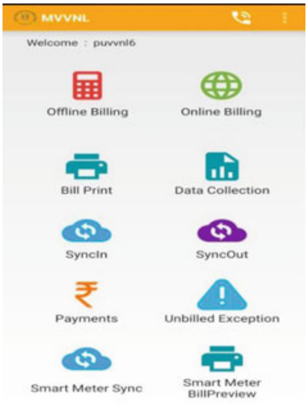
In Uttar Pradesh UPPCL also using Trust Billing (TB) AMBA Dashboard Concept, in which consumers can bring their meter readings at E-SUVIDHA/CSC. E-SUVIDHA/CSC operator punch meter reading brought by the consumer in computer, which is connected to CBS through a dedicated communication link. Bill is generated in the CBS and printed bill delivered to consumer at E-SUVIDHA/CSC for payment.

3 New Trends in Smart Billing Using Android Mobile Application Technology

(1) Android Mobile Billing Application (AMBA) Online& Offline.
(2) Android Mobile Billing Application (AMBA) Online & Offline Based On PROB (Optical Sensor).
(3) Android Mobile Billing Application (AMBA) Real-time Online.

(1) Android Mobile Billing Application (AMBA) Online and Offline

Consumers billing data in Excel sheet encrypted for android mobile application and loaded on billing cloud for android mobile based billing. In Android Mobile Billing Application (AMBA) enables Meter Reader to get access specified DT Code area Consumer's for billing by login and this process called SYNC-IN. Meter Reader has to visit door to door for meter reading and needs to punch it manually in AMBA. After bill generation printed bill deliver to consumer for payment. In this process bill generated but not updated on CBS until meter reader use command SYNC-OUT in AMBA.



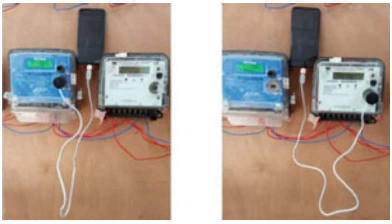
AMBA dashboard

In this Process bills generated before SYNC-OUT called android offline billing and after SYNC-OUT it called android online billing. Meter Readers usually complete SYNC-OUT process at the end of day session of billing. Consumers got SMS on their registered mobile about electricity dues after SYNC-OUT process. In this way consumer got electronic electricity bill or paperless bill. In AMBA Consumer's billing data daily updated itself by CBS, So Meter Reader's start billing as per billing schedule. In AMBA meter reader can also punch various billed/unbilled exceptions also.

(2) **Android Mobile Billing Application (AMBA) Online& Offline Based ON PROB (Optical Sensor)**

AMBA online and offline based PROB (Optical Sensor) is same as previously discuss AMBA Online Offline method, only difference is meter reader do not punch energy consumptions manually rather then he is using PROB (Optical Sensor) to fetch energy meter reading in AMBA. Optical pulse sensor for detecting LED pulses from Utility Meters. This optical pulse sensor can be easily stuck on to the front surface of any utility meter with an LED pulse output. The optical reading head is manufactured in accordance with the standard IEC 62056-21 (IEC 1107).

Prob (optical sensor)



Prob (optical sensor) connection

(3) **Android Mobile Billing Application (AMBA) Real-time Online**

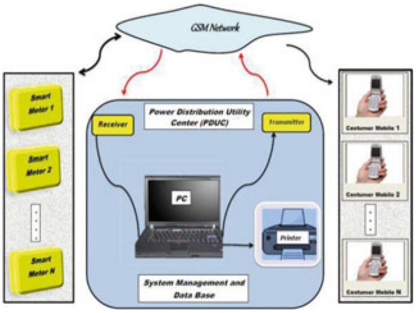
Advancement in technology electricity billing system improved much. UPPCL now focus on customer services and going more smart way in various district of Uttar Pradesh. In AMBA real-time billing Consumers billing data already encrypted by CBS and available on AMBA cloud. In this method SYNC-IN and SYNC-OUT process removed and generated bills updated in real time on CBS with facility of sending dues SMS. AMBA Real-time concept just deployed in urban area and few in rural area of UPPCL jurisdiction.

4 Smart Meter Billing

Smart meters are improved versions of conventional energy meters that are developed after AMR and AMI. The presents design of the simple low cost wireless GSM energy meter and its associated web interface, for automatic billing and managing the collected data. A GSM [2] based wireless communication module is integrated with electronic energy meter of each entity to have remote access over the usage of electricity. A PC with a GSM receiver at the other end which contains the database acts as the billing point. Live meter reading from the GSM enables energy meter is sent back to billing point periodically and these details are updated in a CBS. The complete monthly usage and dues of bill messaged back to the customer after processing these data.

Single Phase Three Phase

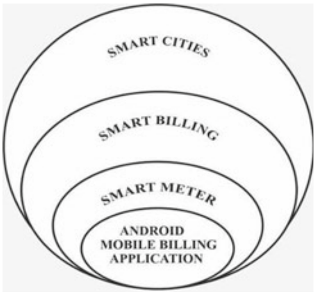
Smart energy meter



Smart energy meter billing via GSM [2] network

5 Billing Efficiency

Billing efficiency is to measure efficiency of the proportion of energy billed out of supplied energy of both metered and unmetered sales to consumers. Real-time communication between DISCOMs and consumers, smart billing meter data can ensure and improve billing efficiency. Replacement of conventional meters with smart meters, billing efficiency can improve from 80 to 100%, and also increase collection efficiency.



Smart billing hierarchy [1]

Smart Meter Performance December 2020							Total Android Mobile Bill Performance (Online + Offline) December 2020				
zone	Total Smart Meter Count	Smart Meter Billed Count	Smart Meter Billed%	Total Input Energy (KWH)	Smart Meter Billed Energy (KWH)	Billing Efficiency (%)	Total Bills Count	Total Online Android Mobile Billed Count	Total Offline Android Mobile Billed Count	Total Android Mobile Billed Count (Online + Offline)	Total % Android Mobile Billed Count (Online + Offline)
#	**1**	**2**	**3(2/1)**	**4**	**5**	**6(5/4)**	**7**	**8**	**9**	**10(8 + 9)**	**11(10/7)**
Bareilly Zone	55,932	54,568	97.56%	19,098,800	18,334,848	96.00%	418,334	67,467	98,434	165,901	39.66%
Lucknow Zone	382	357	93.46%	52,000	50,440	97.00%	349,631	81,454	144,089	225,543	64.51%
Ayodhya Zone	22,639	22,181	97.98%	6,654,300	6,321,585	95.00%	161,710	34,176	108,982	143,158	88.53%
Gonda Zone	78	68	87.18%	6500	6175	95.00%	97,494	30,253	37,510	67,763	69.50%
CESS Gomti Lucknow City	187,408	182,498	97.38%	54,749,400	52,559,424	96.00%	453,579	67,281	71,260	138,541	30.54%
Trans Gomti Lucknow City	109,165	104,218	95.47%	31,265,400	30,014,784	96.00%	391,813	69,885	0	69,885	17.84%
MVVNL	**375,604**	**363,890**	**96.88%**	**111,826,400**	**107,287,256**	**95.94%**	**1,872,561**	**350,516**	**460,275**	**810,791**	**43.30%**

6 Conclusion

GSM enable smart energy meter data and AMBA helps discom/utility to address issue of consumer's energy meter billing. Making smart metering even smarter are cellular communication options enables DISCOMs maintaining a billing network. Cellular technology also gives smart meters inter-operability, coverage, and capacity. This translates to smart meter software that can be updated over the air, like Smartphone apps. Utility providers using smart meters are transitioning to 2G/3G/4G LTE connectivity, which can facilitate innovative solutions in metering and billing.

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Enabling Smart Energy Communities Through PEER Strategies

S. R. Sanjay Kumar and Ishaq Sulthan

Abstract Developing a smart grid is all about leveraging information and communication technology to bring advancements in power system efficiency and reliability. Also, resilient enhancement is crucial for cities, communities, and campus buildings so as to provide a stable power supply for critical loads and essential services during natural disasters and major grid failures. Communities can emphasize the smart grid abilities which improves grid flexibility and provides resilient power options to the consumers. Smart grid enables greater penetration of customer's local renewable and/or clean energy sources (Distributed Energy Resources (DERs)), coupled with energy storage helping in maximizing their electric grid reliability and resiliency. Also, DERs connected to the grid encourages the consumers' participation in the grid services, enabling the role of prosumers. These greater abilities of smart grids will help in minimizing the transmission and distribution losses and the costs associated with it. Smart grids provide more insight into the electricity grid's operational health with the advanced metering and cyber secure communication infrastructure, enabling automatic outage detection and service restoration, making the electric grid strong and smart. GBCI's PEER (Performance Excellence in Electricity Renewal) is a comprehensive framework that assists any city or campus in evaluating their power system performance and encourages the adoption of new technologies that can strengthen a community's access to reliable and resilient power. This paper talks on how PEER strategies provide a roadmap to enable smart energy communities and can facilitate the grid modernization efforts globally, through a case study.

Keywords Smart grid · Grid modernization · Renewable energy · Distributed energy resources · PEER · Advanced metering · Cyber-security

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1 Introduction

Over the last several years, we are experiencing different types of disasters—both natural and man-made disasters such as storms, floods, wildfires, cyber or physical attacks etc. And, our electricity grid remains vulnerable to these diverse threats which causes extensive damage to the grid assets resulting in prolonged outages or blackouts. Power outages are impacting the bottom line for industries and critical facilities across nations.

Hurricane Sandy (2012) was one of the most devastating storms to impact Connecticut's overhead electric distribution network, resulting in over 15,000 outage locations that affected more than 500,000 customers [1]. On the economy, the annual cost of power outages (in 2012 USD) has been estimated between $28 billion to as much as $209 billion, with annual weather-related outages estimated to cost between $25 billion to $70 billion. Also, the U.S. Department of Energy (DOE) estimates power outages are costing American businesses around $150 billion per year [2].

The ways to reduce these potential impacts of disasters on energy infrastructure are to invest in modernization and hardening power systems because, a strong and resilient grid is vital to any nation's security, economy, and quality of life. Investments should also go towards expanding the efforts to improve the ability to maintain and restore power to critical services to hospitals, first responders, water supplies, and communications systems. To drive the required infrastructure upgrades, we need to implement market-based performance tools that help in creating a resilient and sustainable future.

PEER (Performance Excellence in Electricity Renewal) is one such universally applicable tool that supports the energy industry in developing the most reliable, scalable and resilient grid possible. PEER is the world's first certification program that evaluates and improves the power system performance and electrical infrastructure of cities, utilities, campuses and transits. It measures power system performance based on 36 credits [3] classified across 4 categories which are:

- Reliability and Resiliency
- Energy Efficiency and Environment
- Operations, Management and Safety
- Grid Services

This paper details the PEER strategies that provide cities and communities with a framework to implement microgrids with distributed energy resources and integrating it with communication networks and smart devices to enable smart energy communities.

2 Need For Smart Energy Communities

The main need for smart energy communities is to adopt grid design and hardening practices that leverage smart grid and its supporting technologies. Smart energy communities are beneficial as they:

- Increase use of digital information to improve power reliability;
- Improve security, and efficiency of the electric grid;
- Optimize grid operations;
- Develop and incorporate demand response, and energy-efficiency programs, and
- Increase flexibility—encompassing system components from generation to demand to storage.

Smart grids transform the existing grid into a better infrastructure of transmission and distribution. The grid will be able to handle bidirectional energy flows, allowing for possibilities of energy generation from multiple sources such as from solar photovoltaic (PV) panels on building roofs, charging to/from the batteries of electric cars, wind turbines etc., unlike conventional grids that support one-way flow of electricity.

Cities and communities can make the grid more reliable and resilient through the development and demonstration of digital technologies and smart grid strategies. These minimize the possibilities of outages, reduce the impacts, speed recovery during any disasters or threats and improves the values of reliability metrics SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index) specified in IEEE Standard 1366 [4].

These characteristics of smart energy communities viz. distributed energy resources, digital communication technologies, smart metering etc., will be discussed below in correlation with credits of PEER Rating System.

3 Technologies that Enable Smart Energy Communities

3.1 Microgrids and Distributed Energy Resources

Microgrids have become a vital innovation for the power and electricity industry. They provide flexible and efficient power options by reducing losses, allowing places to maintain power when the larger grid is down, provide resilience and mitigate disturbances.

Microgrids enable relatively fast deployment of city or community owned distributed energy resources (DERs), improves grid cybersecurity, and strengthens distribution-level systems. DERs are important for emergency preparedness and recovery in a disaster. If a wildfire or a hurricane strikes, communities need to be self-sufficient, perhaps for several weeks or longer. Microgrids can reduce the number of customers de-energized during any disaster events, as well as provide additional impact mitigation by energizing shared community resources that support the surrounding population.

DERs offer advantages to the nation's energy system that large-scale, capital-intensive, central-station power plants cannot provide. DERs paves the way to increase the percentage of electricity generated from local renewables and/or clean generation technologies. These enable customers to offset their load during peak demand situations (peak-shaving [5]) using local generation or storage systems, when utilities send the demand signals. Otherwise, peak demand charges can sometimes make up most of a customer's electric bill and thus, using DERs to reduce these peak charges can generate significant cost savings for customers. DERs also make customers to engage in grid services by turning into a prosumer, who can both buy electricity from the utility and sell electricity from the local generation sources or storage systems. These strategies benefits the utility by offsetting the need for dispatching expensive generation and also helps in reducing the dependency on fossil fuel-based power generation and its global impact on climate change due to the carbon emissions.

Having determined the local generation percentage, which indicates the percentage of electrical load served by local renewables or clean generation technologies or battery storage systems, one can analyze and implement the DERs needed to support their load demand, including essential and critical loads. This helps cities and communities to ensure uninterrupted power for critical loads and essential services during emergencies that supports community recovery. PEER has recognized these efforts through Distributed Energy Resources and Power Surety and Resilience strategies and requirements respectively.

3.2 Communications Network and Monitoring Systems

The smart energy grid with the help of information and communication technologies (ICT) can improve fault detection and help in self-healing the network without the intervention of technicians, which provides quick power restoration and makes businesses function as usual. Supervisory Control and Data Acquisition (SCADA) or Master Controller plays a key role in enabling grid automation with the capability to monitor and control the whole energy infrastructure remotely. These systems in coordination with advanced meters, ICT and Geographic Information Systems (GIS) [6] addresses the additional capability required for a community to island itself from the main grid during its failures, and address the demand needs with real-time coordination of DERs, storage, and customer loads.

These technologies provide real-time data to both customers and utilities to understand the potential impact of emergency events and act in real-time to mitigate problems and avoid outages before they cause major disruptions.

Through PEER credits—Advanced Metering Infrastructure (AMI) and Master Controller, cities and community projects are advised to permanently install advanced meters for all the customers and master controller to optimize and control the electricity system in real-time. Among the power system design strategies, through Distribution Redundancy and Auto Restoration credit, PEER makes project to ensure that grid power can be supplied via multiple distribution pathways and if the circuits can be automatically re-energized during any faults. Thus, these strategies enhance the overall grid performance and improves the power system reliability and also provides customers with an ability to manage their energy use through smart energy infrastructure.

4 Cyber Security of Smart Energy Infrastructure

Apart from natural disasters, smart energy infrastructure needs to be protected from cyber-attacks, as they are connected to internet and are more dependent on cyber-physical systems such as SCADA and Industrial Control Systems (ICS). Ukraine's power system faced a blackout in December 2015, due to a cyber-attack on their SCADA system, affecting 225,000 customers [7]. The human machine interface (HMI) was targeted, and were used by attackers to remotely open the circuit breakers resulting in total power outage. Similarly, attackers employed powerful malware to infect the ICS of hundreds of energy companies in countries like US and Europe [8].

Thus, communities require protective measures to detect, respond, prevent and recover from any cyber-attacks that does not affect the electricity delivery to customers. Projects need to follow key standards in strengthening the cyber security of the whole smart energy infrastructure. Standards NISTIR 7628 [9] and IEEE 2030 [10] provide guidelines for smart grid and ICS cyber security. It highlights a set of security requirements, practices and techniques that are required in smart grid privacy and security implementation.

PEER aims to build public confidence in grid modernization through its credit—Data Privacy and Cybersecurity. It provides projects with a framework to ensure secure network operation by developing a cyber security policy with practices such as:

- Physical access control of access points;
- Continuous and automated vulnerability scanning;
- Automatic intrusion detection and notification;
- Regular security awareness training, etc.

Smart grid allows for systematic communication between suppliers and consumers, and permits both to be more flexible in their operational strategies. This provides a way for utilities to present the customer's energy usage data in real-time and enables customers to respond demand requests either by reducing energy consumption or by switching to local energy source. This requires the customer's profile and electricity usage data to be safeguarded from unauthorized use or disclosure and ensure their fundamental right to privacy. PEER recommends projects to develop policies that ensure the integrity and confidentiality of customer data that is shared between smart devices in energy infrastructure and energy utilities.

5 PEER Project Case Study

PEER works to advance microgrid operations by certifying privately and publicly owned microgrids. A PEER Gold certified microgrid in Illinois is one of the most technologically advanced microgrids in the world. With live customer loads and having a seamless transition, this microgrid became the first in North America to have such advanced functionalities. It has the capacity to generate up to 1475 kW to power 192 residential and commercial customers within the project boundary.

The microgrid consists of natural gas generators, battery energy storage, and solar and wind generation technologies. 89% of the customers have advanced meters with a bidirectional communication system enabling customer engagement in grid services. This microgrid is the first utility to install a military-grade cyber-secure microgrid controller which enhances the resiliency of the whole energy infrastructure by eliminating every cause of failure.

Also, 100% of the project loads are provided with an alternate power supply, strengthening the power system reliability. Separate backup sources are in place for technology application center control building which controls the microgrid. With these implementations, customers have experienced very less outages, achieving SAIDI of 2.0 min and SAIFI of 0.07 numbers. As a microgrid utility, it demonstrates that—"Decentralization can help tack the energy challenges of the twenty-first century by creating an optimized way to access reliable, green and resilient grid system."

6 Conclusion

Three global trends that are turning the energy sector upside-down are decarbonization, decentralization and digitization. These together compromise what is called as the smart grids. Smart energy communities offer a powerful consideration for what the electrical grid could be. With the advancements made in microgrids, DERs, battery storage technologies, vehicle-to-grid applications etc., we can rebuild a power system which is more sustainable and efficient. With the right combinations of smart energy technologies, communities have the ability to boost their energy resilience while also lowering costs and emissions.

Through PEER certification, cities and communities can assess their whole electrical infrastructure based on a comprehensive, balanced scorecard of sustainable performance criteria and can invest in the right technology that can help in transforming themselves into a smart energy community. With a main vision to deliver sustainable, reliable and resilient power systems, PEER is helping communities demonstrate leadership in designing and/or operating an energy infrastructure that adapts to the realities of human needs, finite resources and a changing climate.

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Distributed Ledger Technology Based Common GIS Map for All Domains in a Smart City

Sanjay Dhonde and Inzamam Ansari

Abstract By allowing multiple departments within Smart City to work on a common GIS map brings lots of benefits on their plate along with few challenges. One of the major challenges is in exchanging and contributing information among various departments. Distributed Ledger Technology (DLT or Blockchain) permits multiple stakeholders (departments) to own, manage and share geospatial data with other stakeholders (departments) almost in real-time. Each stakeholder has their own copy of the data and all changes done with respect to data are recorded on blockchain along with a timestamp. Stakeholders can trace the history of the updated data. A holistic vision provided by DLT based common GIS map would help in planning & coordinating various activities of stakeholders. Various stakeholders within a smart city like Civil Department, Drainage Department, Water Department, Electricity and Public Lighting Department, Metro, Roads Departments, Education department can work together on DLT based common GIS map which would make existing processes fast, more effective and efficient. It would also help in disseminating information for benefit of the public at large and in making various reports like land plot report, zone confirmation report available to the public quickly and efficiently. This paper not only proposes DLT based system but also describes a prototype which was developed using Hyperledger Fabric.

Keywords Blockchain · Distributed ledger technology · Common GIS map · Smart city

1 Introduction

Blockchain is one of the technologies that has created a disruptive change in many industries. Currently, Blockchain is being used in several places and there are numerous applications of Blockchain yet to be discovered and implemented. Blockchain is characterized by its decentralized nature, immutability, high security, the integrity of data stored in the chain and its openness.

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Generally, it is found that multiple organizations within a smart city do have their own copy of geospatial data. This data becomes obsolete after some time in case it is not updated on regular basis. As these organizations work on their own data, they face challenges in working with each other as data is not up to date or synchronized among themselves. Also, there is no simple mechanism available for them where they can work together.

Distributed Ledger Technology (Blockchain) permits multiple stakeholders (organizations) to own, manage and share geospatial data with other stakeholders. There is no central authority to update and communicate data to other stakeholders. Multiple stakeholders maintain their own copy of data, update and share it with others. All the changes done on geospatial data by stakeholders are transparent and pushed to distributed ledgers through a consensus mechanism which creates trust among all stakeholders. These transactions are digitally signed by stakeholders. The geospatial data on the distributed ledger is immutable in nature. Stakeholders can track all the changes done to spatial data since inception and hence it becomes auditable. As each stakeholder has their own copy of the data which enhances data security as well.

In the next section, we give a brief introduction to Blockchain & Distributed Ledger Technology (DLT) and then a brief description of our proposed system with respect to its working. In the fourth section, we have given a description of our prototype for this application of the Blockchain. And finally, we discuss the future scope of this application.

2 Blockchain/Distributed Ledger Technology (DLT)

Satoshi Nakamoto discovered Blockchain in his paper "Bitcoin: A Peer-to-Peer Electronic Cash System" which was the foundation for the blockchain based bitcoin cryptocurrency [1]. Wikipedia defines blockchain as "A blockchain is a growing list of records, called blocks, which are linked using cryptography. Each block contains a cryptographic hash of the previous block, a timestamp, and transaction data" [2]. This system is based on the concept of a decentralized ledger which is shared between all the nodes in a network. A transaction is represented as a block that has a hash value and a hash value of the previous block. Every transaction is verified by the peer network. When a transaction is carried out, the block is linked to the previous block using its hash value. This mechanism ensures that the integrity of the data is maintained.

Wikipedia defines Distributed Ledger as "A distributed ledger (also called a shared ledger or distributed ledger technology or DLT) is a consensus of replicated, shared, and synchronized digital data geographically spread across multiple sites, countries, or institutions. Unlike with a distributed database, there is no central administrator" [3]. All blockchain is considered to be a form of DLT. Every Blockchain is a distributed ledger, but not every distributed ledger is a Blockchain. Distributed ledger technologies, like blockchain, are peer-to-peer networks that enable multiple members to maintain their own identical copy of a shared ledger. Rather than requiring a central authority to update and communicate records to all participants, DLTs allow their members to securely verify, execute, and record their own transactions without relying on a middleman.

In the next section, we will see DLT based system implementing common GIS [4] map for all domains as discussed earlier.

3 Proposed System

The proposed system can be implemented at State, District or City level. The participants on the Blockchain network could be various organizations or departments within an organization working on a common GIS map. These participants in real life could be Infrastructure Development Authorities, Land Registration Authority, Municipal Corporations or Government Regulatory Body.

A GIS map is often made up of multiple layers. For example, you might have one layer that contains the Roads information and the other might contain water pipelines, HT Towers, underground electrical cables etc. So, the Roads department would have ownership of the Roads layer, Water Department would have ownership of the Water Pipelines layer and the Electrical Department would have ownership of HT Towers and underground Electrical Cables layer. Each participant can have multiple layers and the layers are stored on the participant's own shared ledger and can be accessed by other participants. However, the owner of a specific layer can restrict access of own layers to only a few participants whenever and wherever required. This restriction can be imposed through implementation of Private Data Collection [5] in Hyperledger Fabric [6] and Streams [7] in Multichain [8].

Figure 1 shows the high-level architecture of proposed system. Participating Organization's GIS System is a web-based implementation using open source software components i.e. Geoserver [9] as a server and PostGIS [10] as a database. The integration layer is responsible for integrating Blockchain with Participating Organization's GIS System.

The participating organization's users access all layers of Map on their own GIS system. Figure 2 shows how geospatial layers data is flown from participating organization's GIS system to the Blockchain node and vice versa.

Let's see how GIS System users update their layers and share the same with other participating organizations. Lets say that user edits some of the layers and submits the changes to Blockchain using write transaction. This transaction is validated by other validating Peers on the blockchain network. On successful validation, the participating organization's ledgers do get updated layer almost in real-time. Blockchain Platform sends out a custom event notification to Blockchain clients which in turn notifies GIS system of the participating organization.

Thus, the participating organizations who have access to these layers do get the recent changes along with the notification on their GIS system.

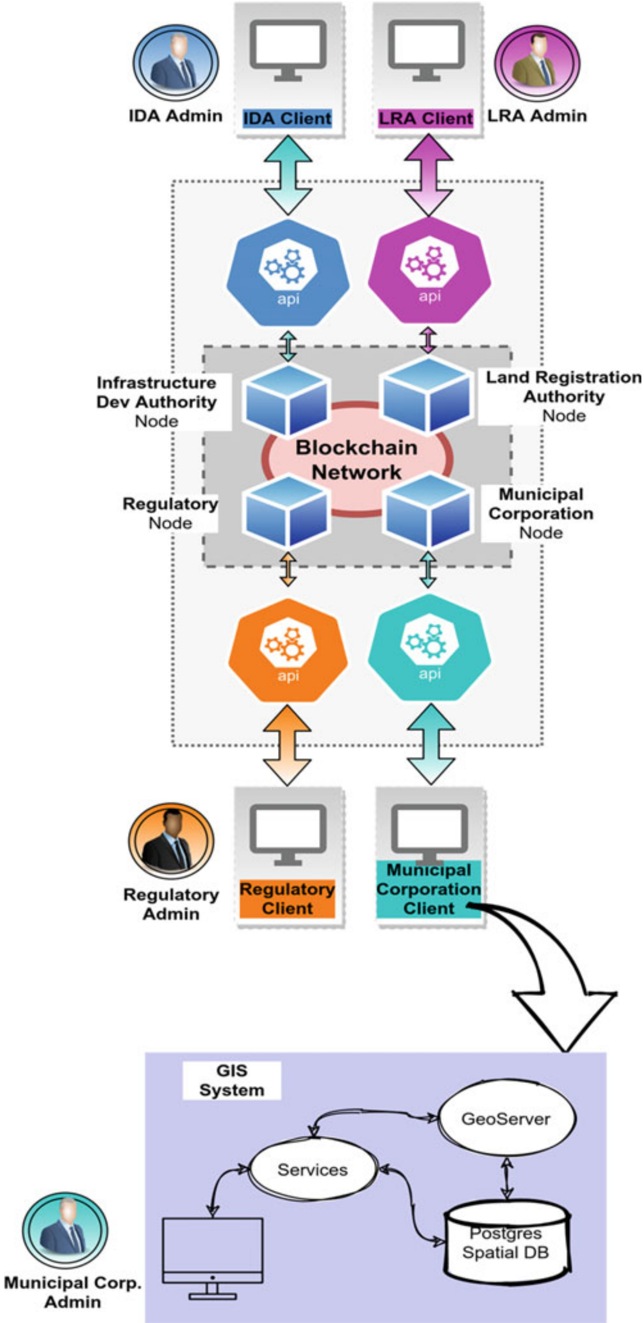

Fig. 1 High-level architecture

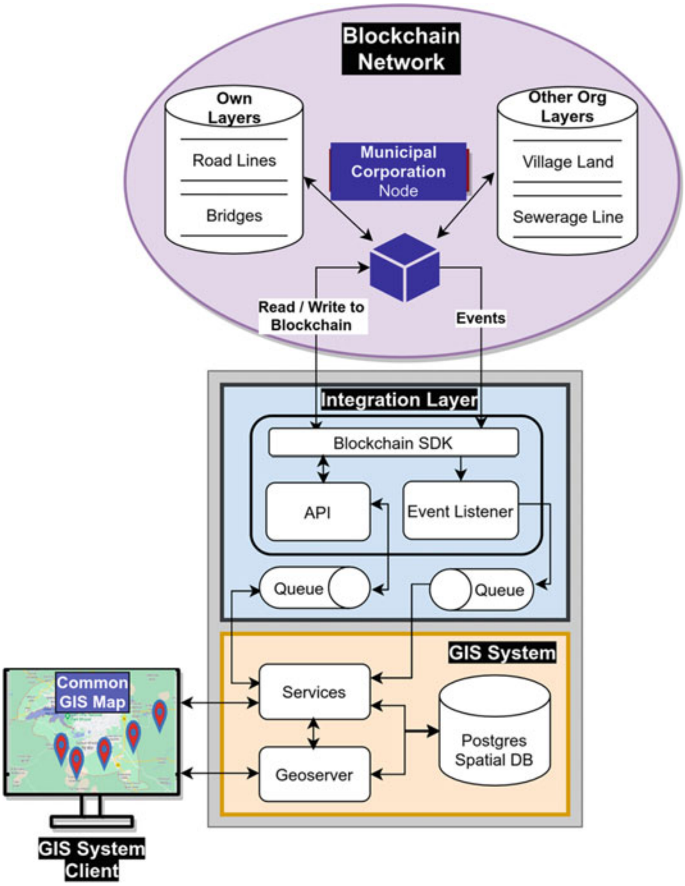

Fig. 2 Data flow diagram for single organization

4 Prototype

A prototype was implemented for this system using Hyperledger Fabric (version 2.2) from the Linux Foundation. Municipal Corporation of Bhopal (MCB) and MPMKVVCL (A State-owned Electricity Distribution Company) were the two participating organizations setup on the Blockchain network. CouchDB [11] was configured as a State database in this prototype.

In this context, MCB wants to move Electrical Poles owned by MPMKVVCL from an existing location to new ones due to road widening work and also wants to keep other stakeholders updated on this change. All geospatial data pertaining to electrical poles are available in electrical-poles layer which is owned and managed by MPMKVVCL. Figure 3 shows the sample asset of the Electrical Pole on blockchain. It shows the existing location coordinates (23.2354768, 77.3345862) of Electrical

```
{
  "id": "\u0000org~layer~fid\u0000org1\u0000road\u00004\u0000",
  "key": "\u0000org~layer~fid\u0000org1\u0000road\u00004\u0000",
  "value": {
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  },
  "doc": {
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      ],
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      "state": "Madhya Pradesh",
      "country": "India",
      "type": "Electrical Pole",
      "project": "Smart City Project",
      "company": "MPMKVVCL",
      "lastShiftOn": "2000-01-30",
      "poleInstalledOn": "2000-01-30"
    },
    "~version": "CgMBBgA="
  }
}
```


Fig. 3 An asset on Blockchain showing existing location of electrical pole (before shifting)

Pole before shifting. In this prototype, MPMKVVCL updates the location of Electrical Pole to its new location coordinates (23.2386789, 77.3378906) and submits the transaction on Blockchain. This transaction updates the Asset of Electrical Pole on Blockchain as shown in Fig. 4. The attributes like lastShiftOn is updated along with its revision (rev) and version (~version) now.

Figure 5 shows the details of the write transaction submitted by MPMKVVCL. Once the transaction is validated successfully, MCB gets notification of this update on their own GIS System almost in real-time. They get the latest version of Asset (Electrical Pole) on their system.

5 Future Work

It was a bare minimum prototype showcasing how multiple organizations can share geospatial data/layers among themselves by making use of DLT. There is a lot of scope for further improvement in the existing integration layer to support the push/pull of geospatial layers from/to Blockchain. Restriction on the access of layers can also be implemented by using private data collection.

```
{
  "id": "\u0000org~layer~fid\u0000org1\u0000road\u00004\u0000",
  "key": "\u0000org~layer~fid\u0000org1\u0000road\u00004\u0000",
  "value": {
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  },
  "doc": {
    "_id": "\u0000org~layer~fid\u0000org1\u0000road\u00004\u0000",
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      ],
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    },
    "properties": {
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      "state": "Madhya Pradesh",
      "country": "India",
      "type": "Electrical Pole",
      "project": "Smart City Project",
      "company": "MPMKVVCL",
      "lastShiftOn": "2021-01-05",
      "poleInstalledOn": "2000-01-30"
    },
    "~version": "CgMBBgA="
  }
}
```


Fig. 4 An asset on Blockchain showing updated location of electrical pole (after shifting)

The system can be further enhanced to provide a one-stop shop access to all types of information/reports e.g. zone confirmation report, land map report etc. Further integration with a payment gateway can also be done to enable e-payment to provide various services to a wide range of customers, government and private institutions.

It can also be enhanced for integrated planning purpose in preparation of Detailed Project Report (DPR), payment of Road Reinstatement (R&R) charges, obtaining faster work permission etc. for different public utilities assets such as Electrical cables, Gas pipelines, Water pipelines, Telecom lines etc. which can reduce execution time and improve better coordination among various stakeholders.

6 Conclusion

Distributed Ledger Technology (DLT) allows multiple organizations to exchange & contribute information among themselves almost in real-time. Due to which organizations always work on the latest and same version of data which in turn makes their work fast, effective and efficient. This also reduces overall time, effort & cost spent by multiple organizations. DLT also enhances data security.

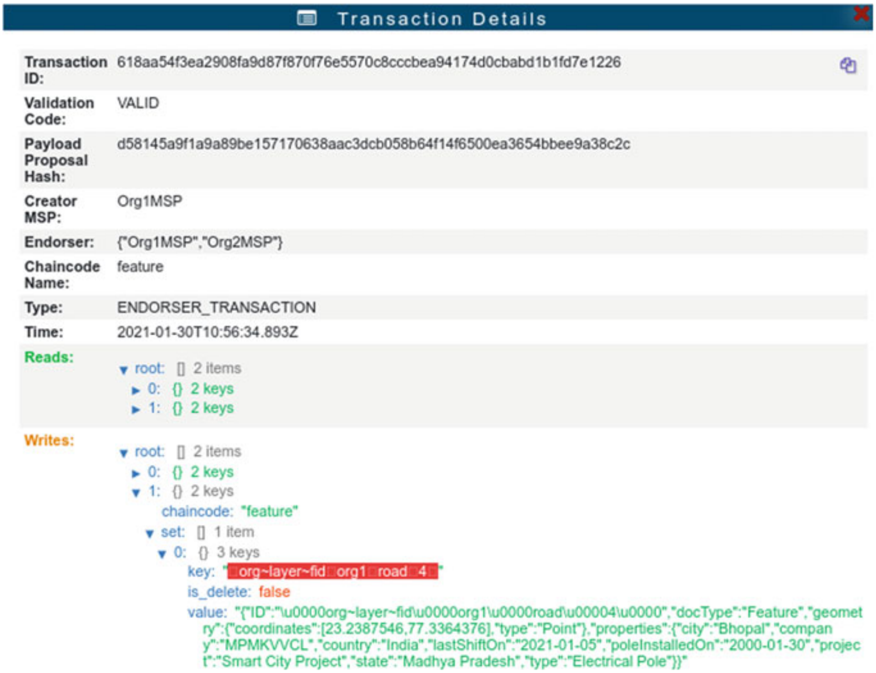

Fig. 5 Blockchain transaction details

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10. PostGIS. https://postgis.net/
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Developing a Regulatory Approach to Enable EV Application as a Virtual Power Plant

Shyamasis Das

Abstract The present paper is concerned with shedding light on an effective regulatory approach to enable the application of electric vehicles (EVs) as a Virtual Power Plant (VPP). Appropriate regulations are critical to facilitate the use and deter misuse of this new solution. The study highlights the key regulatory instruments like price signals which are potential drivers for employing EVs as a flexible grid resource. In this regard, the assessment takes into account the experience of the advanced EV markets which have already made progress in implementing VPP. The study goes beyond delving into the regulatory instruments. It deals with crucial aspects such as defining EVs as a resource and realizing EV aggregation in order to participate in the power market, conflicts of competing needs, safety, interconnection requirements, and communication standards. Moreover, considering the existing electricity market structure in India where the power distribution utilities play a central role and much of the regulations are designed pivoting on power utility engagement, this investigation makes a conscious effort to debate the role of utilities in the resource aggregation. It proposes different implementation models for aggregation with varied levels of utility involvement, with the ultimate objective to establish a competitive and efficient mechanism to unlock the benefits of EV application as a VPP. It is strongly believed that this research would potentially help design an effective regulatory framework to implement EV-based VPP in the country. Electricity distribution utilities, regulatory commissions, fleet operators, charging service providers, and policymakers will immensely benefit from this study.

Keywords Virtual power plant · Regulation · EV · Grid resource

1 Introduction

Electric Vehicles (EVs) are not just a low-carbon mobility alternative, they can be suitably employed as a resource to a country's electricity system. Battery being the

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heart of an EV, the latter can be a manageable electricity load for the grid as well as an energy storage option. Thus, EVs can be utilized for an array of applications as listed below.

- Peak-shaving—The charging of EVs can be done during off-peak hours, thus filling the valleys in the utility load curve. In case the EVs and the charging infrastructure are equipped with electrical bidirectional capability, called V2G, EV batteries can be discharged when there is peak-demand and more supply of power is required in the grid.
- Frequency regulation—A supply—demand mismatch can cause variations in frequency from the set frequency of 50 Hz (Hz) at which an electricity grid is established. The frequency variations can negatively impact the grid stability.
  As compared to the mechanical spinning reserves, EV batteries can act as a quick-response resource. Thus, EVs can potentially offer frequency regulation services in the ancillary services market.
- Energy arbitrage—Leveraging V2G capability, EVs can participate in energy trading. At the time of low electricity price, the battery can be charged with cheap power for storage. The stored electricity can be sold in the power market by feeding back electricity to the electricity system when the energy price goes up. The trading can be done by charging and storing with renewable energy leading to its higher offtake.

Hence, EVs are considered to be an effective and efficient Virtual Power Plant (VPP) [1]. However, a favorable regulatory ecosystem is necessary to enable the application of EVs as a VPP in the electricity market of a country. It would require a number of market mechanisms to tap the potential of EV-based VPP.

2 Objective and Scope of Work

VPP is an evolving intervention globally and is almost a virgin concept in India. Regulators and power utilities in the country are yet to adopt VPP model in the mainstream electricity market. Considering the recent efforts taken toward market reforms which include steps like introduction of Real Time Market and Green Term Ahead Market, implementation of various forms of VPP projects including participation of EVs holds promise. However, the present regulations and market structure in India may not be sufficient to leverage EVs as a VPP resource. In this context, this paper deals with the regulatory framework necessary to realize the application of EVs as a flexible grid resource in India's power market. The intended primary beneficiaries of this study are the Central and State Electricity Regulatory Commissions, power distribution utilities, EV fleet operators, charge-point operators and policymakers.

3 Investigation

The study examines five key aspects of implementation of EV-based VPP:

- Key regulatory instruments necessary for implementation of VPP
- Experience of the advanced EV markets which have already made progress in implementing VP
- Regulatory interventions that are important for participation of EVs in VPP
- Implementation models for EV application as a VPP taking into account the existing electricity market structure in India
- Need for communication standards

3.1 Key Regulatory Instruments and the Experience of Advanced EV Markets

Appropriate electricity price signals to EV owners are necessary to influence EV charging pattern so that considerable share of EVs at a location are charged during off -peak hours and when the share of renewable energy in the grid electricity is high. Moreover, electricity pricing is important to enthuse EV owners to take part in V2G. Thus, electricity price signals help realize the potential benefits of VPP. Introducing Time of Use (ToU) tariffs is considered to be the fundamental step to this end. In this tariff regime, electricity rates change in a premeditated manner throughout the day which may have seasonal variations too. Generally, the rate is lower during off -peak hours and increases when the power demand in the grid is high. Implementation of ToU tariff regime for EV charging is found to be cost-effective. Many countries have introduced ToU tariffs for EV charging. The states of California and Nevada in the US, utilities like RWE and E.ON in Germany and Électricité de France (EDF) in France have applied ToU tariff rates [2]. Utilities in Japan, the United Kingdom (UK), and other countries have also successfully implemented ToU tariffs for EV charging [3]. It is found that TOU rates were able to influence charging behavior of EV users and both the utilities and EV owners benefited from the tariff design. Utilities found it an effective tool for load management whereas EV owners could realize savings in their energy bills [3].

However, ToU rates may have some downsides. Static ToU tariff design is found to be less effective in a situation with high number of EVs in the utility service-area. Static ToU rates may result in new peaks as EV owners start charging at the same time responding to the predetermined electricity price signals. More dynamic electricity pricing where the tariff can vary in smaller time-bands to more aptly reflect the real-time wholesale market prices and grid conditions, is required. Real-time rates would help avoid secondary peaks due to ToU rates and coincide EV charging with the availability of renewable energy. However, there is limited experience even in advanced markets to confirm the effectiveness of such dynamic tariffs on EV charging—whether it would be able to flatten the load curve and synchronize with renewable energy availability. A major concern is real-time pricing may pose to be too complex to implement. EV owners may find it unfeasible to consider. Ultimately, participation in utility programs is less a priority for EV users than meeting their mobility requirements.

Role of load aggregators who can act as a go-between the EV owners and the utilities or the wholesale power market can be potentially important in such scenario. Aggregators can make the price signals to customers predictable and simple but still onboarding the EVs to participate in utility programs to realize the benefits of real-time electricity pricing.

3.2 Regulatory Interventions That Are Important for Participation of EVs in VPP

The benefits of EV-based VPP are not limited to wholesale market. The distribution system can potentially gain from VPP. To this end, a suitable incentive mechanism needs to be introduced by the regulatory commission that would motivate the utility to utilize VPP benefits in its planning and operation, while stimulating the EV-owners to offer services to the distribution system along with participating in the bulk power system. While formulating the incentive system, it is important to recognize that EVs are meant for transport purpose. The EV-owners' interests should be a priority for the regulatory commission. The owners should be given the right to choose to participate in or exit from a program and should not be left exposed to the discretion of the utility. Furthermore, the incentive system should be in sync with the applicable interconnection regulations.

As EV-based VPP has the ability to provide a spectrum of grid services at different levels i.e. from facility level to distribution system to wholesale market, the requirements of these services are likely to vary and sometimes could be conflicting. For instance, a situation may arise when the distribution system faces overloading which is why the utility would send signal to EVs to avoid charging. However, at the same time, there could be an imbalance in the bulk power market and hence, the ancillary service market may encourage the consumers i.e. EV owners to consume electricity to add more load. Thus, the EV owners would be receiving conflicting signals from the two markets. Therefore, appropriate regulations would be required to avoid such conflicts.

Safety of the use of EVs as VPP should be paramount. The regulatory commission should coordinate with other agencies to make sure that the safety codes and standards are adhered to while EVs participate in a VPP program.

Recognizing EVs as a "resource" to power utility is considered as the fundamental regulatory action towards facilitating EV-based VPP program in a market. Current regulatory framework in India lacks a clear provision in this regard. EV charging involves several components such as the EV, the charging facility, the host set-up (in case the charging infrastructure is part of a facility used for a different purpose), and the aggregator, and each of the components can be managed by different entities. Therefore, how regulations define EV as a "resource' would be important since it will effectively lay out the compliance requirements—which entity to maintain compliance with the applicable regulations and meet utility interconnection requirements. Consequently, this would shape the business model for implementation of VPP. Moreover, the definition of grid resource will have different implications. For example, in case the EV is deemed as the resource, the metering should be done near the Electric Vehicle Supply Equipment (EVSE). In such a case, the EV would require monitoring the energy exchanges. Also, the applicable regulations would have to permit the resource to be mobile. Not only that, the EV would have to register to the utility. Such complexity can be avoided if the regulations define the charging facility as the grid resource. In such a case, metering would be at a definite location. Recognizing the aggregator as the resource is also a possible regulatory pathway where the resource would be geographically dispersed. In turn, this would require different set of regulations and a different metering protocol for aggregating the transactions.

As EVs get recognized as a flexible grid resource, it would be important to enable their aggregation considering the fact that individual EVs are not sufficient to provide grid services on standalone basis. To take part in a wholesale market, a grid resource should be above a minimum threshold in terms of capacity i.e. MW, depending on the applicable regulations. Battery size of an EV may not be enough to reach the threshold size. Therefore, EV aggregation is necessary to respond to wholesale market signals. Considering that EVs are spread out over an area, it would be important to ascertain that the regulatory provisions adequately support aggregation of geographically distributed resources.

3.3 Implementation Models for EV Application as a VPP

The next step would be to develop a mechanism for resource aggregation and who can potentially act as the aggregator. In India, the electricity distribution utilities play a central role in the energy market and much of the regulations are designed pivoting on power utility engagement. Hence, there could be a natural bias towards giving the utility the role of an aggregator. While the utility could help align distribution requirements with wholesale market participation, this could lead to monopolistic practices and restrict innovation in VPP market. Hence, it is crucial to debate the role of utilities in the resource aggregation and adopt an implementation model which helps establish a competitive and efficient mechanism to unlock the benefits of EV application as a VPP. There are four implementation models for aggregation with varied levels of utility involvement, as mentioned below [4].

- Utility as the only and exclusive aggregator
- Utility as the meta-aggregator
- Competitive market sans participation of utility

- Competitive aggregation allowing utilities as well as third parties to become aggregators

In the first case, the utility would have the exclusive mandate to serve as an aggregator in the VPP market. Therefore, the utility would have responsibility to enlist EV owners to participate in a VPP program and would be able to manage charging of EVs. However, to effectively aggregate EVs and implement VPP, the utility needs to have full understanding of EVs, commute and charging patterns of subscribers, etc., which is not part of its usual role and operation. Hence, how well a utility can aggregate the EVs and onboard them in a VPP program is debatable. Also, a downside of this aggregation model is the possibility of emergence of a market monopoly which may discourage business innovation. Moreover, there may not be enough driver for a utility to extend all possible benefits to the EV owners in a VPP program. Figure 1 shows the envisaged market interactions in such an aggregation model.

The second implementation model conceives the role of the utility as a meta-aggregator. Instead of the utility, a third-party does the aggregation and acts as the go-between the EV owners and the utility. In this model, neither there is customer-utility interaction nor the aggregator has direct access to the wholesale power market

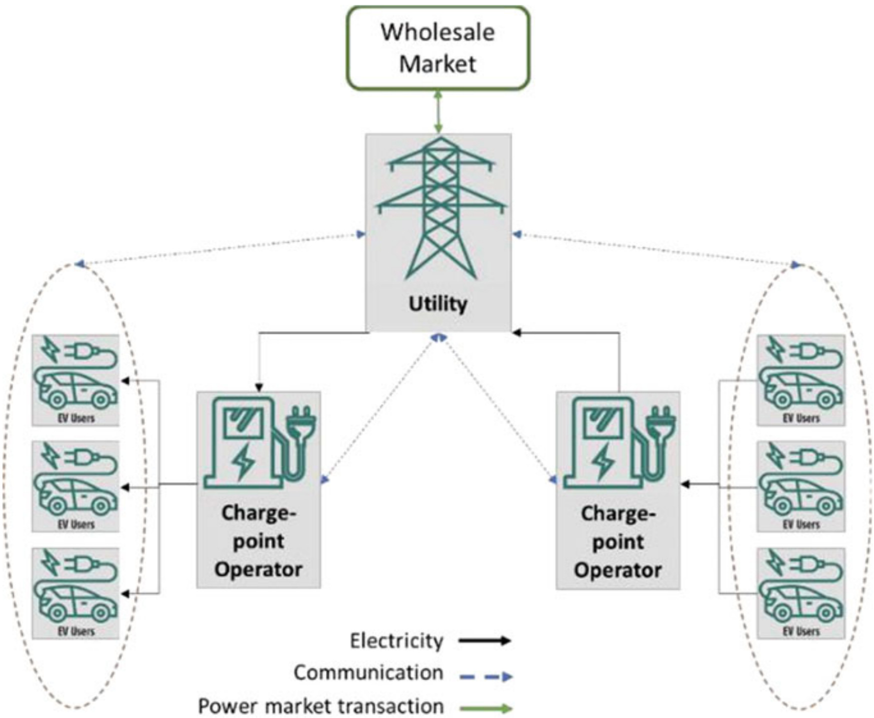

Fig. 1 Utility as the only and exclusive aggregator

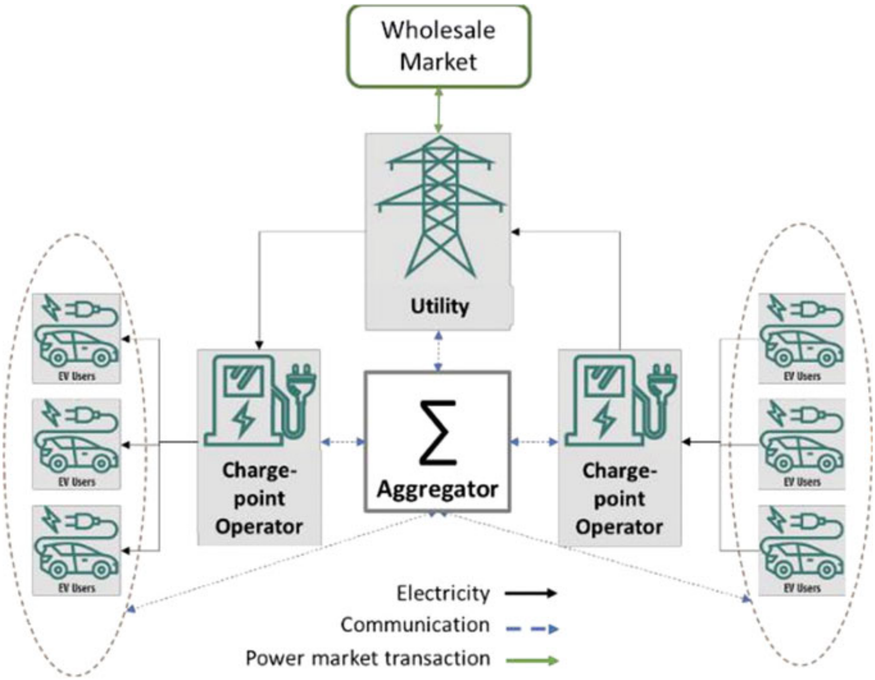

Fig. 2 Utility as the meta-aggregator

(Fig. 2). A key advantage of this model is its ease of implementation. However, it has its share of drawbacks. On one hand, utility-only participation in the wholesale market limits the competition and on the other hand, the aggregator is heavily dependent on the utility for its earning. This warrants close regulatory watch to allow effective utilization of the VPP and appropriate compensation of the aggregating entity.

In the case of the third implementation model, the VPP is carried out without utility involvement. Here, only the third-party is responsible for aggregation and can directly participate in the wholesale and ancillary service markets as well as provide distribution system benefits to the utility. To enable the third-party to offer services to the utility, the latter has to generate price signals reflecting the benefits of grid services. Also, necessary channel needs to be developed to communicate the price signals to aggregators and EV users. Moreover, there should be regulations to accommodate participation of EV-based VPP in multiple markets. The envisaged market interactions in this implementation model are captured in Fig. 3.

As far as the fourth implementation model is concerned, both utility and third-party can compete to aggregate EV load and represent in the wholesale market (Fig. 4). The applicable regulations should allow equal opportunity to the utility and the third-party and facilitate optimum utilization of EVs as a grid resource.

Each of these four implementation or aggregation models has certain advantages accompanied by some challenges or downsides. In any case, the applicable incentive

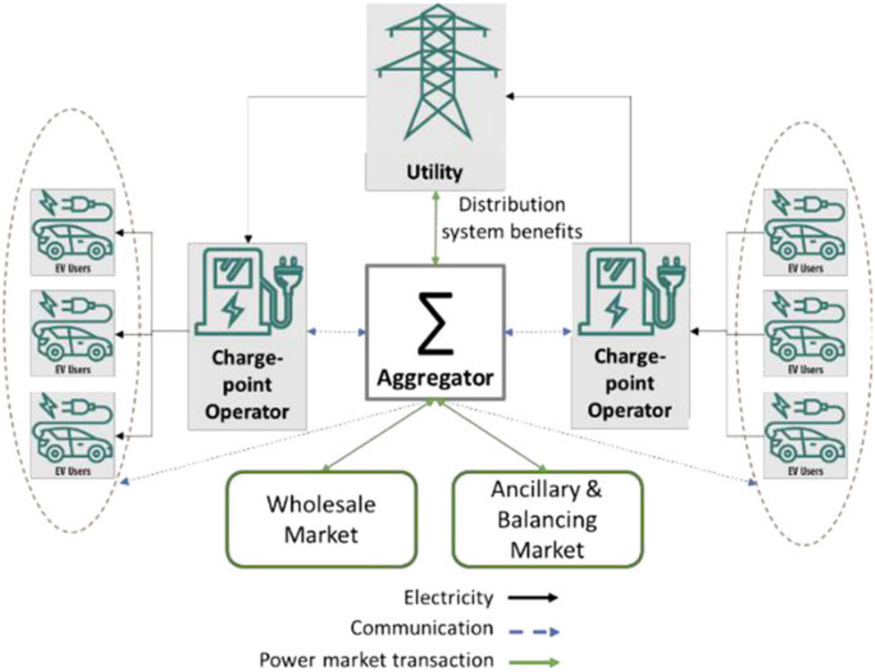

Fig. 3 Competitive market sans participation of utility

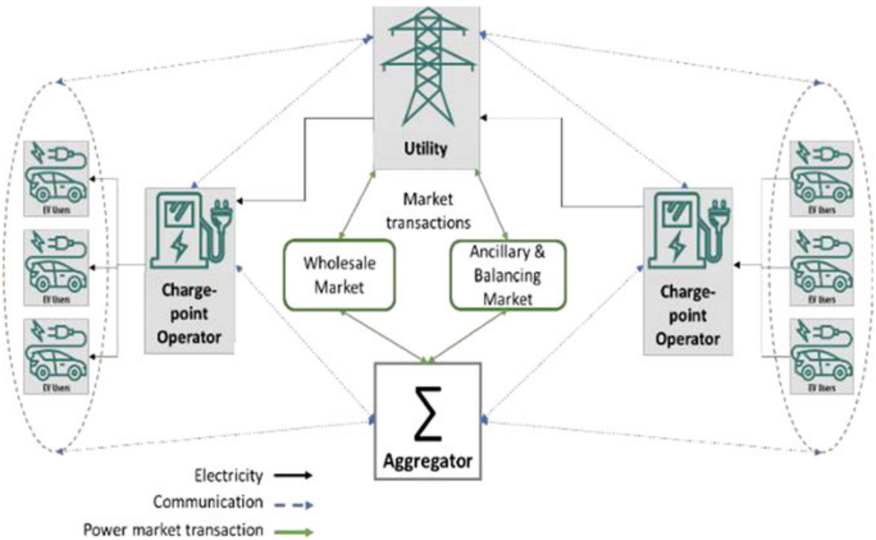

Fig. 4 Competitive aggregation allowing utility and third-party to aggregate

mechanism for VPP requires harmonization with the adopted model. Moreover, the utility and the regulatory commission would have to establish the interconnection rules for the VPP depending on the chosen aggregator model. This is especially important for V2G based programs because the requirements would differ from unidirectional energy flow. One may consider existing net metering regulations in this regard.

3.4 Need for Communication Standards

There are two purposes of communication in case of EV-based VPP: to receive bulk power market signals for the EV and to provide metering data to the market. There is a need for a communication standard to communicate between the aggregator which can be either a power utility or a third party, and the wholesale market. Downstream communication is also important so that every part of the VPP program is able to respond to signals and for that, standards would be essential. Present smart grid communication standards (e.g. OpenADR) can be utilized for necessary downstream communication.

4 Major Findings on the Indian Market

India's EV market is currently at an early stage. The present policies, regulations, and guidelines for electric mobility are yet to attach due importance to EV-based VPP. As a result, the current regulatory framework lacks specific provision for EV participation in a VPP. It is worthwhile to mention here that a number of existing regulations in the country can directly or indirectly enable VPP or its sub-elements and suitable amendments are possible to allow its implementation. Still, there are certain practical barriers on the way to mainstream EV-based VPP. As mentioned before, allowing third-party aggregators to carry out resource aggregation is vital for realizing an effective and efficient VPP market. The current regulations are not sufficient to support "resource aggregation" by third-party aggregators. To facilitate participation of EVs in the bulk power market and ancillary services, the regulatory framework should allow aggregation of geographically spread-out resources such as EVs.

Due to limited regulatory scope for resource aggregation, the key models or tenets for implementation are missing. To address the gaps, the Forum of Regulators (FoR) which is responsible for harmonizing state electricity sector regulations, should endeavor to formulate a model regulation on "distributed resources aggregation". Subsequently, the State Electricity Regulatory Commissions can consider adopting necessary state regulations. It is worth mentioning here that there is an existing "Draft Model Regulation for Grid Interactive Distributed Renewable Energy Sources" [5] that can be suitably tailored to enable resource aggregation along with its different aggregation models. A key challenge is the model regulation does not support the role of third-party in aggregation. To this end, the regulatory commissions should amend the existing regulations such as State Demand Side Management Regulations for recognizing non-utility entities to provide grid services.

Besides the lack of provision for resource aggregation, a major implementation barrier for VPP is the power sector in the country yet to have an effective ancillary services market. Ancillary services such as Fast Tertiary Control, Secondary Frequency Control, Voltage Control, and Black-Start are essential to improve the reliability of a country's electricity system. EVs can be an effective resource to offer services like frequency and voltage support provided the regulatory framework is conducive for EV participation as a VPP in the market. Presently, the country's electricity system depends on only slow tertiary reserves for ancillary services. A thriving ancillary service market is paramount to realize the full spectrum of benefits from EV-based VPP.

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Flexibility Operation of Hydro Power Station: A Case Study on 9PM9Minutes Event on 5th April 2020

Surendra Kumar Mishra and Jaganath Pani

Abstract Hydropower can play a crucial role in India's sustainable development and energy security as it meets the criteria of sustainability, availability and reliability. Hydropower by virtue of its inherent characteristics has gained importance with large scale RE integration and the flexibility it provides has made it amongst best suited to match the rate of variability of RE. Hydro flexibility was successfully tested during the recent 9PM9M event on 5th April 2020. Though the drop in loads was anticipated up to 15 GW but in actual it plunged by 31 GW, nevertheless, it didn't turn out to be difficult task to maintain grid stability given the robust infrastructure, planning and sizeable Hydropower and Gas based generation capacity which had come to the rescue. Hydro generation played vital role in balancing the grid and provided the much more than the envisaged flexibility and ramping rate. The event significantly assessed and marked flexibility in the grid and its manageability. Going forward, the results of the event has provided advocacy of the need of hydropower in the Indian grid as one of the best suited energy sources to meet the variability of increasing RE generation. The paper presents the experience during the event on the flexible operations of hydropower stations with focus on NHPC power stations and its contribution in grid stability and security and future ready.

Keywords Flexibility · Hydro generation · 9PM9Minute · Ramp up-down

1 Introduction

Hydropower can play a crucial role in India's sustainable development and energy security as it meets the criteria of sustainability, availability and reliability. It is an environmentally friendly and non-polluting source of power and is most suitable for balancing renewables. Furthermore, hydropower provides transient stability to the grid. The quick start capability of hydropower plants helps quickly change the output to serve peak demand. As on 30th April'2020, India have 87.03 GW of renewable energy and target is to achieve 175 GW by 2022–2023 and 450 GW by 2029–30.

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During evening peak hours, immediate balancing measures to counter the variability of RE, load demand and grid security can be achieved by Hydro power stations. Similarly hydro plants are supported to bring the required generation at a speed to match the rate of variability of RE. India faced such a situation recently when the Hon'ble Prime Minister of India appealed to the citizens on 3rd April 2020 at 09:10 h to switch off their lights and light lamps/ candles on 5th April 2020 at 21:00 h for 9 min to dispel the "deep darkness" that the pandemic, COVID-19 had brought. Though the drop in loads was anticipated up to 15 GW but in actual it plunged by 31 GW, nevertheless, it didn't turn out to be difficult task to maintain grid stability given the robust infrastructure, planning and sizeable Hydropower and Gas based generation capacity which had come to the rescue. Everything was balanced by maintaining the supply side rather than focusing on the demand side. Hydro generation played vital role in balancing the grid and NHPC power stations provided the much-needed envisaged flexibility and ramping rate. Going forward, the results of the event shall provide more advocacy of the need of hydropower in the Indian grid to meet the variability of RE generation.

2 Pan India Lights Switch-off Event—9PM9Minutes on 5th April 2020

The Hon'ble Prime Minister of India appealed to the citizens on 3rd April 2020 at 09:10 h to switch off their lights and light lamps/ candles on 5th April 2020 at 21:00 h for 9 min to dispel the "deep darkness" that the pandemic, COVID-19 had brought. It was envisaged that the pan India light switch-off will cause sudden drop in power demand followed by sharp increase in demand within short span of time i.e. 9 min and demanded efficient grid management during the event. In order to ensure reliable and secure grid operation during upcoming event, POSOCO anticipated reduction in all India demand during this period of 9 min around 12,000–14,000 MW considering that only lights would be switched off. Accordingly, a detailed advisory was issued by POSOCO on 4th April 2020 afternoon after a conference call with all the State Load Dispatch Centre's and the major hydro plants in the country. In the advisory, POSOCO mentioned that unlike normal operation, this reduction in load of the order of 12–13 GW would happen in 2–4 min and subsequently recover nine minutes later within 2–4 min. This sharp reduction in load and recovery was unprecedented.

2.1 Challenges/Preparedness

2.1.1 Power Plant Participating in the Event

All NHPC power stations were available for participation in the event, except Kishanganga. Out of 19 nos. available hydro power stations, 14 nos. power stations being ‘Pondage / Storage’ had total available capacity of 2888 MW and 5 nos. power stations being ‘Run off the River’ had total available capacity of 1483 MW. List of power stations and available capacities during the event is given below (Table 1):

Table 1 Overload capacity of NHPC power stations

S. No.	Power station	Type of plant	Installed capacity (MW)	Available capacity (MW) as on 05.04.2020	Region
1	Chamera-I	Pondage	540	540	NR
2	Dulhasti	Pondage	390	390	NR
3	Baira Siul	Pondage	180	120	NR
4	Chamera-II	Pondage	300	100	NR
5	Chamera-III	Pondage	231	231	NR
6	Parbati-III	Pondage	520	130	NR
7	Dhauliganga	Pondage	280	280	NR
8	Sewa-II	Pondage	120	120	NR
9	Teesta-V	Pondage	510	510	ER
10	Rangit	Pondage	60	60	ER
11	Loktak	Pondage	105	70	NER
12	TLDP-III	Pondage	132	132	ER
13	TLDP-IV	Pondage	160	160	ER
14	Nimoo Bazgo	Pondage	45	45	NR
	Sub Total (a)		3573	2888	
15	Salal	ROR	690	690	NR
16	Uri-I	ROR	480	480	NR
17	Uri-II	ROR	240	240	NR
18	Tanakpur	ROR	94.2	62.4	NR
19	Chutak	ROR	44	11	NR
	Sub Total (b)		1548.2	1483.4	
	Total (a) + (b)		5121.2	4371.4	

2.1.2 Power Plant Preparedness

All power stations were advised to ensure healthiness of generating units including their auxiliaries mitigating the constraints, if any. Further, pondage/storage power stations were advised on 03.03.2020 to give Declared Capacity for 04.04.2020 so that maximum reservoir level is achieved and maintained preferably near FRL so that plants are ready with maximum plant capacity for sustainable operation at full load, i.e. plant capacity. Sufficient Spinning reserve has been maintained to cater the ramp up/ down during the event on 5th April 2020.

To ascertain the actual ramp up/down of each power plant and as advised by POSOCO, an exercise was carried out on 04.04.2020 (evening hours) and on 05.04.2020 (morning hours). The actual time recorded was shared with POSOCO. NHPC Corporate O&M division also assessed the specific and important requirements of NHPC power stations as stipulated in the POSOCO advisory dated 04.04.2020, and also issued its advisory to all Power stations, important highlights are as under;

1. Ensure implementation and adherence to the Advisory issued by POSOCO vide letter no. NLDC/SO/2020-21 Date: 04th April 2020. Power stations such as TLDP-III & TLDP-IV, controlled by SLDCs should ensure strict compliance to SLDCs directives and guidelines on this subject.
2. All HOPs, Power House-HOD and Key Power House O&M officials shall make themselves available in Power house during this period (1800 h to 2200 h) with required support staff. Everyone should be extremely vigil and alert during this period. Evening shift at all power station locations should be extended up to 2200 h.
3. Operation of Generating Units and Control

    i. Generating units shall be operated strictly to the RLDC/SLDCs guidelines given at point (B) in the advisory dated 04.04.2020 issued by POSOCO.
    ii. Follow any real time instructions/schedule given by RLDC/SLDCs.
    iii. All the available generating units should be on bar to provide maximum MVAR support. The Schedule MW to be distributed to all the generating units for flexibility and smooth ramping up/down.
    iv. Close monitoring of operating parameters needs to be done.
    v. Manual intervention shall be generally avoided except under exigencies during the event.
    vi. Frequency Control: Change in droop setting from existing setting to 2% as directed by POSOCO and confirm to respective RLDC/SLDC as per time schedule and also to O&M division.
    vii. Voltage Control:
        a. Stator terminal voltage set Point must be kept at Normal Voltage (11/13.8 kV).
        b. Excitation must be kept at Automatic Voltage regulator Mode (AVR) with all the limiters in service, such that stator terminal voltage

remains at rated Value irrespective of Bus voltage (Local Grid) provided that MVAR of unit is within capability curve. Optimum MVAR support to grid is to be ensured.

viii. Protection Setting change:
   a. "Low Forward Power" tripping/Opening of CB (except control shutdown) if any, may be disabled.
   b. Over frequency: Stage-I: 52.5 Hz for 10 s,
      Stage-II: 55 HZ for 1 s.
   c. Time Delay for "100% Stator Earth Fault" may be made more than or equal to 1 s.
   d. Further to the directive of NLDC on over fluxing setting, power stations were also advised for following modification in protection setting:
   e. Over Fluxing of Protection in Generator/ Transformer Protection Relay was modified to 110%(pick up) with 10 s time delay.
   f. First stage Over Voltage time delay setting of all 220 kV transmission line modified to 10 s from 5 s.

ix. Data telemetry and communication to SLDC/RLDC needs to be ensured all the time. The SCADA/DCS/telemetry data/numerical relays must be synchronized with GPS. Further, it is to ensure that the GPS clock is synchronized with IST.

x. Black Start preparedness i.e. healthiness and auto operation of DG set, availability of experienced operating staff, readily available operating procedure and setting modification etc. to be ensured.

The necessary confirmation on the preparedness and protection setting changes was communicated to POSOCO and respective RLDCs.

To review the preparedness and discuss any specific opinion of the generating utilities, POSOCO held a meeting on 04.04.2020 at 1830 h through videoconferencing, wherein it was suggested that the load variation as per the grid frequency is the responsibility of the power stations and they shall follow load variation considering 5-min scheduling as indicative to the extent of conformity with grid frequency. In line with the discussion, following additional measures were advised to power stations for smooth operation of units during the period, as under:

All units to be synchronized with grid irrespective of schedule.

Power stations should identify the sequence of generating units to be taken one by one for Ramp Down and Ramp Up of load (Illustration: Exact generating unit no. to be identified as preference for Ramp Down and similarly for Ramp Up).

HOP should nominate one Operation Coordinator for the period, preferably from the nodal officer already communicated to RLDC, who shall only give instruction to operator for load variation as per grid frequency and procedure already circulated.

HOP/Nodal officers should keep their mobile numbers free and watch it continuously during the period for any calls / messages, etc. from RLDC.

Unit MW, MVAR, Voltage, Frequency has to be monitored on minute basis and also log prepared and submitted to O&M division for onward submission to RLDC and analysis.

Key officials be present in the Control Room along with operators. Other officials/maintenance staff shall position themselves appropriately in power house locations/floors.

DG set be kept in running condition and manned during the period.

2.2 Real Time Event Monitoring and Analysis

All power stations had synchronized units by 20:00 h and generated power as per the schedule given by RLDCs/SLDC. By 20:00 h all power stations confirmed on availability of key officials in power house control room and their readiness. CMD, Director (Tech.), and O&M division key officials were logged into NRLDC web page, NHPC power stations webpage, etc. for live operation of power stations and grid.

Considering the expected load variation in the grid, NRLDC issued real time ramp up-down to be followed by each power station considering the anticipated variation in grid frequency as given below. The information was immediately shared with power stations and confirmation was received by 20:30 hrs.

Grid frequency was 50.02 Hz at 20:30 h, and gradually started dropping with generation getting gradually reduced at thermal Inter State Generating Stations (ISGS) to near technical minimum level of 60 % by 20:55 h and simultaneously hydro generation was increased to maintain the load generation balance (as per POSOCO advisory).

2.3 All India Demand and Generation

As per the POSOCO report the total reduction in all India demand recorded during the event was 31089 MW. All India demand started reducing from 20:45 h and minimum demand of 85,799 MW was recorded at 21:10 h. Subsequently, from 21:10 h, the demand started picking up and settled around 114400 MW at 22:10 h. Grid Frequency during the event remained in the range of 50.26 Hz to 49.70 Hz with maximum and minimum frequency of 50.259 Hz and 49.707 Hz recorded at 21:08 h and 20:49 h respectively (Graph 1).

All India demand and hydro generation details for the event are as under (Table 2):

During the event, NHPC generation stood at 4144 MW at 20:45 h, peaked at 4199 MW at 20:50 h and ramp down to 746 MW at 21:10 h (Graph 2).

Graph 1 All India demand meet

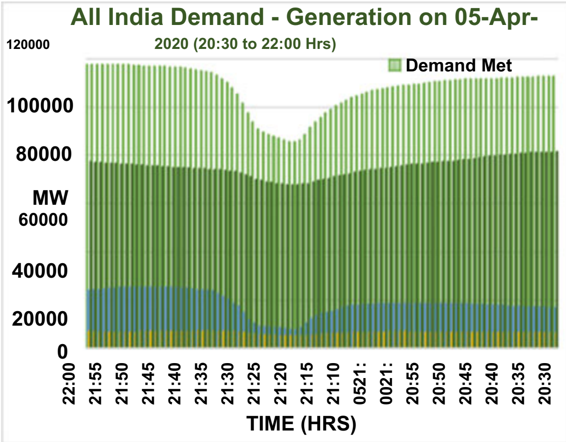
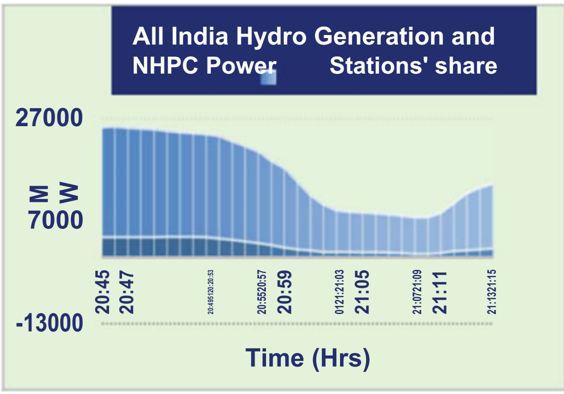


Table 2 All India Hydro and NHPC power position

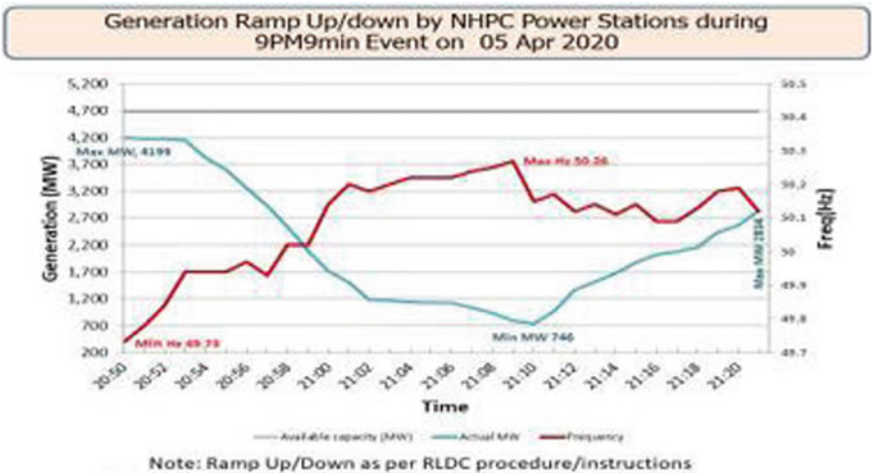
Time (h)	All India Demand (MW)	Reduction w.r.t all India Demand at 20:45 h (MW)	All India Hydro (MW)	Total NHPC (Hydro) MW
20:45	116,887	0	25,559	4144
20:50	115,775	−1113	24,838	4198
20:55	113,251	−3637	22,848	3596
21:00	101,667	−15,220	14,890	1716
21:10	85,799	−31,089	8016	746
21:15	95,795	−21,092	14,520	1884
21:30	108,808	−8080	18,923	

Graph 2 All India demand meet by hydro



2.4 Hydro Power: Necessity For Power System Stability & Security

During the event, Load reduced by 31 GW against envisaged 12–14 GW The maximum grid frequency observed was 50.26 Hz Hydro Power provided the flexibility of 17.5 GW (68.6%). NHPC power stations provided flexibility of 3453 MW i.e., 11% on all India basis (31 GW) and 20% in total hydro flexibility (17.5 GW). 2802 MW (29%) in NR and 595 MW (10%) in ER during the even (Graph 3;Table 3).



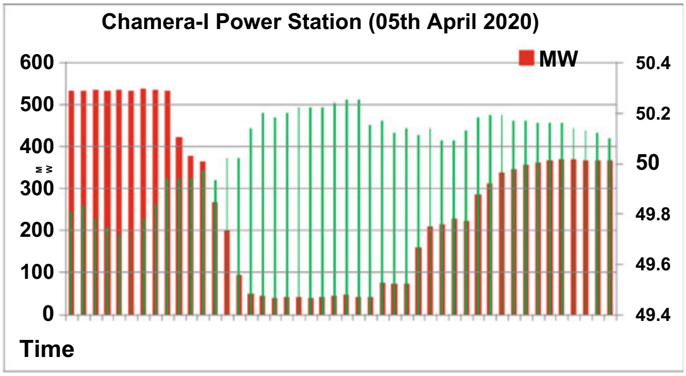
Graph 3 Generation ramp up/down during event

Table 3 All India hydro demand meet during event

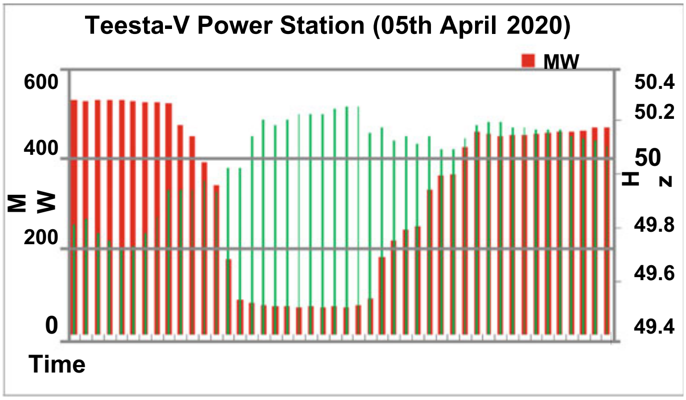
All India and NHPC profile during the event on 05.04.2020			
Time	20:50	21:10	**Change**
Frequency (Hz)	49.73	50.26	**0.53**
All India			
All India demand met (MW) (B)	115,775	85,799	−29,976
	24,838	8016	−16,822
NHPC			
NR	3395	593	−2803
ER	734	139	−595
NER	70	15	−55
NHPC total (C)	4199	746	−3453
NHPC to All India hydro (C/B), %	16.9%	9.3%	20.5%

Response of NHPC Power Stations during 9min9pm event Chamera-I was injecting 533 MW @ 20:50 h and started reducing generation as stipulated by RLDC and generation dropped to 41MW @ 21:02 h and maintained this generation upto 21:10 min. Power Station started Ramping-Up as stipulated by RLDC with drop in grid frequency (Graph 4).

Teesta-V was injecting 523 MW @ 20:50 h and started reducing generation with change in grid frequency and generation dropped to 79MW @ 21:02 h and maintained this generation upto 21:10 min. Power Station started Ramping –Up with drop in grid frequency (Graph 5).

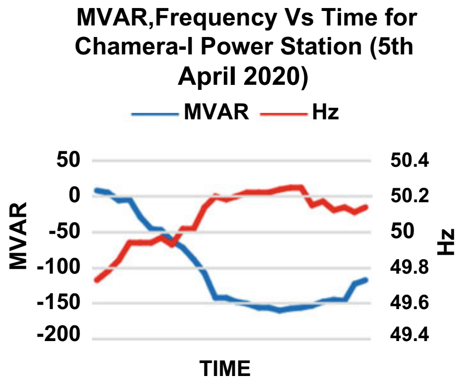


Graph 4 Response of Chamera-I power station



Graph 5 Response of Teesta-V POWER STATION

Graph 6 Voltage-MVAR graph of Chamera-I power station



2.5 Voltage Control & Reactive Power Management

Efficient voltage control and Reactive power management both are required for system reliability and power transfer across the transmission network. Change in grid frequency affects the reactive power capability of the generators. Studies show that relation of Reactive power with respect to frequency is negative. MVAR absorption by the generator is high when frequency is high and vice versa. Same has been witnessed during the event (Graph 6).

3 Conclusion

There was merely a 60 h pre-planning window, post the Hon'ble PM's declaration for switching off lights on 5th April 2020 at 21:00 h for 9 min and to light diyas, etc. as a sign of solidarity in the fight against the coronavirus pandemic. The planning and coordination among grid constituents was well managed. Though the drop in loads was anticipated up to 15 GW but in actual it plunged by 31 GW, nevertheless, it didn't turn out to be difficult task to maintain grid stability given the robust infrastructure, planning and sizeable Hydropower and Gas based generation capacity which had come to the rescue. Everything was balanced by maintaining the supply side rather than focusing on the demand side. The Hydropower & Gas power stations were identified well before the actual event to manage the ramp up/down requirement of the load demand and in balancing the frequency. The hydro generation proved to be a shock absorber in the event. A 49.70 Hz frequency was achieved before to the start of the event at 20:45 h, which helped the grid in providing margin to compensate when the frequency is increased due to a decrease in demand. Frequency would have increased much more if the step to ramping up of power had not taken place initially. In actual scenario, the effect of 31GW on frequency should have been by 2–3 Hz but it was mere 0.50 Hz only due to the efficient planning by boosting the Hydro and gas based generation and using it as per the response. This had no impact on the grid because the grid frequency during the event was in the range of 50.26–49.70 Hz. This has also supported to maintain voltage without difficulty. Hydro generation played vital role in balancing the grid and NHPC power stations provided the much-needed envisaged flexibility and ramping rate. Going forward, the results of the event shall provide more advocacy of the need of hydropower in the Indian grid to meet the variability of RE generation.

Disclaimer:

The views expressed in the paper are the opinion of authors and may or may not be that of the organization to which they are affiliated.

Reference

1. POSOCO report on 9PM9MIN event

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Artificial Intelligence (AI) Powered Customer Care

Tanmay Dalal, Prakhar Chaudhary, Sanjay Singh Rawat, and Yuti Metha

Abstract This paper provides details on how Utilities can ensure elevated customer experience by reinventing the customer care experience leveraging Artificial Intelligence (AI). The paper introduces AI Powered Care—which as a concept is not just limited to only chatbots but extends seamless customer interaction both internally in the organization and externally through different channels. AI can provide Utilities with avenues to service customers in their preferred channels. AI can predict customer behavior and identify and nurture the most valuable leads, through in image and voice recognition are driving the growth of the regional market. Artificial Intelligence market will surpass $100 billion by 2025 and expected to trim business cost by more than $8 billion per year by 2022.

Keywords Artificial Intelligence · Predictive customer care analytics · Virtual agents · Robotic process automation · Interactive IVR

1 Introduction

Utilities have been known to be stragglers in adopting latest technologies when it comes to customer experience, when compared to their counterpart industries such as Telecom, Financial Services etc. Every Utility spends millions every year to address customer concerns and issues through contact centers and other channels. The CIO teams are under constant pressure to reduce the operating costs while

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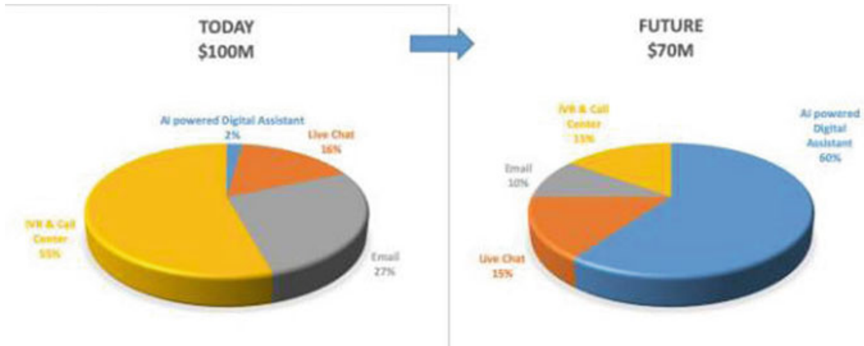

Fig. 1 Reduce customer care cost from $100 M to $70 M over 5 years

meeting the rising customer expectations. This is due to reduced revenue growth with the customers becoming self-sufficient owing to solar rooftop panels. There is a need for Utilities to reinvent their current customer service model to incorporate Artificial Intelligence to elevate customer experience, reduce operating costs while being hyper relevant to their customers.

2 The Business Case

Utilities currently spend millions to service their customers mainly through voice channels i.e. call centers and IVR, which is expensive and inefficient. As can be seen in the below figure, typically 50–60% customers still prefer using the traditional call center channel to get their queries resolved. There is need for Utilities to reinvent this model by deflecting these calls harnessing the power of AI, thus resulting in savings up to 30% over a period of 3–5 years (Fig. 1).

3 The Platform

As can be seen in Fig. 2, there are two key facets of AI Powered Care platform:

a. Virtual agents for customer interactions across multiple channels with live agent handoffs as well as process automations for back office optimizations
b. Predictive Customer Care Analytics to monitor, measure and optimize performance internally and externally.

Few examples of use cases across different Utilities domains can be seen in the Fig. 3:

When we combine these components, the Utilities derive value for their employees as well as the customers.

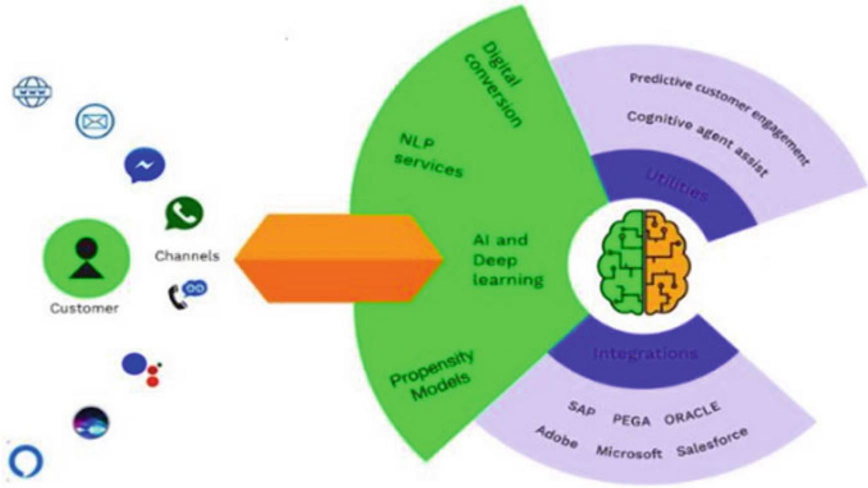

Fig. 2 AI powered care-platform

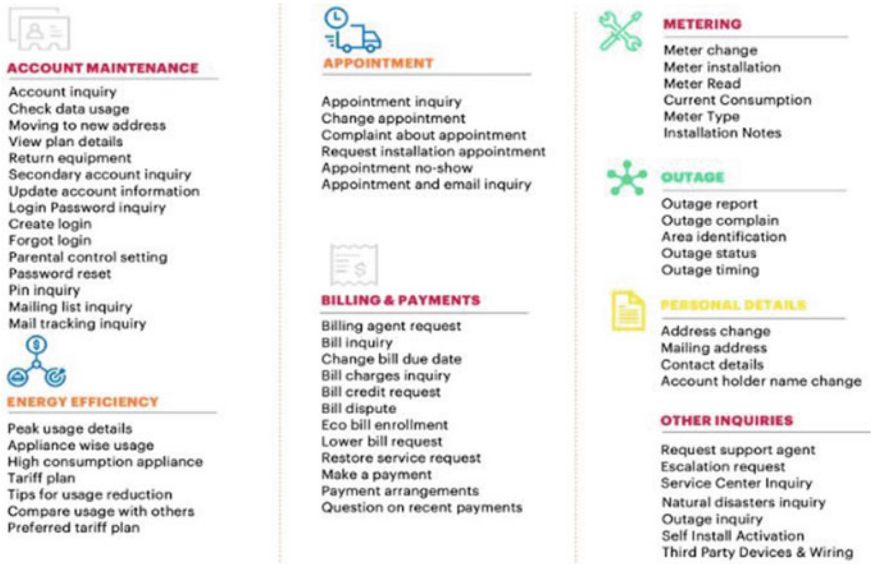

Fig. 3 Use cases across the utilities value chain

3.1 Virtual Agents

New Avatar: The virtual agents are the first point of contact enabling customers to interact with the Utility via their preferred channels—be it social media and digital

Fig. 4 Engage where the customers are

assistants for the millennial customer base or traditional IVR and voice for the elder generation (Fig. 4).

Embedded Intelligence Using Conversational AI

These virtual agents are using natural language processing and advanced machine learning techniques leveraging the knowledge base of past call center conversations of at least 2–3 years using a mix of supervised and unsupervised learning with real time training and learning. Key queries that can be answered include:

1. FAQ based interactions: How to pay bill, where is nearest payment center, what is the contact number etc.
2. Transactional interactions: Personalized interactions such as current outstanding payment, current bill, report outage, register a complaint, consumption information etc.
3. Conversational interactions: Engage the customer in conversation with contextual information like payment plan negotiation, high bill enquiries, energy efficiency suggestions etc. (Fig. 3).

Propensity Models: As a part of the analytics engine, there will be propensity models which will enable us to proactively reach out to customers to offers better products and services, reduce churn, offer energy efficiency services etc. Below figure shows details of some of these (Fig. 5).

Reinforcement: The agents also have the capability of seamless handover to an actual human agent if needed, and this conversation is then used as feedback for supervised learning so that, next time the virtual agent can handle this query on its own.

Automation: To handle repetitive and simple tasks such as business process exception management for billing or address updation for customers, meter reads submission, meter reads mismatch resolution etc. virtual agents will trigger relevant robotic process automations as can be seen in the Fig. 6.

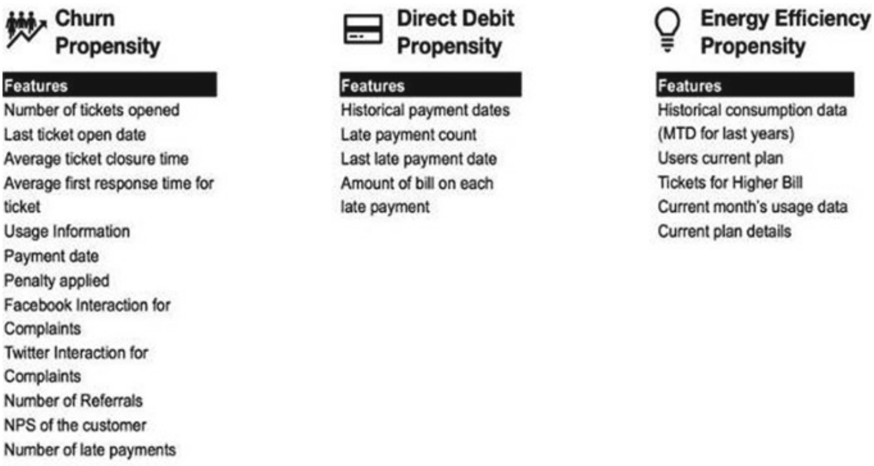

Fig. 5 Propensity models

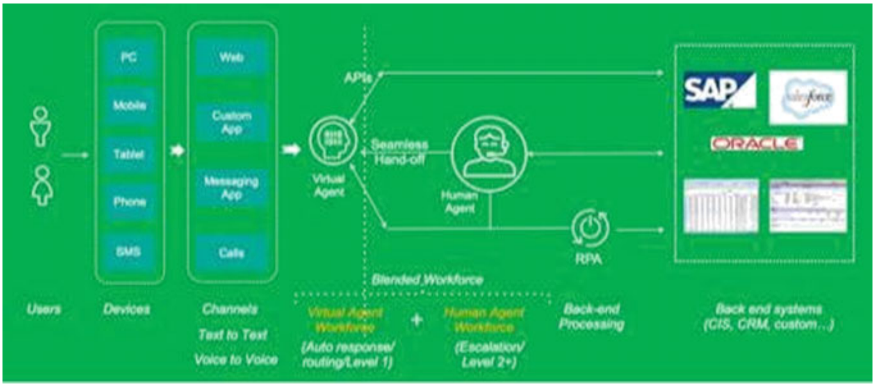

Fig. 6 Live agent escalation and Robotic Process Automation (RPA)

Microservices: API Management Layer which will essentially help to integrate with the relevant backend billing, CRM, MDM, Outage Management systems which will ensure hyper relevant conversations with the customers.

Omnichannel: Customers interact with their utility across all channels like phone, mobile, online-aim is to experience them all into seamless omnichannel. This can made possible using single AI engine and enabling adaptors to multiple channels via relevant SDKs or APIs. For example. For Facebook messenger we can use their APIs for Google Home we can use the actions SDK.

3.2 *Predictive Customer Care Analytics*

The virtual agents will be complemented by the advanced analytics engine which will help in monitor, measure and optimize the performance of virtual agents across channels.

Predictive customer care Analytics enabled recommenders can implement a multitude of analytic engines, such as interaction reason prediction, sense and respond, next interaction predictor, or next best offer optimizer.

The cross-channel analytics should enable us to measure the utilization of different channels along with most popular user journeys to enable the business users to measure the ROI on their investments. As can be seen in Fig. 7, cross channel analytics of users.

The other important aspect is to optimize the existing contact center by monitoring current performance as well as prescribing intelligent actions leveraging AI and

Fig. 7 Cross channel analytics

machine learning algorithms to reduce the average handling time and increase agent productivity.

The solution should empower business to analyze and anticipate customer calls based on past customer interaction records. It should provide a visualization in terms of the key performance indicators of a call center like first call resolution rate, abandonment rate and customer satisfaction score.

It should also enable business to understand the reasons, dissatisfaction and analyses pattern of customer calls then provide an in-depth analysis. It helps to determine repetitive calls by deriving a probability for each customer call category and thereby forecasting the overall call volumes and recommend various options of staffing the agents. As seen in below figure, performance management dashboard of customer call center (Fig. 8).

We have recommendation algorithms suggest trainings based on individual agent performance on KPIs. This enables the agents to be better equipped with skills and

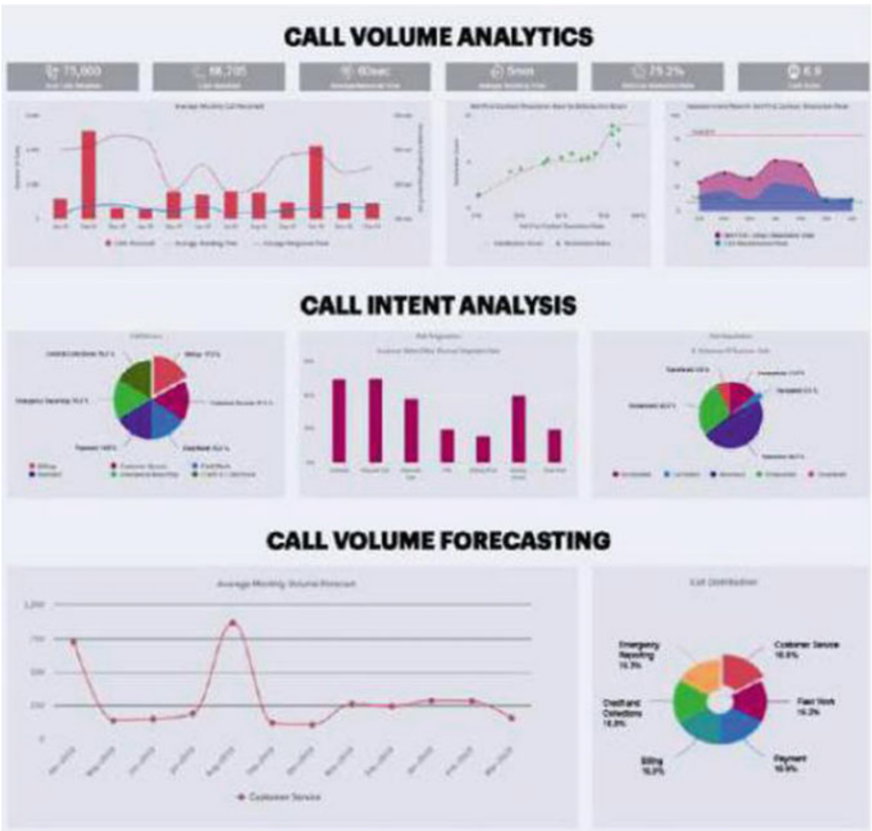

Fig. 8 Call center performance management

knowledge to drive calls efficiently resulting in better customer service. Let's have a glance to some AI algorithms used for better customer service.

- Call Center Performance Analytics

Algorithm	Formula	Description
Bivariate Analysis	$X^2 = \sum (O - E)^2 / E$ where O represents the observed frequency. E is the expected frequency Correlation = Covariance(X,Y) / SQRT(Var(X)* Var(Y))	Customer Satisfaction score is one of the most important factors for the success of an effective call center operation. This correlation analysis helps the business to understand the root problems and reasons causing customer dissatisfaction
Logistic Regression	$\ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 x_{1,i} + \cdots + \beta_m x_{m,i}$	Logistic regression is a method used to analyze data in order to predict discrete outcomes.
Artificial neural network	$f(x) = K\left(\sum_i w_i g_i(x)\right)$ $w_{ij}(t+1) = w_{ij}(t) + \eta \frac{\partial C}{\partial w_{ij}} + \xi(t)$	The model here tries to understand this pattern between the unlikely events and customer complaints so that the business can focus on actions to make sure that those events are eliminated or reduced by call center agents

- Complaints Management

Algorithm	Formula	Description
Gradient Boosting modelling	$F_m(x) = F_{m-1}(x) + \nu \cdot \gamma_m h_m(x), \quad 0 < \nu \leq 1,$ where parameter ν is called the "learning rate".	This model will help to identify unique patterns and characteristics of repeated complaints and utilize this information to narrow down on customers with similar properties
Latent Dirichlet allocation, TF-ISF Naive Bayes classifier	$P(W, Z, \theta, \varphi; \alpha, \beta) = \prod_{i=1}^{K} P(\varphi_i; \beta) \prod_{j=1}^{M} P(\theta_j; \alpha) \prod_{t=1}^{N} P(Z_{j,t} \mid \theta_j) P(W_{j,t} \mid \varphi_{Z_{j,t}})$ $TFISF_{sentence} = \sum \left(\frac{\text{Occurrences Of Word In Sentence}}{\text{Words In Sentence}}\right)_{word} + \log\left(\frac{\text{Total Sentences}}{\text{Number of sentences having word}}\right)_{word}$	It helps to manage customer complaints in an automated and structured fashion increasing customer satisfaction. Modeling is applied to classify and summarize customer complaints received via different channels.

3.3 *Customer 360° View*

This digital empowerment also makes the customer data trails can be processed and analyzed to provide hyper-personalized customer experience by enabling brands with a single, actionable, real-time customer 360° view to understand the customers and their evolving expectations. Customer 360 view serves as a catalyst in utilities value chain. This Intelligent UX is capable to analyze each customer journeys and help utility segment customers for Sale, Support and marketing campaigns and channel for better customer reach. Below figure shows the 360° view of customer (Fig. 9).

Fig. 9 Customer 360-degree processes

4 Conclusion

Utilities need to differentiate and use AI as a technology to engage intelligently. It not only helps Utilities save on operating costs but reinvent the way their customers interact with them, enabling hyper personalization. It will also ensure optimization of their current call centres and help them differentiate in the competitive markets by providing elevated customer experience.

AI powered Care solution drive value for Utilities CXOs and their customers as follows:

- Intelligently drive customers to digital experiences
- Provide Conversational interaction increasing digital adoption and containment
- Implement AI to automate and deliver consistency across channels
- Proactively eliminate call to the call centres
- Optimize existing call centres and increase agent productivity
- Decoupled from existing systems reduce cost of care >30%.

Strategy and Workplan for Rollout of Smart Meters in Prepaid Mode

Tanmoy Mitra

Abstract The power utilities across India are looking at smart metering with AMI towards accurate energy meter reading collection without manual intervention, improving revenue performance, remote connection and disconnection of power, facilitating real time analysis of power consumption/power quality parameters by the consumers and use of analytics on the huge volume of data generated by the smart grid system for building an effective decision support system. However, use of smart meters in postpaid only mode may not overcome many of the issues associated with the conventional metering system. Postpaid smart metering cannot ensure 100% collection efficiency as the remote disconnection procedure is partially dependent upon human intervention and procedural bottlenecks. Also, although postpaid implementation of smart metering collects energy meter readings automatically, the implementation still requires preparation of revenue bills in the utility's revenue billing system as well as printing and dispatching the same to consumers' premises. This involves considerable operational cost as well as time. The objective of this technical paper is to formulate robust and workable strategy plus workplan for rolling out smart metering in prepaid mode. The strategy takes care of migration of non-smart to smart prepaid mode, migration of smart prepaid to smart postpaid mode, migration of standalone prepaid mode to smart prepaid mode, integration of utility's billing engine with the MDMS system of the smart metering system, appropriate frequency of invoicing of consumers, automatic connection/disconnection of consumers based on their account balance and facilitating real time tracking of account balance by the consumers. The workplan suggests ways to minimize resistance from consumers, if any, during rollout of smart metering in prepaid mode.

Keywords Smart metering · Smart prepaid metering · MDMS · Remote connection · Remote disconnection · APIs for smart prepaid · Flat tariff for smart prepaid

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1 Introduction

The roll out of smart prepaid metering by power utilities can happen in any of the following ways or combination of them:

- Replacement of conventional postpaid energy meters with smart meters in prepaid mode.
- Replacement of non-smart stand-alone prepaid meters with smart meters in prepaid mode.

2 Conventional Post-paid to Smart Prepaid (Strategies)

More than 99% conventional energy meters across India are operating in postpaid mode. The primary features of this metering mode are:

- Meter reading is manual and prone to errors/manipulation.
- Non-payment of dues by consumers, in most cases, do not result in disconnection of service line owing to resistance by consumers, shortage of utility's manpower etc.
- Consumers have no way to view their real time consumption and power quality parameters.

A smart prepaid meter will eliminate the above issues and ensure high billing efficiency as well as 100% collection efficiency. However, consumers habituated with receiving bills with low unit consumptions and non-payment of dues may offer stiff resistance. The utility's meter readers, who are involved in manipulation of meter readings, may offer indirect resistance by spreading rumours among consumers by predicting very high bills in case of smart prepaid metering.

The following strategies may help in overcoming the above-mentioned resistance:

- Extensive consumer awareness regarding the benefits of smart prepaid metering may be conducted via newspapers, social media, TV, FM radio stations, NGOs, small public meetings and through government public relation offices.
- The utility must ensure that a mobile app is made available to the consumers for viewing their real time consumption as well as power quality. Necessary publicity in this regard should be carried out via traditional as well as social media.
- During replacement of the postpaid meters with smart prepaid meters, the security deposit amount against the postpaid connection along with accumulated security deposit interest may be considered as the initial prepaid balance of the consumer.
- The concerned consumers may be given a one-time incentive in the form of a top up of a certain amount in his/her prepaid balance.

3 Non-smart Stand Alone Prepaid to Smart Prepaid (Strategies)

The stand-alone prepaid metering mode has the following features:

- The consumers must punch in lengthy vend codes, sometimes as long as 160–200 characters, in order top up their prepaid balance.
- Automatic disconnection happens if the prepaid balance of the consumer is exhausted.
- No manual intervention in meter reading and billing process.
- Remote connection-disconnection of service is not possible.
- In most cases, consumers are unable to view their real time consumption and power quality parameters.

The following strategies are suggested for replacement of stand-alone prepaid meters with smart prepaid meters:

- Extensive awareness campaigns via traditional and social media intimating the existing stand alone pre-paid consumers that there is no need of punching in lengthy vend codes in case of smart prepaid meters.
- Consumers are to be intimated that they will be able to view their real time consumption, prepaid balance and power quality parameters through a mobile app.
- During meter replacement, the existing prepaid balance of the consumer may be transferred to his/her smart prepaid balance.
- The benefits enjoyed by the consumer e.g., happy hours, emergency balance etc. are continued in case of smart prepaid metering also.

4 Technical Workplan

The technical workplan can be broadly divided into two phases:

- Meter Replacement Phase

  During meter replacement phase, the following information shall be captured and synced with the billing database of the utility:

  - Consumer Number
  - Consumer Name
  - Consumer Address
  - DTR Name
  - Feeder Name
  - Latitude of consumer premises
  - Longitude of Consumer Premises
  - Old meter's make and serial number
  - Old meter final reading (in kWh)

– Balance of old meter in case of prepaid meter replacement (in Rs.)
– New Meter make and Serial Number.
– Initial Reading of new meter (kWh)
– Pole Number (if available)
– Phase of connection (single or three phase)
– Consumer Category
– Date and time of replacement
– Meter seal details
– Name of personnel and contractor engaged for the replacement of the meter.

During meter replacement, a meter replacement slip may be handed over to the consumer, which will contain details about his old as well as new meter including the existing balance of the old stand-alone prepaid meter.

- Operational phase
  The smart prepaid mode may be implemented in the following manner:

– The billing parameters (kWh, PF, MD etc.) of the smart meter shall be collected by the MDMS (Meter Data Management System) and the same shall be passed to the billing application at a predefined period every day.
– Based upon the billing parameters collected as described above, the billing application will invoice the consumer, once every day. The invoicing shall be done by the system as per approved tariff. However, there will be no concept of a due date.
– The system will check whether the invoice amount is lower than the balance amount of the consumer as maintained by the system. If yes, then the invoice amount shall be deducted from the balance amount and the new balance amount shall be updated in the billing system. If no (after factoring in the emergency balance, if any) then the following actions may be initiated:

The invoice amount shall be deducted from the balance amount and the new balance amount shall be updated in the billing system.
The consumer will get SMS/email/push notification in the mobile app, requesting him/her to top up his/her balance within 24 (twenty-four) hours failing which his/her service connection shall be disconnected (remotely via auto-command initiated from the billing system).
Before next invoicing of the consumer, the available balance of the consumer shall be checked. If the balance is still found to be negative or zero, then the consumer's service connection shall be immediately disconnected by auto command initiated from the billing system.
As and when the consumer pays, his/her balance will be updated in the billing system. If a disconnected consumer tops up his/her balance, the system shall immediately check whether the updated balance is positive and if yes, the consumer's service connection shall be reconnected.

No disconnection will take place on holidays and happy hours. However, the consumer shall be intimated via SMS/email/push notification in the mobile app if his/her balance is exhausted.

- On the date of post-paid to prepaid conversion, a final post-paid bill shall be prepared by the billing system against the concerned consumer. The concerned consumer, during his next recharge/top up, shall have to top up his balance by an amount which is more than the amount of his/her final post-paid bill. Due intimation in this regard shall be made to the consumer via SMS/email/push notification in the mobile app.
- The utility may think of allowing instalment plans against the final bill amount as described above if requested by the consumer. In case of instalment plans, the consumer must top up his balance every month and ensure that his first recharge/top up of every month, during the instalment period, must be more than the instalment amount.
- The consumers must be given adequate facilities for topping up their smart prepaid balance via online as well as offline payment [1].
- The consumers must be given the facility to apply for change of their metering mode from smart prepaid to smart postpaid/conventional postpaid/stand alone prepaid or vice versa. Utility's CRM application should facilitate such requests in online mode along with necessary data syncing with concerned MDMS application.

5 Application Programming Interfaces (API)

In order to carry out the aforementioned workplan, the following APIs are proposed for data exchange between the billing application of the utility and the MDMS (Meter Data Management System) installed at the smart grid control Centre.

- API for billing parameter push from MDMS to utility's billing application (API hosted at MDMS provider end and called by utility's billing application).
- API for updating meter replacement data in utility's billing engine (API hosted at utility's billing application end and called by MDMS application)
- API for updating new service connection/change process data at MDMS provider end for syncing of master data (API hosted at MDMS provider end and called by utility's billing application)
- API for remote disconnection of service (API hosted at MDMS provider end and called by utility's billing application)
- API for remote connection of service (API hosted at MDMS provider end and called by utility's billing application)
- API for sending push notification to consumers via mobile app (API hosted at MDMS provider end and called by utility's billing application)
- API for providing balance of smart prepaid consumer (API hosted at utility's billing application end and called by MDMS application)

- API for providing payment history of smart prepaid consumers (API hosted at utility's billing application end and called by MDMS application)
- API for providing connection status of a smart prepaid consumer (API hosted at utility's billing application end and called by MDMS application).

6 Separate Tariff Structure for Smart Prepaid Consumers

The target consumer segment of smart prepaid metering is the domestic category of consumers. In most utilities across India, domestic consumers are billed on a two part, block rate tariff. Such tariff structures require extensive calculations and hence may demand very high system resources in case of daily invoicing by the billing application.

The utilities may approach concerned regulatory commissions for introduction of flat rate tariffs for smart prepaid consumers. A flat rate tariff shall require considerably lower system resources during daily invoicing of smart prepaid consumers by the billing engine.

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Optimizing Electric Vehicle Charging with Charging Data Analytics

Tayyibah Khanam, Ivanshu Kaushik, Mohammad Saad Alam, Sanchari Deb, and Yasser Rafat

Abstract Electric vehicles are considered as viable replacements to gasoline cars since they help in reducing harmful emissions and stimulate power generation through renewable energy sources, hence contributing to sustainability. However, one of the significant obstacles in the mass deployment of electric vehicles is the charging time anxiety among users and thus, the subsequent large waiting times for available chargers at charging stations. Data analytics, on the other hand, has revolutionized the decision-making tasks of management and operating systems since its arrival. In this paper, we attempt to optimize the choice of EV charging stations for users in their vicinity by minimizing the summation of time taken to reach the charging stations and the waiting times for available chargers. The proposed framework utilizes real-time data and historical data from all operating charging stations in the city to assist the user in finding the best suitable charging station for their current situation and can be implemented in a mobile phone application.

Keywords Electric vehicles · Charging infrastructure · Data analytics · Waiting times

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1 Introduction

With the evolving need for sustainable mobility, expansion of the Electric Vehicle (EV) market has emerged as a viable solution. However, EVs are still a rare sight in developing countries like India, mainly because of the challenges faced by users in the adoption of electric vehicles as their primary modes of transport. The introduction of EVs has brought about a need for adequate charging stations with efficient charging strategies for mass-market adoption. Remaining Useful Time (RUL)/range anxieties, cost anxieties and charging time anxieties remain the top three issues which can't be negotiated from a consumer point of view. Thus, for mass-market adoption, these anxieties must be addressed by governmental policies and EV management firms.

Data, on the other hand, is heterogeneous and abundant in the transport sector, thus giving rise to transport 'big data'. In this digitalized era, mobile phone applications have revolutionized the managing and organizing tasks for several users across the globe, majorly by leveraging transport big data. Some common features available in the existing EV charging mobile applications [1] are

(1) Locating charging stations from a worldwide database.
(2) Filtering out stations by—specific locations or routes, types of chargers, legend names etc.
(3) Providing real-time status of chargers.
(4) Trip Planning and booking time slots for EV charging in advance.

Li [2] in his study has extensively used EV trajectory data and data from several other sources to optimally place new charging stations in urban cities, intending to minimize the average time to the nearest charging station, and the average waiting time for an available charging point. Similarly, several studies in the recent past have attempted to optimize EV charging through different approaches such as—switching to green energy charging sources [3], EV Charging station layout to reduce excess driving distances and energy overheads [4] and minimizing charging costs and power balancing [5]. However, existing frameworks, especially the existing mobile phone applications, don't optimally assist the EV users in finding the most suitable charging station concerning time constraints in the present Charging Pile Network (CPN) of cities. Thus, the objective of this paper is to address charging time anxieties by assisting an EV user find the most optimal choice of an EV charging station in his/her vicinity, which simply translates to 'reducing the time taken to find an EV charger'. Thus, we propose the framework of an additional feature capable of working on a mobile phone application that not only saves time but can also reduce the overall travel costs in the future.

The proposed methodology is based on comparative analysis of all possible suitable chargers filtered by user inputs. A comparative analysis is conducted on all potential EV chargers from the user's perspective based on real-time datasets. The rest of the paper is structured as follows—the methodology in Sect. 2 describes the data as well as solution framework with the help of a pseudocode and a flowchart. While Sect. 3 generalizes the results obtained, Sect. 4 discusses the potential limitations from the author's point of view. Finally, Sect. 5 concludes the paper's objectives.

2 Methodology

Suppose an EV user travelling on a particular route needs to charge his/her EV shortly. The mobile application comes into play when the user needs to find a charger with lowest travelling time as well as soonest possible available. We begin by describing the types of data required by our framework, followed by the solution framework itself in the following sections.

2.1 Data Description

Initial one-time data procured by our framework and stored in the database:

(1) Location of each Charging Station
(2) Total number of Chargers in each station
(3) Type of each charger.

User data is collected as 'filters' applied by the user to better sort out chargers that can potentially be considered by the user, rest of the chargers are then excluded from our study at this stage. In our framework, users are provided with the facility of filtering out charging stations according to the current maximum possible driving range of their EV and further filter out the charger type capable of charging their EVs (Table 1).

Real-time data is also expected to flow in our ideal framework through various data collecting devices such as sensors and smart meters, following which this data can be stored in the database. Here, real-time data consists of the current status of every charger—whether available or occupied and if occupied, the percentage charged of the EV getting currently charged.

Historical data of each charger can be ingested and stored in the database, essential for the calculation of 'waiting times'. Through sensor devices installed in each charger, we intend to record the time taken to charge an EV from a% to b% (where b is usually full charge = 100%) in smaller percent intervals (such as 10% in our study) for each EV previously charged.

Table 1 Key notations and terminologies

Notations	Descriptions
n	Number of charging stations
S_n	'nth' charging station
P_k	Number of charging points in each charging station 'Sk'
P_{km}	'mth' charger of 'kth' charging station

2.2 Solution Framework

Filtering out Potential Chargers: Based on the filter inputs provided by the user (the type of charger and maximum driving range), our framework pulls out a set of potential charging stations whose chargers need to be considered while picking out the most optimal charger and hence the most optimal charging station.

For instance, the user specifies the range of seeking a charging station as "d" kilometres with a charger type 'B'. In this case, our framework filters out all operating charging stations with type 'B' chargers in the range of "0 to d" kilometers. Let the set of filtered charging stations be SC = $\{S_1, S_2, \ldots, S_x, \ldots S_b\}$ (where b = [0, n]) each at a distance of dC = $\{d_1, d_2, \ldots, d_x, .., d_b\}$ kilometers respectively. Thus, the set of charges being considered in our study is PC = $\{P_1, P_2, \ldots, P_x, \ldots P_b\}$ where $P_k = \{P_{k1}, P_{k2}, P_{k3} \ldots \ldots\}$ for k = 1, 2, …x, …b.

Calculation of Travel Times: Irrespective of which station is the nearest, second nearest (and so on) to the user, the time taken to reach a particular station plays a much more important role in our study since our goal is to minimize the time taken by an EV user to find a charger as explained previously. The time taken to reach a station depends on the distance as well as the current traffic congestions of that route and thus at this stage, our framework is expected to utilize the Google Maps Distance Matrix API [6] to calculate the set of travel times $dt_C = \{dt_1, dt_2, \ldots, dt_x, \ldots dt_b\}$ for each charging station where dtx = time taken to reach station 'x' in current traffic conditions (Fig. 1).

Once the API calculates travel times for individual charging stations, we sort these travelling times in ascending order. For this analysis, let's assume the sorted output is $dt_1 < dt_2 < \ldots. < dt_b$, where Station 1 requires minimum travel time.

Total Time to charge: Since our framework procures real-time status of each charger across $S_1, S_2, \ldots S_b$, current occupancy status (occupied/available) of chargers in each charging station is made available to the user. Ideal case scenario would be the availability of chargers in the nearest charging station i.e. S_1. However, in reality, preoccupancy of all chargers in a charging station is highly likely to happen once the mass adoption of EVs takes place in the near future.

In this situation, the user can do either one of the two things.

Option 1: Either the user can decide to go to the next nearest charging stations in the order of S_2 then S_3 and so on till S_b.

OR

Option 2: The user can go to the nearest charging station i.e. S_1 and wait for any one of the chargers to be available.

This is where our framework will come into play by performing a comparative time minimization analysis on the set of Total Times (TC) of all occupied/available chargers in the set of considered chargers PC. Here, TC = $\{T_1, T_2, \ldots, T_x, \ldots T_b\}$ where $T_k = \{T_{k1}, T_{k2}, T_{k3} \ldots \ldots\}$ for k = 1, 2,….x, …b. Hence, $\mathbf{T_{xy} = dt_x + wx_y}$. Our job here is to find the charger y corresponding to station x for which Txy is minimum.

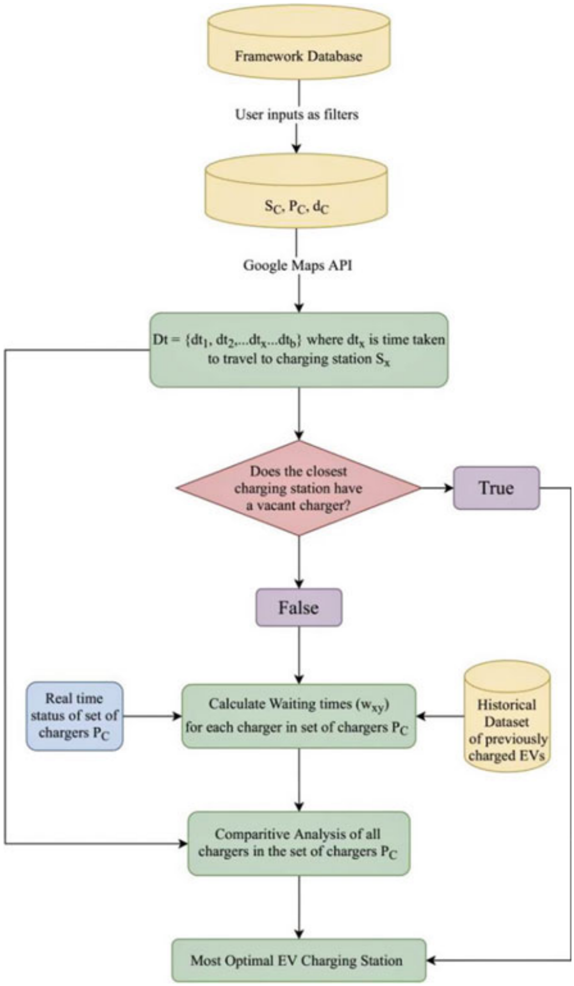

Fig. 1 Flowchart of the methodology utilized in this study

Calculation of Waiting Times: Since the Google Maps API provides us with information on the least travelling times among the set dtC, our job is now restricted to find the waiting times 'w_{xy}' for each charger 'y' in the charging station S_x to finally minimize T_{xy}.

To find w of a charger, historical data of previously charged EVs stored in our database is utilized. Suppose at a particular time when the user seeks assistance from his/her mobile application to charge an EV, an occupied charger P11 (charger 1 of station S_1) has charged an EV by "g%". Using historical charging data, we aim to find out the time taken by the charger P11 to charge rest of the "(100-g) %" at the car getting charged presently as follows—

(1) Firstly, the percent battery level (g %) of the EV currently getting charged at P11 is recorded and sent to the processor.

(2) From historical data, the times taken by EVs getting previously charged at charger P11 to charge from g% to 100% are retrieved from the databases. Due to lack of datasets, we have considered 5 EVs in our study.

(3) Next, we perform a supervised machine learning algorithm—Regression to predict a continuous outcome (which is the waiting time 'w_{11}' in this case) based on the values of predictor variables which are averages of the historic time data sets. We particularly perform Polynomial Regression of 5th degree since it can suit all types of EV charging profiles while preventing overfitting and underfitting to finally give reasonable outcomes. Briefly, the goal of Polynomial Regression model is to build a mathematical equation that predicts waiting time of the present car getting charged as a function of the waiting times of the previously charged cars at the same charger. The waiting time "w11" thus calculated is sent to the output generating framework (Figs. 2 and 3).

(4) The two critical parameters for evaluating the waiting time regression algorithm are Least squared errors (LSE) and total waiting times. Although the total waiting times predicted by both Linear Regression Model (simply averaging) and Polynomial Regression Model are comparatively close in the case of many chargers, the Linear Regression model generally has a very high LSE, thus making it inappropriate for practical purposes.

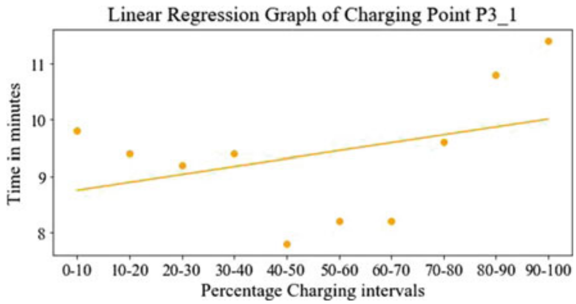

Fig. 2 Linear regression (simple average method) for charger P_{31}

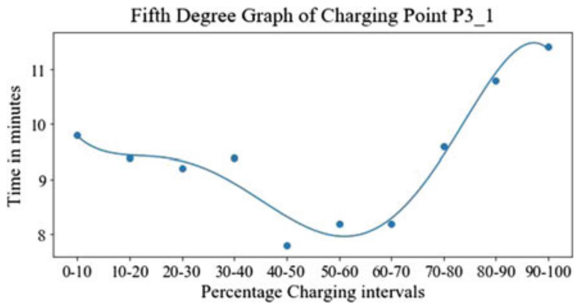

Fig. 3 Polynomial regression graphs for charger P_{31}

(5) Similarly, waiting times for all chargers in the set of chargers P_C is calculated as (w_{11}, w_{12}, w_{13}…) for chargers at S_1, (w_{21}, w_{22}, w_{23}…) for chargers at S_2 and so on till S_b.

Comparative Analysis on Total Times: The final comparative code on Total Times is run using inbuilt functions in python on the set of times Txy to find the minimum T_{xy}. Let us assume that T_{xy} assumes minimum at 'x = q' and 'y = r' where charger 'r' with type 'B' belongs to 'qth' charging station from the set of charging stations SC such that

$$\boldsymbol{Min(T_{xy}) = Min(dt_x + w_{xy}) = (dt_q + w_{qr})}$$

The pseudocode for the proposed framework is described below

Inputs: Current Location, Historical Data, Real-time Data, User Inputs

Outputs: Most optimal charger and Charging Station, Total Waiting Time

Description:

```
1: function FindWaitingTime (Percentage Charged) {
   Use Polynomial Regression on Historical Data to estimate waiting time
   return waiting_time
end
}
2: function FindTimeAndDistance (Current Location, Final Location) {
   Use the Google Maps API to find the Distance and Time required
to reach Final Location from Current Location
   return travel_time, travel_distance
end
}
3: In the main function { for
every station in the city:
    Compute the travel time and distance using FindTimeAndDistance
          () for every charger in that station:
              Compute waiting time using FindWaitingTime ()
                     TotalTime ← waiting_time +
                     travel_time store TotalTime
return charger and charging station with minimum
TotalTime }
```

Thus, our framework assists the user for the most optimal choice of a charger, which would be charger 'r' belonging to charging station 'q' at that particular time instant considering the current status of chargers across the city and the current traffic conditions. Google Maps API can further be utilized for best route guidance and so on to the most optimal charging station.

3 Results

To verify our framework code, we tested our framework using one-time data of 27 EV charging stations in the city of Mumbai. Since real-time data sets and historical data sets are not available in EV charging stations of Indian cities, the rest of the data was assumed for this study. With user location at (19.112705, 72.888662) and maximum driving range of the user as—20 km, the most optimal charger was charger P_{31} corresponding to charging station S_3 (TATA Power Charging Station) with a Total Time to Charge = T_{31} = 27.263 min.

4 Limitations

The regression method helps in the prediction of the waiting time of the current charger based on its historic charging profile. However, many research articles have stated that EV charging till 100% is not the best practice as it reduces battery life and affects battery health too [7]. Due to this reason, several users might disconnect the charger before reaching 100% based on personal perception, which can't be assumed or generalised. Similarly, an EV user might disconnect the charger at any time before 100% due to his/her time constraints, which can again not be generalized but is assumed to happen rarely. Hence, this approach might result in the deviation of actual waiting times than the calculated ones and hence affect the decision making of the EV user.

Further, EV Charging profiles are expected to differ with different types of vehicles such as bus, truck, car, two-wheeler, bicycle etc. Hence, while calculating waiting times of existing type 'H' vehicle getting charged, historical data of previously charged type 'H' vehicles only need to be considered. Further, within the same vehicle type, charging profiles can also differ due to the differences in battery elements and manufacturer specifications. Due to lack of data sets and rarity of EV users in Indian cities, this issue was passed over in this study but can be entertained in future when EVs are adopted widely by users to give accurate results.

5 Conclusion

In this study, we have proposed a framework which attempts to analyze the most optimal charger and hence charging station considering time as the deciding factor. While travel times to charging stations depend on traffic conditions and route lengths, we have attempted to minimize the 'total time to charge' by optimizing the variables of importance through Polynomial Regression. The evaluation results demonstrate that our framework could successfully reduce the total time to charge by 20–30% by assisting the users. While it is possible that the most optimal charging station recommended by our framework might be ecologically unsustainable (corresponding to chargers having much higher travel times and distances), we expect our framework to successfully work in a city with mass EV adoptions among users which directly results in an interconnected and stronger CPN.

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Towards Smart Utilization, Maintenance and Planning of Distribution Transformers Using Smart Meter Data

Karunakar Jha, Hariom Sharma, and Tushar Sharma

Abstract Distribution utilities regularly face the challenge of overloading in the distribution transformers due to seasonal variations, load growth, and network changes. Additionally nonlinear loads causing harmonics are also contributing to overloading. Sustained overloading leads to increased technical loss, transformer failures, voltage distortion and loss in supply reliability. Availability of quality data for distribution transformers has been a major challenge in distribution operations. Traditionally utilities collect the data of transformer loading from site manually using measuring instruments like millimeter, usually once or twice a day at fixed timings. This is very cumbersome and possible for only a small number of transformers for a small duration only. Besides the quality of data is not good as often the measured value at fixed interval do not coincide with the actual overload. Additionally it is a safety issue for utility personnel the site at odd hours. Hence the practice is not very effective in overload detection. The Smart meter roadmap adopted by TPDDL envisions installation of smart meter for all distribution transformers and consumers in next 5 years. All distributions transformers in TPDDL installed with energy audit smart meters over RF Canopy communication infrastructure in the first phase of Smart meter project. The data from these meters are sent to HES (Head End system) at regular intervals. From HES the data is sent to MDM (Meter Data Management) for analysis and customized reports. The availability of smart meter data for the distribution transformers is creating opportunity to harness host of information like **load profile, Phasor, harmonics, unbalance and sustained overloading**. These information are helping the operation and maintenance team to assess the condition of transformers, plan maintenance actions, and augment overloaded transformers in

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the nick of time before significant damage to the transformer may occur. The integration of intelligent information from smart meters with the operation & maintenance practices are unlocking new values for the utilities in multiple ways like

- Transformer Augmentation/deaugmentation based on actual load.
- Impact of Voltage Unbalance Factor (VUF), Harmonics at peak load.
- Overload monitoring of HVDS transformers where transformer meters are unavailable.

These potential for enhanced values for the utilities has resulted into development of multiple analytical tools based on the data from Smart DT meters. This paper explicitly describe about the needs/purposes, methodologies adopted and hindrances faced in the creation & implementation of the analytical tools and the value accessed from them. It also examines the potential for its application in other applications like real time loss calculation of transformers.

Abbreviations

TPDDL	Tata Power Delhi Distribution Limited
T&D	Transmission and Distribution
DT	Distribution Transformer
HVDS	High Voltage Distribution System
AMI	Advance Metering Infrastructure
MDM	Meter Data Management
HES	Head End Server
RF	Radio Frequency
CUF	Current Unbalance Factor
VUF	Voltage Unbalance Factor
TOU	Time of Unit
PCC	Point of Common Coupling
LV	Low Voltage
HV	High Voltage

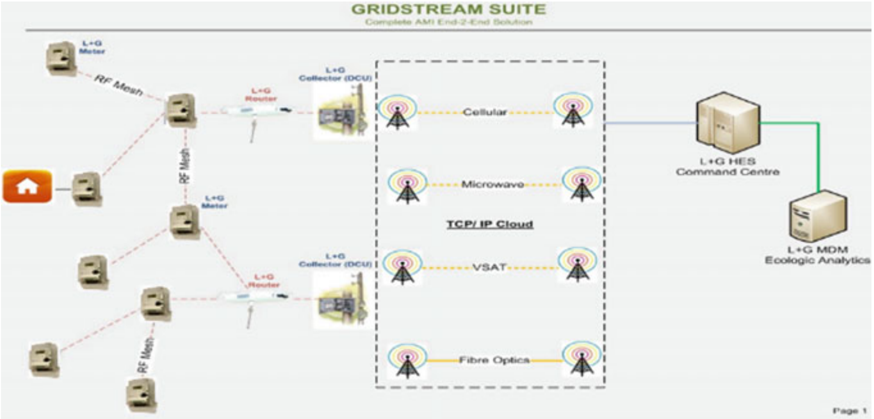
1 Introduction

Tata Power Delhi Distribution Limited (TPDDL) is a Power Distribution Utility, distributes electricity in North and North-West part of Delhi, serving about 1.7 million consumers. TATA Power-DDL has always been an early implementer of latest technologies & procedures in India and has perhaps most number of standalone and integrated platforms in use. These procedures have also been instrumental in improving the overall performance of the company and also been able to deliver business benefits in terms of return on capitalization of assets and improving reliability. TPDDL's competence in adaptation of latest technologies makes it very appropriate to achieve high standards in optimization of resources in maintenance and management of Distribution Transformers.

As a part of Government Initiative, TPPDL has installed 2Lk Consumer smart meters and 5000 DT smart meters for Real-time data availability better load management, Reduction of T&D Losses.

2 Smart Meter Overview

Smart meters enable two-way communication between the meter and the central system. A smart meter is usually an electrical meter that records consumption of electric energy in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing purposes.



Smart meter Communication Diagram

3 National Smart Grid Mission—Smart Meters

Under National Smart Grid Mission there are 6 basic technologies/functionalities adopted:

Advanced Metering Infrastructure (AMI), Peak Load Management, Power Quality Management, Outage Management, Micro grids, Distributed Generation.

4 Benefits of Smart Grid Deployments

- Reduction of T&D losses.
- Peak load management, improved QoS and reliability.
- Reduction in power purchase cost.
- Better asset management.
- Increased grid visibility and self-healing grids.
- Renewable integration and accessibility to electricity.
- Increased options such as ToU tariff, DR programs, net metering.
- Satisfied customers and financially sound utilities etc.

5 National Tariff Policy for Smart Meters

3. The Appropriate Commission may provide incentives to encourage metering and billing based on metered tariffs, particularly for consumer categories that are presently unmetered to a large extent. The metered tariffs and the incentives should be given wide publicity. Smart meters have the advantages of remote metering and billing, implementation of peak and off-peak tariff and demand side management through demand response. These would become essential in future for load-generation balancing due to increasing penetration of intermittent type of generation like wind and solar power.

Appropriate Commission shall, therefore, mandate smart meters for:

(a) Consumers with monthly consumption of 500 units and more at the earliest but not later than 31.12.2017;

(b) Consumers with monthly consumption above 200 units by 31.12.2019.

6 Smart DT Meters Parameters and Data Availability

As smart meters data is readily available at Server the data can be utilized for Real time DT Load Monitoring, Real time DT Loss calculation, Outage management, Correct Consumer Mapping etc.

Parameters available at Head end server includes per phase Current (Ir, Iy, Ib), Voltages (Vr, Vy, Vb), Power factor (pf), THD parameters.

7 Introduction of Unbalance Factors in Voltage and Current

Generating units supply three-phase sinusoidal positive sequence voltages, which are balanced in terms of their amplitudes and 120 phase differences at a single frequency. Any deviations from these two basic characteristics introduce an unbalanced condition. Hence, the terminology of unbalanced can be classified into three main parts; amplitude unbalance of the fundamental, phase difference unbalance of the fundamental, and unbalanced harmonic disturbances. Occurrence of at least one of these features is enough for a distribution network to become unbalanced.

The voltage and current unbalances are serious power quality problems with and mainly affecting low-voltage electricity distribution three-phase systems. In a three-phase system, the current unbalance is due to load unbalance, while it is considered as the main cause of voltage unbalance. The electricity utilities and distribution network operators are responsible for providing of symmetrical voltages system at the point of common coupling between distribution gird and customers' internal network. The duty of current balancing is solidarity of both of electricity suppliers and customers. The utilities must do it for voltage balancing by equally distribution of single-phase customers between three phases, while three-phase customers have no responsibility for doing it for their single-phase loads. According to this paper, the power quality penalty and unbalanced current-based tariff are innovated for encouraging them to do it like as utilities.

8 Causes of Unbalance in Distribution System

Unbalanced conditions are principally caused by both structural and operational factors. Structural unbalance is usually negligible and can occur due to incomplete transposition of transmission lines and cables, asymmetrical distribution of wiring of transformers, open-D (V–V) or open-Y–open-D connected transformers, capacitor banks, aged fuses, etc. Nevertheless, operational unbalance can be considerable when single-phase and two-phase loads as well as any unbalanced three-phase loads such as arc-furnaces are being supplied by the distribution network.

The Discoms try to provide a balanced voltage system at the point of common coupling (PCC) between the distribution gird and the customers' internal network. Under normal condition, line voltages are determined by:

- terminal voltages of generators,
- the impedance of power transmission network,
- the loads connected to the distribution grid.

The system voltages at generation power plants are generally symmetrical due to the construction and operation of synchronous generators used in power networks. Therefore, the centralized generation generally has no unbalance.

In most cases, the asymmetry of the loads is the main cause of unbalance. The low-voltage (LV) loads like as residential facilities are usually single phase.

In the layout of an electrical wiring system feeding these loads, the load circuits are distributed among the three-phase systems, for instance, one phase per floor of an apartment or building or alternating connection in rows of houses. Still, the balance of the equivalent load at the central transformers fluctuates because of the statistical spread of the duty cycles of the different individual loads. Therefore, the unequal distribution of single-phase loads between three-phase lines is the main cause of current and voltage unbalance.

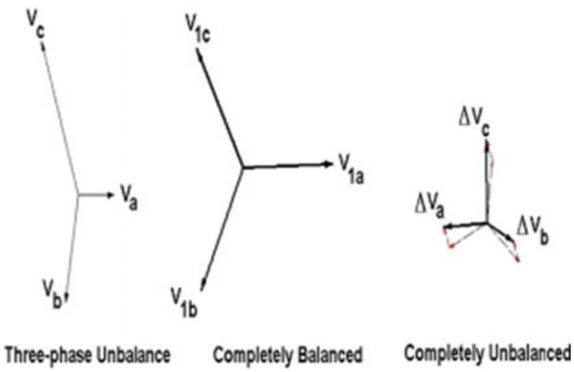
9 Unbalance Formulation

9.1 Symmetrical Sequences

According to this method, a three-phase unbalanced system is decomposed into three balanced components as: direct (positive) sequence, inverse (negative) sequence, and homopolar (zero) sequence, indicated by subscripts: d (+), i (−), and h (0).

The unbalance quantity of voltages and currents are calculated by the ratio of negative to positive sequences. According to this relation, the negative sequence is expressed as percentage of the positive sequence:

$$\mathrm{VUF\%} = [\mathrm{Vi/Vd}] * 100$$
$$\mathrm{CUF\%} = [\mathrm{Ii/Id}] * 100$$



9.2 Average of Three Phases Values

In this method, the quantities of voltage and current unbalance are measured and calculated by the ratio of maximum deviation from the average of three phases' values to the average. According to this relation, the maximum deviation from the average is expressed as percentage of the average:

$$\text{VUF\%} = \left[\text{maximum deviation from average Voltage/Average Voltage}\right] * 100$$

$$\text{CUF\%} = \left[\text{maximum deviation from average current/Average current}\right] * 100$$

10 Unbalance Effects

Three-phase unbalance imposes certain consequences on the distribution networks, including power losses of substation transformers and lines along with the viable capacity of transformers out of their nominal balanced ratings. The unbalance of power systems contributes to the intensification of physical process of losing energy. Moreover, when a distribution transformer is operating under unbalance condition, then the transformer will be unable to serve up to its nominal ratings because of unequal current magnitudes. This section intends to analyze and express the share of unbalance of distribution works on the power losses and loading capacity of transformers.

10.1 Power Loss

The power losses are created because of reduction in the capacity of three-phase electrical facilities as motors, transformers, cables, and lines due to negative sequence. Meanwhile, if various transformer losses were analyzed exclusively in terms of unbalance issue, copper losses have the largest share which will vary with the unbalanced load currents.

10.2 Energy Loss

The copper (energy) loss is proportional to the square root of current and then increase due to current unbalance. It is calculated that 33% of current unbalance cause to 16% of energy losses.

10.3 Loading Capability of Unbalanced Transformers

Unbalance condition reduces the actual loading capability of a distribution transformer, where the maximum current of the three phases determines the remaining capacity of transformer. In this situation, the substation transformer may not be able to supply the load as much as it is designed to. In practice, when the maximum current reaches the overload zone, even if the other two phases operate well below their rated currents.

11 Unbalance Standards and Limits

11.1 Voltage Unbalance

There are different standards about the limits of voltage unbalance. It is recommended that electric supply systems should be designed and operated to limit the maximum voltage unbalance up to 3% when measured at the electric-utility revenue meter no-load conditions.

The standard states that 1% of voltage current unbalance can create 6–10% current unbalance.

11.2 Current Unbalance

Unfortunately, there is no standard limit for current unbalance. The maximum standard limit of current unbalance due to 3% of voltage unbalance can be advised as 30%.

11.3 Power Unbalance

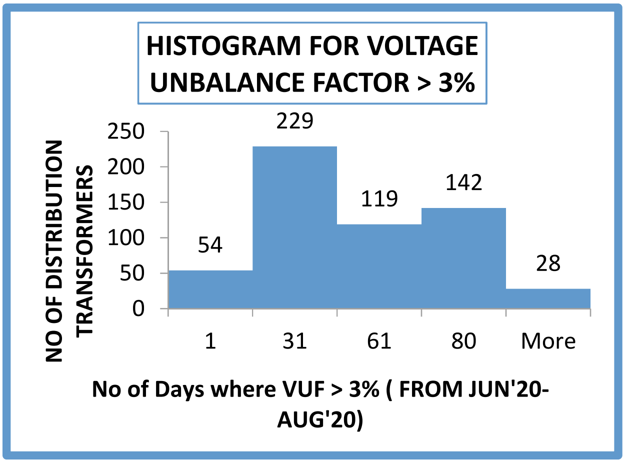
The voltage and current unbalance cause to power unbalance. The quantity of power unbalance can be measured or calculated same as voltage and current unbalance by means of sequences or average. Nearly 33% Unbalance in Power is measured from Current and Voltage Standards

12 Case Study: TPDDL

In TPDDL, total metered Distribution transformers is 5000. Before the installation of smart meters the loading was captured by taking manual data from the meter end. Thus there is always a risk of life and failure of transformer as loading is not done on real time basis.

Post Installation of smart meters, data is readily available at HES and real-time DT Loading can be analysed thus asset optimisation can be done and DT Failure can be avoided.

It is identified that during Peak summer FY 20–21, 572 Distribution transformers having VUF > 3% thus CUF > 30% and contributing to 33% power loss. During the three month's peak course 28 transformers have been reported having VUF > 3% for more than 80 days.



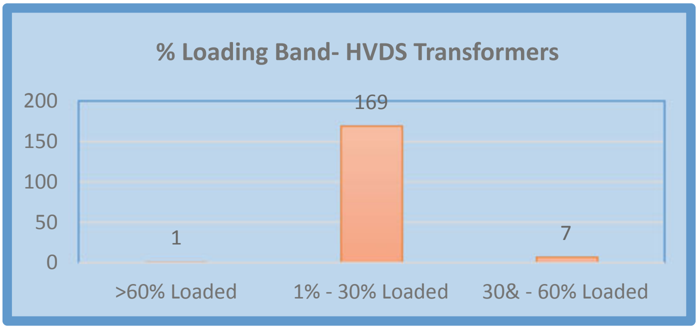
13 Other Smart Meters Usage

13.1 Calculation of Peak Load of HVDS Transformers Using Consumer Smart Meters

Identification of transformer loading at HVDS location is a challenge as there are no meters installed. As a result it is not feasible to calculate loading of Transformers at these location. With the help of consumer smart meter Transformer loading is calculated where there is 100% coverage of smart meters at consumer level.

14 Case Study: Zone 521 Pooth Khurd

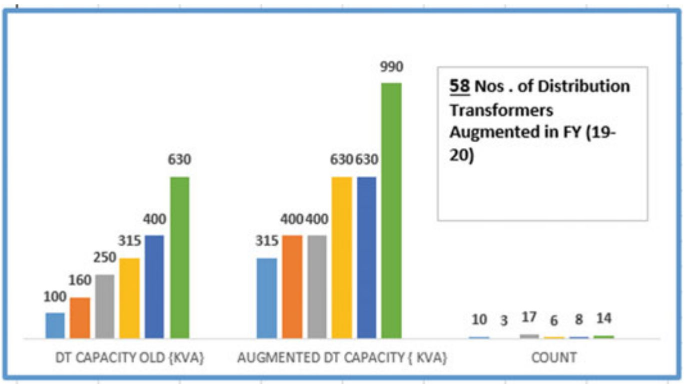
The report was generated for 177 Transformers having 321 Consumer attached to them, using load Analysis and interval data of consumer smart meters.



14.1 Asset Optimisation

With the help of daily Peak load data of transformers, Overloaded transformers were identified and better transformer Utilisation was obtained thereby saving the most critical asset of the company.

In the FY 2019–20, 58 DT have been Augmented due to overloading of transformers and transformer failure was averted.



Smart LT Network Equipment: Introduction of Smart, Compact & Aesthetic LT Feeder Pillar

V. T. Naraynan, Ajay Potdar, Ramesh Kharat, Alapathi Bhanuji, Vikas Koul, and Swapnil Rao

Abstract This paper highlights applications and advantages of using Compact Hexagonal feeder pillar. In a metro city where space is a major constraint. In present distribution Networks, the conventional LT feeder pillars which are used in the system are associated with many challenges. The biggest being the footprint requirement in a metropolitan city where space availability is big concern. Some other challenges being the conventional feeder pillar doors are very easy to open and have exposed bare busbars which are vulnerable to theft by direct tapping which is the most common method of stealing electricity. Also these conventional feeder pillars act as visible and physical obstacle and if installed on footpaths and road sides, causes problems to pedestrians and residents living in narrow and congested lanes.

Keywords Hexagonal feeder pillar · Distribution · CSS-consumer substation · LT-feeder pillar · Hexagonal feeder pillar · Distribution management system component

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1 Introduction

Power distribution utilities have equipment's, such as feeder pillars, meter rooms, distribution boards, electric poles etc., installed on public road/Premises. Hence it is crucial to protect general public from such hazards by maintaining healthy/safe conditions and periodic inspections of the equipment. Tata Power operates with philosophy of "Leadership with Care" and Safety as one of the core values. Tata power has walked extra miles to ensure safety of public, installations and personnel. Along with technical solution, digital solutions have been emphasized and practiced in Tata Power.

In present distribution Networks, the conventional LT feeder pillars which are used in the system are associated with many challenges like being prone to theft, Safety accidents apart from being bulkier in size. To overcome above challenges, hexagonal Feeder Pillars have recently been introduced into the Tata Power Mumbai distribution network. These feeder pillars are optimally sized and offer an overall space reduction of around 30% when compared to its conventional counterparts. These are fully reliable, completely safe and are available with anti-theft features. Parameters like—Current, Voltage, Temperature, etc., can be seamlessly monitored and available over SCADA network. This empowers utility to take preventive measures and minimize overload/overcurrent conditions. There are other unique features like anti-theft which allows opening of door only by authorized person with help of password protected lock openable through a password key.

2 Ease of Use

2.1 Problems with Existing Designs

Conventional doors (easy to open) expose bare busbars which are vulnerable to theft by direct tapping, the most common method of stealing electricity. Also Visible and physical obstacle and if installed on footpaths and road sides, causes problems to pedestrians and residents living in narrow and congested lanes.

2.2 New Age Hexagonal Feeder Pillar

Hexagonal Feeder Pillars are optimally sized, fully reliable, completely safe and available with anti-theft features. Parameters like—Current, Voltage, Temperature, etc., can be seamlessly monitored and available over SCADA network. This empowers utility to take preventive measures and minimize overload/overcurrent conditions. There are other unique features like anti-theft which allows opening of door only by authorized person with help of password protected lock openable through a password key.

Hexagonal Feeder Pillar

3 Advantages Over Earlier Designs

- Compact design: The new design brings a big advantage towards space saving. These feeder pillars helps reduce foot print utilisation by 25–30 percent. With reduced size the design helps reduce capex expenditure in addition to have reduced land utilisation which finds it a greater advantage in metro cities like Mumbai
- On-Load Connect—Disconnect: These feeder pillars have live load connect-disconnect ability with gang operation feature.
- Touch-Proof safe design: The design implements complete safe design with touch proof facility resulting in having tremendous advantage of being super safe installation
- No need of lugs: These Feeder Pillars employ lug free feature where lugs are not required
- Modular: These feeder pillars are completely modular and thus breakdown in one section can be repaired or resolved without affecting other sections
- Energy Efficient: With highly energy efficient feature, these feeder pillars prove to be the best in class for the use in large scale in a utility.

Hexagonal Feeder Pillar

Asset Performance Management Using Machine Learning

Somesh Kumar, Vinit Mishra, Abinash Singh, Amit Sharma, Vivek Singh, and Hem Thukral

Abstract Utilities have assets spread across diverse geographies which are very difficult to monitor and provide timely attention on daily basis. In addition, unplanned downtime often costs utilities 10× the cost of planned maintenance. Traditional approach for asset reliability leverages the first principles model. Artificial Intelligence (AI) and Machine learning (ML) techniques appear to solve the same problems but differ in areas of human intervention and accuracy of prediction. A widespread integration of machine learning in Asset Performance Management (APM) marks a transition from estimated engineering and statistical models towards measuring patterns of asset behavior. Utilities are adopting the proliferation of advanced technology where they can predict failures before they occur and build proactive maintenance plan, thereby improving reliability and expenditure. Asset Performance Management (APM), with the capability to analyses large data sets from both IT and OT systems from field assets, helps take 3R decisions (Repair Vs Replace Vs Refurbish). This paper presents a case study of an Indian utility on APM using Machine Learning techniques on Distribution Transformers wherein the failure rate was reduced from 8 to 9% by estimated 2–3% thereby providing system reliability and estimated savings of USD 1.31 million per annum (for 20,000 DTs) through a reduction in transformer repair charges. These ML techniques can also be used for

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cables, switchgears and other critical assets across the power generation, transmission, distribution and renewables value chain thereby transitioning from Time-Based maintenance (TBM) to Condition-Based Maintenance (CBM).

Keywords Time-Based maintenance (TBM) · Condition-Based Maintenance (CBM) · Predictive Maintenance · Asset Performance Management (APM)

1 Introduction

Top priorities for power utilities today are improving reliability, performance and safety. They are focusing their efforts and resources on controlling costs and maximising value from existing investments. Utilities can gain the highest return on critical assets with the help of Predictive analytics that supports the predictive maintenance programs using AI/ML solutions. Predictive Analytics solution provides early warning notification and diagnosis of equipment issues days, weeks or months before failure. This helps asset intensive power utilities to reduce equipment downtime, increase reliability, and improve performance while reducing operations and maintenance expenditures.

Artificial Intelligence (AI) and Machine Learning (ML) are offering new possibilities that can help utilities to gain insights from sensor data from IoT (Internet of Things) and OT (Operational Technologies) systems, thus enables to assess the risk of failure or assessing conditions of assets. Asset performance Management using Machine learning will fine-tune the capabilities and learn based on the actual real-time behavior of the equipment under all conditions. It helps the utilities to measure the overall health of assets classified as High, Medium, and Low Risk with the capability to have drill-down analysis for high-risk assets. It will also include seasonal variations components, start-up/shutdown, deteriorating process, and mechanical performance, and changing duty cycles, etc. Thus helping to do risk analysis and enable the model to predict asset failure, thus giving the report for the stakeholder to act and take corrective actions. APM today essentially involves condition monitoring, asset integrity, and predictive maintenance.

APM tool typically capture data related to asset condition which includes work order history, asset failure records, process data via plant historian, inventory related data and condition monitoring tools data to provide a holistic view of the asset performance. This data is then able to be used for reliability analytics and asset health visualization, to support development and fine tuning of various asset models including lifecycle cost and reliability modelling, and as the base data set to support the various APM capabilities.

2 Background

Manufacturing or production system to measure the performance of the asset always existed. Guidelines with the intention to increase business efficiency and customer satisfaction, ISO 9000, a quality management standard was developed in 1987. Embedding a quality management system within an organization, increasing organization's productivity, reducing unnecessary costs and ensuring quality of processes and products are the ultimate goals of ISO 9000. Even though, most of the medium and heavy industry went for inculcating and certification of ISO 9000, there still remains a gap to take care of the internal process and performance to assess the performance and manage the assets throughout its life cycle. PAS 55 (Publicly Available Standard 55) was developed in 2004 that provides objectivity across various aspects of good asset management from lifecycle strategy to everyday maintenance in terms of Cost/Risk/Performance, thereby bridging the gap and shortcomings in these aspects for industries All aspects of the asset lifecycle: from the first recognition of a need to design, acquisition, construction, commissioning, utilization or operation, maintenance, renewal, modification and/or ultimate disposal have been integrated by PAS 55. However, a new ISO standard was still in demand for the asset performance management to be acceptable by all in terms of long-term planning and reliability aspects for the industries. These efforts ultimately gave birth to ISO 55000 which consists of three standards.

ISO 55000—It provides critical overview, concepts and terminology needed to develop a long-term plan that incorporates an organization's mission, values, objectives, business policies and stakeholder requirements.

ISO 55001—It specifies the requirements for the establishment, implementation, maintenance and improvement of an asset management system. It can be used by any organization to determine which of its assets this International Standard is applicable.

ISO 55002—It offers interpretation and guidance for such a system to be implemented in accordance with the requirements of ISO 55001.

By adopting ISO 55000 series organization is enabled to achieve its objectives through the effective and efficient management of its assets with increased productivity and enhanced reliability. By implementing this asset management system, it can be assured that organizations can achieve its objectives consistently and can also sustain the progress over time. Other than ISO 55000 series, ISO 5001 was released in 2011 for energy management, ISO 27001 was released in 2013 for information security and ISO 45001 for occupational health and safety was released in 2018. Since early 2000, professionals from industries started to look at the assets and its performance with application of latest Information and Communication Technology (ICT) available to minimize cost and risk in industry from an asset life cycle perspective in order to maximize productivity and improve reliability. Professionals' research in this area resulted into different approaches and framework for Asset Performance Management. The latest technological perspectives inclusion in the framework led to a revolution in the application of big data and analytics. There is enormous amount of data generated by the asset management system which varies volume, variety, velocity value and veracity. The data characteristics could be structured, semi-structured and unstructured. A huge business opportunity for the industry exists in the data analytics software and AI/ML platforms [1].

3 Asset Pefomance Management

Today APM has become necessity for power utilities to address their major pain areas.

Common pain areas for utilities nowadays are:

- Higher operation and maintenance costs
- Reliability and safety (compliances)
- Operational efficiency
- Ageing infrastructure
- Shifting from traditional to proactive asset management approach.

As the future is shifting for greater emphasis on optimizing asset performance, return on asset investment and contribution to the business, the asset management approach today is more focused on to the asset's health condition monitoring, asset risk analytics and AI/ML data study solutions to meet the stakeholders demands and regulatory compliance. In order to achieve sustainable asset productivity with a good return on investment, asset owners require APM solution support.

Today power utilities need to improve the reliability and performance of the assets, which have affected the organizational risk and effectiveness with efficiency and profitability. Proactive asset performance management approach maintains assets at minimum costs at reduced inventory, reduced downtime/forced outages for assets with outsourcing, accurate risk analytics and reliability improvement. In order to achieve the operational readiness of the assets, APM considers the asset life cycle and whole life value from the owner and operators' perspective. So, to realize the accurate and reliable asset health condition and value addition, detailed business and asset strategy need to be developed based on the diagnosis and prognostics of the assets. But usually it's been seen that most of the end-users demand a 'quick-fix' solution due to non-integration and linkage of stakeholders' requirements with business objectives and a proven APM system. The APM tool cannot achieve the targeted performance if it is used poorly. Identification of the root cause for the non-performance is possible only if, a proactive-based holistic approach is adopted. Many enlightened world-class utilities are now convinced of the potential benefits of this proactive and holistic approach [1].

3.1 Proactive Asset Management—Approach

Technology changes often provide the boost for business process improvements that enable more effective deployment of resources. In order to shift from predictive to proactive maintenance particularly for critical assets, IIoT (Industrial Internet of Things) and advanced analytics using AI/ML will provide the base. AI and ML detects anomalies and predicts incident in real-time, to enable predictive maintenance, assist faster decision making and remote asset monitoring. AI learns on its own, in real time, making it easy to automatically develop hundreds of accurate models for different individual assets as opposed to traditional, thus enable operations and maintenance personnel to address equipment issue before the problem occur and significantly impact the operations. These techniques can easily identify the underperforming assets and increases assets utilization. Industry personnel can know and understand the actual and expected performance for an asset's current ambient, loading and operating conditions with the help of predictive analytics using AI/ML More data and process variables can be accessed and analyzed with the use of IIoT. More accurate diagnosis of the pending issue with fewer false positives can be achieved with multi variant analytics and it also help to identify failures way earlier than the actual occurrence. IIoT connects intelligent physical entities (sensors, metering devices, transmitters, assets, and products) to each other, to internet services, and to applications. The IIoT architecture builds on current and emerging technologies such as intelligent equipment with an IP address, machine-to-machine (M2M) communications, mobility, cloud computing, data analytics, and visualization tools. The data coming from a particular machine or class of assets can be combined with advanced data analytics to offer new opportunities for improving asset reliability, uptime, and longevity. The device data, combined with algorithms designed for that specific type of equipment, provide a means to assess asset health condition with higher accuracy (identify specific components and failure modes with longer advanced notice) and reliability (detect a higher portion of pending failures with fewer false alarms). The combination can significantly improve equipment uptime and reduce maintenance costs by recognizing a problem long before it can cascade into a complete failure or an equipment breakdown with a much larger impact on business performance [2].

3.2 Asset Performance Management—Pre-requisites

Some of the essential prerequisites without which APM system will not work effectively in an organization are:

- Visible corporate leadership—Baseline reliability performance expectations
- Data quality and robust production monitoring should be of the utmost importance to reduce errors and mitigate operational risk

- All data inputs should be verified and tested to ensure models are performing on accurate data sets, with periodic review procedures
- Robust cybersecurity which include data encryption and business continuity management plans is sensitive and critical to ensure incident management frameworks
- Professionals for risk and operational should be closely involved in the creation and ongoing oversight of any model leverages AI or ML
- A good partnership establishment with Digital Technology Services to develop and implement change
- Clearly defined roles and responsibilities impacting maintenance, operations and the entire organization
- Establish Business KPI's (Key Performance Indicators) and provide consistent methods of calculations or build criteria
- Conduct risk-based criticality assessment of plant equipment (ABC indicator)
- Establish Root Cause Analysis
- Establish RCM (Reliability Centered Maintenance), Reliability Engineering, Statistics
- Workflow roles and responsibilities
- Inspection Module and Management Empowerment.

3.3 Asset Performance Management—Functions

APM captures data related to asset condition which includes work order history, asset failure cause details, maintenance schedules/frequencies, delay and loss accounting, online condition data via plant historians, and condition monitoring data such as vibration monitoring, oil lab analysis results and other inspection results to provide a holistic view of the asset performance. This data is then able to be used for reliability analytics, asset risk analytics and asset health visualization, to support development and fine tuning of various asset models including lifecycle costing and RCM modelling, and as the base data set to support the various APM capabilities shown in Fig. 1 [3].

Asset Health/Condition Monitoring—APM supports the identification of physical abnormal conditions, through the automation of Asset Health data gathering and analysis, in order to trigger physical intervention or initiate changes to maintenance strategies to avoid reoccurrence of failures/faults [3].

Maintenance Strategy Development—APM support the development and ongoing refinement/optimization of equipment maintenance strategies in order to better manage asset risk, resources, support increased availability and reduce operation/maintenance cost [3].

Asset Integrity Management—APM supports the calculation of risk & the remaining useful life of assets. APM helps in generating, implementing and executing optimized inspection strategies. It also facilitates the compliance processes [3].

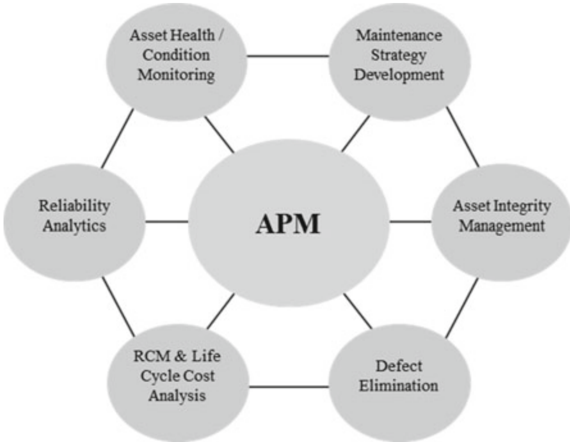


Fig. 1 APM functions [3]

Defect Elimination—APM supports the systematic identification and elimination of critical and recurring defects impacting performance through the application of targeted root cause analysis, development of appropriate action plans and real time tracking/monitoring of the completion of action plans [3].

RCM (Reliability Centered Maintenance) and Life Cycle Cost Analysis—APM provides tools to develop component level models of mobile and fixed assets of the industry to support benchmarking, equipment repair/refurbish/replace decisions and project option assessment [3].

Reliability Analytics—APM provides tools to query, extract, visualize and analyze structured and unstructured data from process systems/maintenance systems/CBM tools to support reliability analytics [3].

3.4 APM Using AI/ML—Approach

Any predictive analytics problem can be divided into 5 steps after getting data and each step can use different approach based on the use case, situation, data availability and data quality.

Cleaning data and data modelling to have homogeneity

Data comes from different sources and can be in different levels (time period, structure, unstructured) which can't be directly ingested by models. For that one unified data model should be created. Missing values are treated with imputation techniques [4].

Data transformation

There are three common data transformations are scaling, attribute decompositions and attribute aggregations.

Feature selection and reduction/Feature Engineering

The idea of a feature, separate from an attribute, makes more sense in the context of a problem. A feature is an attribute that is useful or meaningful to a particular problem. It is an important part of an observation for learning about the structure of the problem that is being modelled. In asset related problems, load profile could be an observation, but a feature might be a number of occurrences crossing threshold.

It includes feature importance, feature extraction, feature selection, feature construction, and feature learning.

Handling rare event

Most of asset related use cases are based on rare event and should be handled differently. The biggest problem related to rare event modelling is the sampling since the data is much skewed. Standard classifier algorithms like Decision Tree and Logistic Regression have a bias towards classes which have number of instances. They tend to only predict the majority class data. The features of the minority class are treated as noise and are often ignored. Thus, there is a high probability of misclassification of the minority class as compared to the majority class. There are multiple sampling methods to resolve this which can be used based on data availability such as Random under-sampling, Random over sampling, cluster-based over sampling, Informed Over Sampling, and Modified synthetic minority oversampling technique [5].

Create Machine learning Model and Evaluating the Model

Machine learning at its most basic is the practice of using algorithms to parse data, learn from it, and then decide or prediction about something in the world. So rather than hand-coding software routines with a specific set of instructions to accomplish a particular task, the machine is "trained" using large amounts of data and algorithms that give it the ability to learn how to perform the task. Two different kind of machine learning is used based on the use case.

- **Unsupervised learning**: This type of learning doesn't need tagged or labelled data. For e.g. customer segmentation where we just want to identify customers with potential revenue for targeted marketing. Clustering and Association related problems are solved using this technique. Most common algorithms are k-means, PCA, Hierarchical cluster analysis.
- **Supervised learning**: This type of learning is based on labelled data and algorithms learns from training labelled data apply that to unseen data. For e.g., historical faults of assets can be used to learn and to predict future faults. There is many supervised learning like Logistic regression techniques, Tree Algorithm, Neural Network [5].

Table 1 Confusion matrix

Actual	Predicted	
	Positive class	Negative class
Positive class	True positive (TP)	False negative (FN)
Negative class	False positive (FP)	True negative (TN)

Evaluation of a classification algorithm performance is measured by the Confusion Matrix which contains information about the actual and the predicted class (Table 1).

4 Case Study—APM in Discom

4.1 Problem Statement

Asset faults results in high expenditures throughout the year impacting the overall budget planning for CAPEX (Capital Expenditure) and OPEX (Operational Expenditure). The reliability of feeder is impacted due to unpredicted asset faults. Faults are currently unpredictable and hence impacts the planning of field crew. It causes loss of revenue to the utility in form of opportunity cost.

4.2 Approach

- Collect data in a more structured way and analyse it from the consistency perspective. Input data can be of different types. Asset data includes Asset type, Asset class, Asset routing, length, section, year of manufacturing, Number of repairs etc. Interval data includes 15 min interval against current flow parameters, fault data, Voltage data. Three layered approach is followed as shown in Fig. 2.

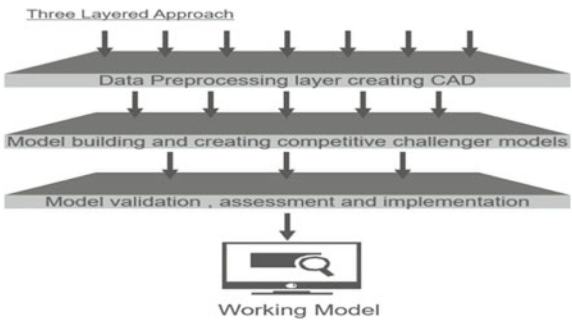


Fig. 2 Three layered approach for analytics models

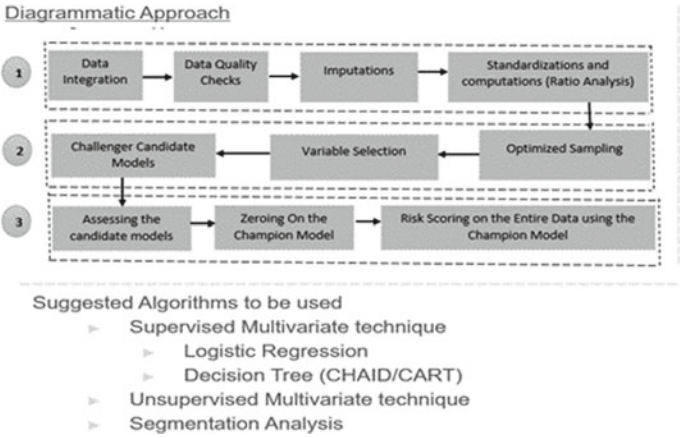


Fig. 3 Asset health index diagrammatic approach for analytics including predictive analytics/risk scoring

- Develop the predictive model by using the historical data. The predictive model is constantly being "trained" with confirmed and non-confirmed cases. The model generates potential cases with a certain probability.
- Generate results and validate them on the field. The outcomes are introduced in the model in order to calibrate it better as shown in Fig. 3.

4.3 Objective of the Modeling

The objective of the modeling techniques is to rightly classify the outages as outages and the non-outages as non-outages.

The target or the dependent variable is Outage (1 = Yes and 0 = No) [6].

Sampling Technique:

The sampling technique incorporated is balance stratified sampling of equal proportions.

The modeling framework:

Different Challenger Machine Learning Techniques Used (Challenger Champion Modeling Framework).

- Logistic Regression Techniques
- Full Fit Model
- Forward Regression
- Backward Regression
- Stepwise Regression.

Tree Algorithms

- Decision Tree with Assessment Criteria Misclassification
- Probability Decision Tree with Assessment Criteria Average Square Error
- High Performance Tree (With increased number of iterations)
- Random Forest
- Gradient Boosting (Assessment Criteria: Misclassification)
- Gradient Boosting (Assessment Criteria: Average Square Error.

Network or Artificial Intelligence

- Normal Neural Network
- Neural Network fed from Champion Logistic Regression Model
- Neural Network fed from Champion Tree Model

Other Special and Customized Modeling Techniques

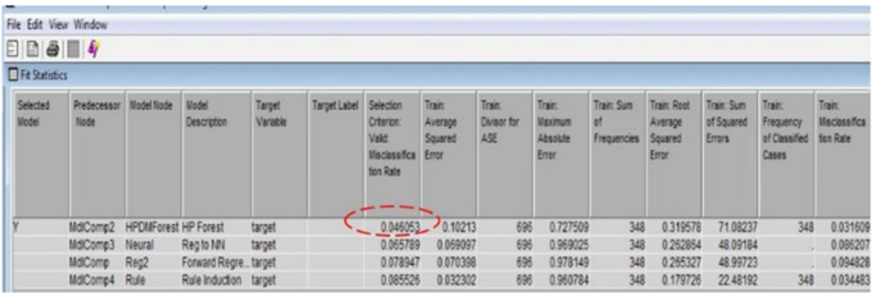
- Memory Based Reasoning
- Rule Induction
- SVM (Support Vector Machines)
- BN Classifier (Bayesian Network).

Case 1 (Balance Stratified Sample: Sample with outage: non-outage is 50:50 ratio)

From all these techniques the champion of the champion model is HP Random Forest with the validation misclassification rate is **4.60%** (Marked in red in Fig. 4) (Table 2).

Case 2 (Prior Probabilities in the ratio of 0.998 for the non-event to 0.002 for the event)

From all these techniques the champion of the champion model is Regression and Neural Network combination with the validation misclassification rate is 18.42% (Marked in red in Fig. 5) (Table 3).



Selected Model	Predecessor Node	Model Node	Model Description	Target Variable	Target Label	Selection Criterion: Valid: Misclassification Rate	Train: Average Squared Error	Train: Divisor for ASE	Train: Maximum Absolute Error	Train: Sum of Frequencies	Train: Root Average Squared Error	Train: Sum of Squared Errors	Train: Frequency of Classified Cases	Train: Misclassification Rate
Y	MdlComp2	HPDMForest	HP Forest	target		0.046053	0.10213	696	0.727509	348	0.319578	71.08237	348	0.031609
	MdlComp3	Neural	Reg to NN	target		0.065789	0.069097	696	0.969025	348	0.262864	48.09184	.	0.086207
	MdlComp	Reg2	Forward Regre...	target		0.078947	0.070398	696	0.978149	348	0.265327	48.99723	.	0.094828
	MdlComp4	Rule	Rule Induction	target		0.085526	0.032302	696	0.960784	348	0.179726	22.48192	348	0.034483

Fig. 4 Fit statistics—Case 1

Table 2 Classification table—Case 1

Data role = TRAIN target variable = target Target label = ‘ ‘					
Target	Outcome	Target percentage	Outcome percentage	Frequency count	Total percentage
0	0	95.5307	98.2759	171	49.1379
1	0	4.4693	4.5977	8	2.2989
0	1	1.7751	1.7241	3	0.8621
1	1	98.2249	95.4023	166	47.7011
Date role = VALIDATE target variable = target Target Label = ’ ‘					
Target	Outcome	Target percentage	Outcome percentage	Frequency count	Total percentage
0	0	91.566	100.000	76	50.000
1	0	8.434	9.211	7	4.6053
1	1	100.000	90.789	69	45.3947

Model Node	Model Description	Target Variable	Target Label	Selection Criterion: Valid: Misclassification Rate
Neural	Reg to NN	target		0.184211
Reg3	Backward ...	target		0.203947
Tree2	Probability ...	target		0.256579
Rule	Rule Inducti...	target		0.5

Fig. 5 Fit statistics—Case 2

Table 3 Classification table—Case 2

Data role = TRAIN target variable = target Target label = ‘ ‘						
Target	Outcome	Target percentage	Outcome percentage	Frequency count	Total percentage	Adjusted percent of predict/decision variable
0	0	100.000	87.931	153	43.9655	0.1759
0	1	10.769	12.069	21	6.0345	0.0241
1	1	89.231	100.000	174	50.0000	99.8000
Date role = VALIDATE target variable = target Target label = ’ ‘						
Target	Outcome	Target percentage	Outcome percentage	Frequency count	Total percentage	Adjusted percent of predict/decision variable
0	0	90.0000	71.0526	54	35.5263	0.1421
0	1	23.9130	28.9474	22	14.4737	0.0579
1	0	10.0000	7.9847	6	3.9474	7.8789
1	1	76.0870	92.1053	70	46.0526	91.9211

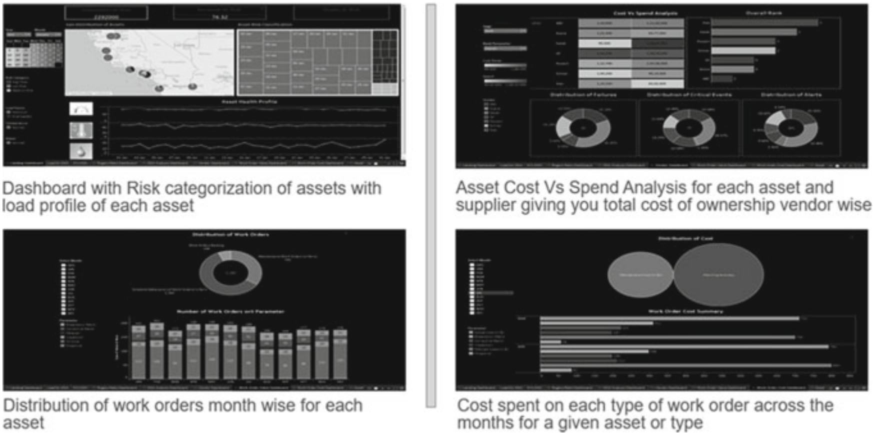


Fig. 6 Asset health index dashboard

4.4 AHI Visualization/Dashboards

Based on the above case study AHI dashboards have been developed as shown in Fig. 6. Dashboards have been prepared for various asset-based data analytics, e.g.

- Asset Risk categorization with load profiles
- Asset cost vs expense analysis
- Work order details of assets
- Asset cost spent analysis as per work order type.

5 Challenges in Implementation of APM in Indian Utilities

- Complex legacy IT systems limit the ability to adopt modern technologies and flexible IT processes
- Inadequate data architecture slows down the innovation and transformation process
- Difficulty to move past the pilot stage and scale up leads to limited value creation from innovation
- Uncertainty towards the overwhelming number of technologies creates difficulties in prioritization of investments
- OT penetration in distribution utilities in India in very low
- There is no regulatory mandate for utilities to adopt ISO 55000 series
- Identify available data sources across the organization [7]
- Cleanse data to reflect consistent and accurate values [7]
- Map data to ensure all relevant data for accurate analysis [7]
- Consolidate IT and OT data sources to a centralized system [7]

- IoT devices are designed to be able to communicate and relay data, thus creating a risk to data security
- Lack of digital transformation unlocking the potential of assets to empowers and to adopt predictive maintenance (PdM) strategies.

6 Conclusion

Organizations are under considerable pressure to develop and implement measurement of asset performance to achieve and manage organization's objectives. The strategy which an organization employs to manage the performance and maintenance of critical infrastructure and assets plays a major role in the reliability, availability, maintainability and safety of the utility as a whole. Studies show that unplanned downtime can cost 10 times more than planned maintenance due to the disruption to business and high cost of repair. AI/ML delivers proven technology solutions for APM, analytics driven processes to reduce maintenance, supply and compliance costs, greater system resiliency to emergencies and natural hazards and improved safety outcomes by reducing number of people in high risk situations. By integrating process visibility, data intelligence, pattern recognition and predictive analytics into their asset management portfolios, asset-centric organizations can ensure the performance of their critical assets while reducing operational costs and risks at the same time.

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Electric Cooking—The Way Forward

Reji Kumar Pillai, Reena Suri, Suddhasatta Kundu, Balasubramanyam Karnam, Akshay Kumar, and Shuvam Sarkar Roy

Abstract About 4 million people die prematurely from diseases caused by household air pollution, primarily from cooking with firewood, charcoal and biomass. As of 2019, 63% rural and 18% urban households in India use firewood, dung cakes or biomass for cooking. In 2019, nearly 600,000 people died of household air pollution in India. Having electrified almost all households in the country and with surplus electricity generation capacity, India should actively promote electric cooking. Increasingly higher share of electricity is being produced from renewable resources and during many time slots during the day, cheap electricity is available on the grid. During 2018-19, 1500 million LPG cylinders were distributed in the country which is not sustainable from the perspective of cost and energy efficiency. New city gas distribution networks cost Rs. 25,000 per connection. In order to meet the NDC targets it is imperative that emissions from the kitchen must be reduced drastically. Electric cooking is the fastest and least cost route to achieve these multiple targets which will also reduce LPG imports saving billions of dollars leading towards *Atmanirbhar Bharat*.

1 Introduction

With surplus electricity generation capacity and having electrified almost all households in the country today, India is heading towards an electric future. Electricity being the cleanest fuel at the user-end and increasingly larger share of it being produced from renewable sources, one very important area requiring electrification is cooking. Globally, around 3 billion people cook using firewood, charcoal, biomass, dung cake or kerosene which creates in house air pollution. Globally about 4 million people die prematurely each year from diseases caused by household air pollution. India tops the list with 800 million people continuing to use firewood, dung cakes, charcoal or crop residue for cooking. While 76% of urban households in India have access to liquefied petroleum gas (LPG), 63% of rural households still

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use firewood or biomass for cooking.[1] Even in urban India, about 18% households use firewood or biomass for cooking as of 2019.[2] According to a study by World Resources Institute (WRI), while the average PM2.5 in rural India is in the rage of 22–112 $\mu g/m^3$, the indoor PM2.5 concentration ranges from 106 to 512 $\mu g/m^3$. This explains why 600,000 people died of household air pollution in 2019 in India.[3]

In the recent past, the Government of India (GoI) has undertaken several targeted programmes to provide urban and rural households with access to clean cooking energy and to electrify almost all households in the country. Pradhan Mantri Ujjwala Yojana launched in 2016 provided credit-linked subsidised LPG connections to over 77 million households till August 2019 making the total LPG connections to 150 million households. While Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) completed electrification of all the 619,000 villages by April 2018, another very successful program, SAUBHAGYA, has electrified almost all (>99%) households by March 2019. India is aiming to be a gas-based economy with the target to meet 15% of its primary energy demands through natural gas by 2030. Piped Natural Gas (PNG) is expected to play an important component of this plan. City Gas Distribution (CGD) licences have been issued to towns in 228 districts of the country and the PNG networks are being built on fast track. As of 2019, there were about 5.4 million domestic customers of PNG which was scheduled to reach 10 million by 2020 (Covid-19 lockdown has slowed down the activities in 2020). In 2020–21, GoI allocated a budget of Rs. 37,256 crore to LPG subsidies and an additional Rs. 3659 crore to Kerosene[4] subsidies.

With every home already connected to the electric grid, it makes immense economic sense to promote electric cooking which is the preferred mode of cooking in many developed countries. Transporting LPG cylinders is expensive and inefficient from the perspective of energy efficiency and cost involved. Billions of dollars of investment is required for building new PNG networks in towns across the country. While the thermal efficiency of the LPG stoves is about 55–57%, that of electric cookers is in the range of 74–84%. Wide variety of electric cooking appliances are available at affordable prices which include electric pressure cooker, induction cooktop, hot plate, kettle, microwave oven, electric oven, electric rice cooker, steam cooker, air fryer etc. Electric cooking is cost-effective, safer, more energy efficient, and require less maintenance than the conventional cooking methods and is free of emissions. Presently, about 24% of the electricity consumed in India is generated

[1] According to the Petroleum Planning and Analysis Cell (PPAC) of Ministry of Petroleum & Natural Gas, there were 265.4 million domestic LPG connections by March 2019 which was estimated to reach 278.7 million by March 2020. This perhaps included multiple connections in one household and small businesses. However, several other studies and reports indicate majority of the rural households continue to use firewood/biomass for cooking.

[2] Source: Roadmap for Access to Clean Cooking Energy in India—https://bit.ly/39diPuX.

[3] Source: Report by Health Effects Institute, USA.

[4] Source: Demand for Grants 2020-21 Analysis Petroleum and Natural Gas—https://bit.ly/3nW7Rhr.

from renewable resources and planning to expand it to 40% by 2030.[5] For comparison of consumption of LPG cylinders with that of electricity, 10 LPG cylinders (of 14.2 kg each) per year can be substituted with 1460 units (kWh) of electricity at the rate of average 4 units per day.[6] India has surplus electricity generation capacity and during many time slots throughout the day, electricity is cheaper on the grid and can be allotted for cooking at subsidized rates. This will also help increase the electricity demand and balance the load on the grid as well as improve the finances of the electricity distribution companies. Electric cooking will avoid import of LPG thus saving billions of dollars and help towards *AatmaNirbhar Bharat*.

More importantly, to meet the 2030 NDC targets committed by India, emissions from the kitchens must be reduced considerably and electric cooking is the least cost and fastest option to achieve that.

2 Cooking Energy Scenario in India

Besides the in-house air pollution,[7] the use of firewood for cooking has led to deforestation, soil erosion, water stress and GHG emissions. This is a well-recognized problem for decades but globally all efforts were focussed on improving the efficiency of cook stoves. The incremental improvements in the efficiencies of cook stoves over the years have been defeated by millions of cook stoves added each year as population increased and the poor and middle-income groups were deprived of access to clean cooking fuels. In a NITI Aayog paper, Arvind Panagaria and Anil Kumar Jain wrote "India chose to go for a two pronged strategy of LPG for urban India and biomass for rural India ….it may be stated that for rural India, which comprises 69% of the nation's population as per 2011 census, we have had no 'clean cooking fuel' strategy—instead we only had an 'efficient cook stove' strategy". As of 2019, 63% rural and 18% urban households in India still use firewood for cooking. According to a study paper by CEEW[8] in 2016, less than 1% rural households in the states they surveyed had the so-called efficient cook stoves. In 2016, GoI launched the nationwide LPG program which gave subsidized LPG connections to about 77 million households till August 2019. Kerosene use over the past ten years has reduced drastically which is a very good achievement (Fig. 1).

Firewood and biomass are gathered (not purchased) and hence even subsidized LPG cylinder is expensive for the poor; and many despite having LPG connections, continue to cook with firewood and dung cakes. Although NITI Aayog's Clean

[5] Source: CEA monthly installed capacity.

[6] NITI Aayog Study Report—https://bit.ly/3pZJCkl.

[7] An estimated 4 million premature deaths are caused each year by indoor air pollution caused by existing cooking practices still widespread in many parts of Southeast Asia, Latin America, and Africa. In Africa alone, the African Development Bank (AfDB) estimates that over 600,000 deaths per year are caused by existing cooking practices, the majority of which are concentrated in sub-Saharan Africa; (Hivos 2019 Report).

[8] CEEW Paper https://bit.ly/3nQ1BYo.

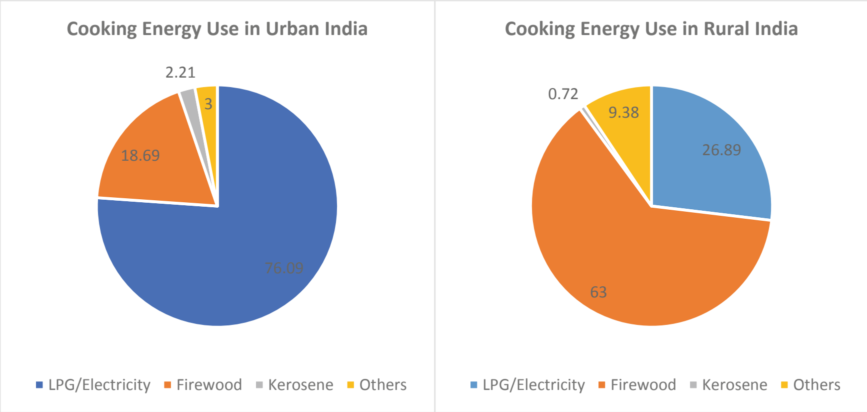

Fig. 1 Cooking energy use in urban and rural India (Census 2019) (https://bit.ly/3l565Jd)

Cooking Energy Roadmap envisions to eliminate the use of all cooking arrangements that cause household air pollution across the country by 2025, the India Energy Security Scenario (IESS) tool projects that in 2047, under the optimistic 'Determined Effort Scenario', 20% of rural households will still be reliant on biomass for cooking.

2.1 *LPG and PNG Programs*

It is assumed that approximately 150 million households have LPG connections and 5.4 million have PNG connections, as already stated. This leaves 100 million+ more households without access to clean energy for cooking. At an average of 8–10 LPG cylinders per household per year, filling, transporting, storing, local distribution and transporting back the empty cylinders would amount to 1200–1500 million LPG cylinders per year.[9] Not to mention the gas leakage, injuries and other dangers that are involved in this process. Although thousands are employed in this logistics of LPG cylinder distribution, it is not an economically viable business that India should undertake for a long time to move billions of LPG cylinders to millions of homes annually. The difficulties at customer end with LPG refilling and consumption are myriad—timely delivery of cylinder at door step is a challenge, gas stoves are inefficient which require periodic cleaning and repairs, the kitchen gets dirty with black soot; and there are accidents from gas leakage. The thermal efficiency of the LPG stoves is about 55–57%; much lower than the 84 per cent efficiency of electric induction cooktops.

[9] According to PPAC data, oil marketing companies packaged 21.7 million metric tonnes (MMT) of LPG during 2018–19. At the rate of 14.2 kg per cylinder, this amounts to approximately 1500 million LPG cylinders.

The new CGD networks being built involve huge capex running in to several hundred crores of rupees per city. The average cost of laying new PNG network is around Rs. 25,000 per customer. Building CGD network, its maintenance, metering, billing and collection processes are an additional cost to the economy. If the ultimate goal of the CGD network is to supply customers with clean cooking energy and the same goal can be accomplished more effectively with electricity already present in the consumer premises, why invest in constructing a parallel infrastructure? Electric cooking appliances can be promoted or provided in households for the fraction of the capex needed to create new CGD networks. In a developing country with competing demand for resources, a rethinking on investment on CGD networks as against promoting electric cooking is necessary.

3 Electric Cooking—The Way Forward

Today, a large range of electric cooking appliances are available at affordable prices that can cook all items in any regional cuisines in India. The range include electric pressure cooker, induction cooktop, hot plate, kettle, microwave oven, electric oven, electric rice cooker, steam cooker, air fryer etc. A detailed list of different makes and models of electric cooking appliances is presented at Appendix-A.

Hot plate is the most common electric cooking device which has a shock proof and stable body with a heat regulator that maintains a range of pre-set temperatures. It is safe and almost maintenance free. Most electric cooking devices have flat heating surface and hence it is efficient to use flat bottomed utensils. Induction cooktops operate on the principle of electromagnetic induction. In an induction cooktop (“induction hob” or “induction stove”), a coil of copper wire is placed under the cooking vessel and alternating current (AC) is passed through it to create oscillating magnetic field which wirelessly induces an electrical current in the vessel. This large eddy current flowing through the resistance of the vessel creates resistive heating. Since induction heating only heats the vessel placed over it, the air outside the vessel does not become hot, so the kitchen is comparatively cooler. Induction cooktops have a thermal efficiency of up to 84%. They are available in both, single burner and multiple burner models. The main advantage of induction cooktops is higher safety as the surface of the cooktop gets heated only if it is in contact with the vessel, thereby reducing the chances of burn injuries.

Microwave oven heats the food through microwave radiation injected directly into the food exposing the food to the radiation. Microwaves are produced inside the oven by an electron tube called a magnetron. The microwaves are reflected within the metal interior of the oven where they are absorbed by food. Microwaves cause water molecules in food to vibrate, producing heat that cooks the food. When thick food items are cooked, the outer layers are heated and cooked by microwaves while the inside is cooked mainly by the conduction of heat from the hotter outer layers. There are many discussions regarding the health effects of microwave and induction cooktops. However, there is no conclusive scientific evidence commonly accepted on this issue.[10]

There is tremendous cost saving potential in using efficient electric cooking appliances such as slow cookers and electric pressure cookers. Over a one-hour cooking period, a pressure cooker uses approximately one quarter (¼) of the electricity of an electric hot plate. Over a 4-h cooking period, the gains increase further—a pressure cooker is twice as efficient as a slow cooker, six times as efficient as an induction cooktop, and fully 7 times as efficient as an electric hot plate. Electric rice cookers and air fryers have also become very popular. The chart below from *Beyond Fire—How to Achieve Electric Cooking (2019)* by Hivos (and presented to World Future Council) gives the comparison of electricity consumption by different electric appliances for cooking (Fig. 2).

Table 1 presents the pros and cons of LPG and electric cooking.

According to a NITI Aayog study in 2019, "*the consumption of 8 to 10 LPG cylinders (14.2 kg each) per year is equivalent to electricity consumption of nearly 4 kWh per day. This implies that at prevailing electricity prices, the electric solution costs about the same as the LPG solution at the crude oil price of around $40 per barrel. Hence, the electric solution to cooking would be financially feasible, especially if the government decided to give an electricity subsidy equivalent to that on LPG*"[11]. This fact is illustrated in Table 2.

For mainstreaming electric cooking, it requires cost-effective production and distribution of appliances, efficient after-sales facilities, standardised testing and quality standards, and creative options for end-user financing. Electric grid has reached every village and home. If electricity replaces cooking gas, the additional cost of transporting cooking energy can be avoided. The increasing share of renewable energy on the grid would further reduce the carbon footprint of cooking. Electric cooking can also make use of solar power in both urban and rural areas. This will be more viable in rural areas where electricity grid may not be very reliable but solar energy is easier to provide (Table 3).

Due to erratic power supply with frequent outages in most parts of the rural areas, electric cooking has not made significant penetration in rural India. This situation will soon improve as the next goal of Government of India is to provide stable 24×

[10] Both microwave oven and induction cooktop generate non-ionizing electro-magnetic frequency (EMF) radiation. Ionising radiation, which can remove tightly-bound electrons from atoms, causing them to become charged, is less risky in very tiny amounts (such as x-rays) but can cause problems when exposure is high (burns and even DNA damage). However, non-ionising radiation is a type of radiation that has enough energy to move atoms around within a molecule but not enough to remove electrons. Because the radiation from microwaves is non-ionising, it can only cause molecules in the food to move. In other words, microwave radiation cannot alter the chemical structure of food components. While the EMF from induction cooktops is in the range of 24 kHz that of microwave ovens is in the range of 2450 MHz. The US Federal Standard 21 CFR 1030.10 limits the amount of microwaves that can leak from an oven throughout its lifetime to 5 milliwatts (mW) of microwave radiation per square centimetre at approximately 2 inches from the oven surface. A measurement made 20 inches from an oven would be approximately 1/100th of the value measured at 2 inches from the oven. https://thehealthsciencesacademy.org.

[11] CEEW-NITI Aayog Report (*https://bit.ly/37bj7zX).

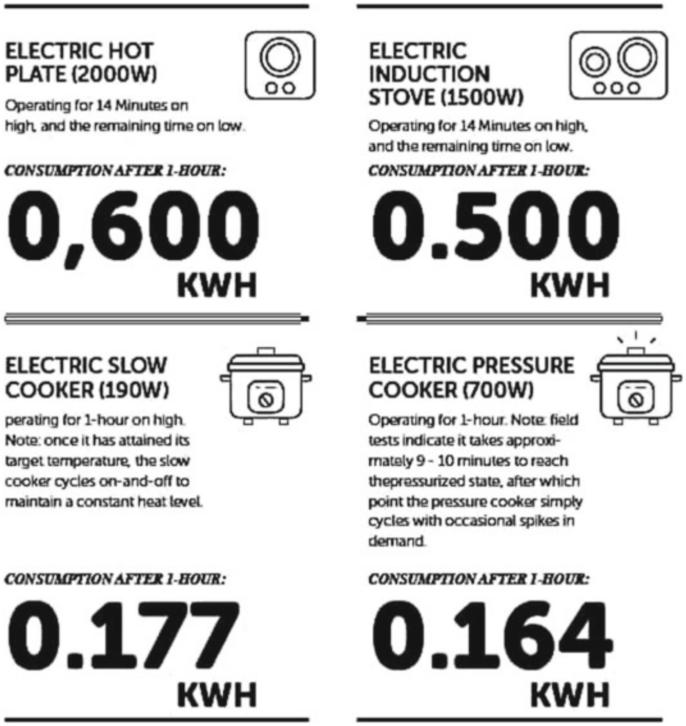

Fig. 2 Overview of electricity consumption profiles of different cooking appliances[12]

7 power supply to all households. The connected load of 200–300 W was given to the newly electrified houses under the rural electrification schemes. The majority of electric cooking appliances, however, require 1000 W (1 kW) or more. This would be a short-term limitation, and as we improve medium and low voltage networks in semi-urban and rural areas, the capacity can be upgraded for each household with a minimum load of 3–5 kW. Network planning and equipment sizing must be done taking in to account the cooling and cooking loads that are likely to be added in the next 10–15 years. The capex for the grid strengthening may be taken up in phases, feeder by feeder by re-allocating funds from LPG subsidy.

There are often debates about inability to cook many Indian dishes on electric cookers. Difficulty in controlling heat on an electric cooker to prepare roti and dosa is another complaint. After extensive deliberations on these issues with different stakeholders, we believe that these problems can be overcome with practise and constant improvement in the functionalities and performance capabilities of different cooking appliances.

[12] Beyond Fire How to Achieve Electric Cooking (https://www.hivos.org/document/beyond-fire-how-to-achieve-electric-ooking/).

Table 1 Pros and cons of gas versus electric cooking

Gas stoves	Electric stoves	Induction stoves
		
Pros		
• Great control over the heat • Wide range available • Perfect for cooking Indian dishes • No restraints on utensils types • Generally faster to cook	• No fear of inflammation • Great in energy efficiency • Releases less heat output	• Simple to use and setup • Multiple cooking option with auto switch-off • Great energy savings • Heats the utensil and not the entire stove • Does not cause heating issues like gas stoves
Con		
• Could prove dangerous due to their inflammable gas • Surroundings can heat up • Produces GHG	• Hot elements could accidently burn your hands at times • Takes more time to heat up; Much slower cooking times for Indian food (Dal+Curry+rice/rotis) • No electricity, No cooking • Can only be used for flat surface utensils	• Initial expenditure is high • No electricity, No cooking • Limited types of utensils that you can use on this. New type of utensils required which is expensive for rural India
Comparing the energy efficiency		
40% Energy efficiency	74% Energy efficiency	84% Energy efficiency
Costs of the heating 10 L of water		
Rs. 5.09—For subsidised cylinder Rs. 10.8—For unsubsidised	Rs. 5.2 Per 10 L of water	Rs. 5.91 Per 10 L of water

*Source*www.hmezene.com

4 Electric Cooking—Balancing the Load on the Grid

By encouraging households to moderately adjust the timing of their cooking with electrical appliances so that the total load can be kept within the sanctioned limits during peak hours, electric cooking can assist the grid in demand growth and load balancing. The aim of such load-management techniques is not to regulate demand patterns strictly or to require users to cook at inconvenient times of the day, but rather to provide signals to customers to inform them when supply is more limited and when it is more abundant. With increasing share of renewable energy resources (solar and wind) which are intermittent, grid balancing or stable operation of the

Table 2 Comparison of cost of cooking with LPG and Electricity

Parameter	LPG	Electricity	Assumptions/remarks
Energy in Mega Joules (MJ)	46.1 MJ/kg	3.6 MJ/kWh	
Price per MJ (INR)	1.38/MJ	2.22/MJ	LPG: Price of a 14.2 kg Cylinder assumed at Rs. 900 Electricity Tariff of Rs. 8/kWh considered
Efficiency of the cooking appliances	50%	80%	LPG: Average efficiency of LPG stoves at 50% is considered Electric Cooktops: 80% efficiency considered for calculations (induction cooktops efficiency is 84% while coil-top cooktops are in the range of 74–80%.
Scenario-1: To boil 10 L water require 3.15 MJ			
Energy required with the cooking appliance	6.3 MJ	3.94 MJ	50% efficiency for gas stove and 80% efficiency for induction cooktop is considered
Cost to boil 10 L water	Rs. 8.69	Rs. 8.75	Cost of LPG and electric cooking is almost same
Scenario-2: To cook 1 kg rice require 1.5 MJ			
Energy required with the cooking appliance	3.0 MJ	1.88 MJ	50% efficiency for gas stove and 80% efficiency for induction cooktop is considered
Cost to cook 1 kg rice	Rs. 4.14	Rs. 4.17	Cost of LPG and electric cooking is almost same

Table 3 LPG and kerosene subsidies

Subsidy amount in INR (crores)	2018–19 (actual)	2019–20 (revised budget estimates)	2020–21 (budget estimates)
LPG	20,268	34,086	37,256
Kerosene	4569	4483	3659
Total amount	24,837	38,569	39,915

grid by matching demand and supply has become a major challenge. It is essential to have loads that can be interrupted (or shifted) to increase the flexibility of the grid. The cooking appliances if connected through a smart plugs, can be remotely turned on and turned off. There is surplus energy on the grid at several time slots in a day, and it could be made use for cooking by sending price signals (rebates on electricity tariff) to customers. Similarly, when supply is lesser than demand during peak hours, the higher tariff signals could prompt the customers to turn off their cooking (and other) appliances. With a Time of Use (ToU) tariff for electricity, customers can voluntarily (either by automation or manually) change their electricity usage to reduce their energy costs. ToU tariffs unlock flexibility on the demand side and can thus increase the penetration of renewable energy and greatly improve the reliability and predictability of the system.

Government of India is about to launch a new program mandating smart meters for all electricity customers which will be rolled out in next 4–5 years nationwide. Smart meters with two-way communication (between the utility and the customer) will help customers view their electricity consumption in real time and schedule many tasks (cooking, washing, ironing, water pumping etc.) to non-peak hours when the electricity tariff is low.

Even 100 million households using electricity for cooking (@4 kWh per day) will contribute to additional 146 billion units (BU or TWh) of electricity consumption from the grid. This would improve the plant load factor of the generation assets considerably. This will also contribute to better utilization of the electricity generation assets which in turn would reduce the electricity tariff.

4.1 Electric Cooking—Saving Billions in Forex and Generating New Jobs

Government of India subsidy towards LPG and Kerosene is huge and most of these fuels are imported.

Moving from LPG and Kerosene to electric cooking could phase-out these subsidies faster and re-allocate for strengthening the electricity distribution network in semi-urban and rural areas in a phased manner as well as subsidize appliances for electric cooking to the needy sections of the society.

Promotion of electric cooking will generate huge demand for electric cooking appliances. Almost all such appliances are manufactured locally in India with very little import content in few of them thereby promoting *Atmanirbhar Bharat*. This will also create large number of jobs within the country.

4.2 Electric Cooking—Helping Meet NDC Goals

The shift from firewood, charcoal, dung cake, kerosene and LPG/PNG to electricity for coking will reduce greenhouse gas emissions considerably and the indoor air pollution will be fully eliminated. India is making strong progress towards greening the electric grid with larger share of renewable energy. Under the Paris Agreement, India has committed to produce 40% of its total energy requirements from renewable resources thereby reducing emissions by 30% 2030. Switching to electric cooking will richly contribute to meet the NDC goals at marginal cost.

5 Recommendations

Today, electricity is the primary energy source for lighting, cooling (fans, air coolers and air conditioners), water pumping, washing, ironing etc. in most households. Electric kettle, mixie and grinder are also commonly used in urban and rural households. People are familiar and comfortable with use of different electrical appliances and it would not take much effort and time to motivate them to shift to electric cooking.

It is high time to admit that the ongoing *efficient cook stove* program has not made any impact in reducing indoor air pollution or reducing LPG consumption or in motivating people to move away from firewood and biomass for cooking. Several decades of efforts and resources have gone waste. Still several national and international agencies are engaged in the promotion of efficient cook stove initiatives. These must be stopped and all efforts must be targeted to promote electric cooking. Even if people adopt the "efficient" stoves, the impact from the incremental improvement in the efficiency is defeated by the sheer number of new units added each year.

Government should formulate new policies and programs to promote electric cooking. LPG subsidies may be re-allocated to fund the capex for strengthening the electricity distribution networks in semi-urban and rural areas. The minimum load for all electricity connections should be enhanced to 3–5 kW. We are no more in an era of scarcity, rather we have surplus electricity generation capacity. Medium voltage and low voltage network should be strengthened to support this minimum 3–5 kW load for all households. That will help people move to electric cooking as well as give them access to cooling. As the summer temperature in India keep going up every year, it would be difficult for people to live without access to cooling[13] and those who can afford an air conditioner will acquire it and providing load enhancements selectively will not be viable, particularly in rural areas.

To promote the electric cooking the immediate next steps recommended are listed below.

1. Assessment of feasibility of transition to electric cooking in urban, semi urban and rural area in different states in India
2. Assessment of the electricity supply status and grid capability to support cooking appliances in households
3. Estimation of capex to strengthen the medium voltage and low voltage grids to provide 24×7 supply as well as 3–5 kW connections to all households so that they could use electric cooking appliances and air-conditioners
4. Life cycle cost comparison of building new city gas distribution networks to supply PNG as against strengthening the electric network for transition to electric cooking in semi-urban households
5. Estimation of annual cost of LPG cylinder distribution in rural areas as against strengthening the electric network which is one time cost

[13] ISGF White Paper on District Cooling Systems: https://indiasmartgrid.org/resourcecenter.php.

6. Assessment of availability of electric cooking appliances in different regions, its cost and performance, roadmap for augmenting the manufacturing capacity of such appliances in the country
7. Assessment of skill development and employment generation potential in the electric cooking domain as against the job losses in LPG distribution
8. Detailed assessment of health benefit from transition from firewood/biomass/kerosene etc. to electric cooking and avoided cost towards providing healthcare to millions suffering from indoor air pollution
9. Detailed assessment and estimation of the environmental benefits from electric cooking by reducing GHG emissions and avoiding deforestation
10. Development of different strategies for promotion of electric cooking and campaigns for consumer awareness and adoption of electric cooking appliances and practices
11. Technical feasibility studies for leveraging renewable energy for electric cooking and integration of cooking appliances with the grid—smart cooking with green electricity bought from the cheapest resource on the grid!

To conclude, we propose that a new program may be launched by Government of India with participation of all State Governments, electric utilities and all other related stakeholders and civil society associations. This program may be taken up in a mission mode.

Appendix A: List of Electric Cooking Appliances with Indicative Prices

See Table 4.

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Table 4 Overview of various electric cooking appliances

Category	Sample items with photos			Price range (INR)	Remarks (more model of different makes)
	Power demand (W)	Popular brands	Picture		
Hot Plate	1000	BAJAJ VACCO, Electric TAWA HOT Plate		1000	https://amzn.to/33HF20H
	2000	BAJAJ VACCO, Electric Coil Hot Plate		1565	
	1500	ORBON Big Butterfly		2159	
Electric Kettle	1800	Philips HD9303/02 1.2-Litre Electric Kettle		2230	https://amzn.to/3mFeDYE
	1500	Kent 16023 1500-W Electric Kettle		1140	
Electric Pressure Cooker	1000	NutriBullet NutriCook Smart Electric Pressure Cooker		9489	https://amzn.to/3g7x06h
	500	Prestige Delight PRWO 1-L Electric Rice Cooker		1399	
	900	Glen Electric Steam Cooker		2895	

(continued)

Table 4 (continued)

Category	Sample items with photos			Price range (INR)	Remarks (more model of different makes)
	Power demand (W)	Popular brands	Picture		
Induction Cooker	2100	Philips Viva Collection HD4928/01 2100-W Induction Cooktop		2499	https://amzn.to/3g7GQVH
	1800	Pigeon Induction Cooktop		2229	
	1200	Prestige Induction Cooktop		1587	
	2000	iBell Induction Cooktop		1375	
Microwave Owen	1950	LG 28 L Convection Microwave Oven		17,940	https://amzn.to/36FIfjd
	2200	IFB 30 L Convection Microwave Oven		13,990	
	1200	IFB 20 L Convection Microwave Oven		7321	
Electric Owen	1280	Pigeon by Stovektaft Electric Oven		3260	https://amzn.to/3lDRMvq

(continued)

in standards development and help utilities, regulators and the Industry in technology selection, training and capacity building.

Table 4 (continued)

Category	Sample items with photos			Price range (INR)	Remarks (more model of different makes)
	Power demand (W)	Popular brands	Picture		
	1200	Bajaj Majesty 1603 Electric Oven		3899	
Air Fryer	1425	Philips Daily Collection HD9218		9699	https://amzn.to/2IbFCw5
	1500	Kenstar Aster Digi Oxy Fryer		5499	
Slow Cooker	200	Haden 189677, Slow Cooker		2499	https://amzn.to/3gaFw4m
	280	Bergner Elite, Slow Cooker		2779	

Sustainable Air Conditioing with District Cooling System (DCS)

Reji Kumar Pillai, Reena Suri, Suddhasatta Kundu, Shuvam Sarkar Roy, Balasubramanyam Karnam, Akshay Kumar, and Parul Sribatham

Abstract The summer temperature been on the rise constantly all across India during the past 3 decades. Soon the maximum summer temperature will exceed 50 °C in Northern India making it extremely difficult for people without access to cooling. India Cooling Action Plan (ICAP) targets incremental improvements in efficiency of equipment to reduce cooling demand by 25–30% by 2037–38 which is likely to be defeated by sheer increase in the number of air conditioners. Radical approaches are required to address the cooling challenge. District Cooling System (DCS) is an alternative route to address the space cooling challenge effectively. This paper highlights the DCS technology, the technical and commercial benefits it can offer and business models for effective DCS implementation.

1 Executive Summary

The summer temperature has been on the rise constantly all across India during the past 3 decades. The maximum temperature in Delhi has increased in the last 3 decades by 6 °C to exceed 48° in 2019. At this rate by 2030, the summer temperature could be well over 50 degrees making it almost impossible for people to live, work or commute without cooling. Traditionally, space cooling in buildings is provided with room (window) air conditioner (AC) or centralized AC plants. With increasing economic prosperity, urbanization and rising temperatures, sale of room ACs are set to increase rapidly. Installed stock of room ACs in India increased from two million units in 2006 to 30 million units in 2017 and is expected to be between 55 and 124 million by 2030.[1] While nationally less than 10% of the urban household's own room ACs, in Delhi almost 30% households own ACs.[2] Already, ACs are accounting for up to 60% of the summertime electricity use in Delhi. Per another estimate, about

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[1] https://www.ibef.org/download/Consumer_Durables_June_2019.pdf.

[2] Per Motilal Oswaal Report of April 2018, out of 65.13 million urban households, only 6.28 million own ACs where as in Delhi out of 2.34 million households, 688,888 of them had ACs. Total market

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700 million new ACs by 2030 and 1.6 billion units by 2050 are expected to be added globally. This level of proliferation of ACs will worsen the crisis by increasing the ambient temperature and widen the divide between those who can afford to stay cool and those left out in the unbearable deadly heat!

Room ACs emit heat to the atmosphere creating hot pockets in many parts in a city and increase the overall ambient temperature in the locality. Similarly, millions of air-conditioned cars in large cities like Delhi emitting heat make it very uncomfortable for pedestrians and commuters on 2-wheelers and 3-wheelers. This situation is set to aggravate as the number of rooms ACs and air-conditioned cars are increasing by the day. High temperatures are already affecting people's ability to work, making people sick**,** and outright killing thousands of elderly and children in low-income communities who cannot afford cooling. While cooling is a luxury at moderate to high temperatures, it is an essential need at temperatures above 40 °C.

The India Cooling Action Plan (ICAP) issued in March 2019 aims to reduce cooling demand by 25–30% and reduce cooling energy requirements by 25–40% by 2037–38 from 2017–18 levels. ICAP targets efficiency improvement and material substitution and related topics that will yield incremental improvements. The problem being so critical and imminent, it requires a radically different approach—incremental improvement in the efficiency of room AC units and better construction materials will not help to mitigate this challenge. District energy systems are being successfully implemented in many parts of the world have evolved as a matured technology. In the Indian context, the district cooling system (DCS) presents an opportunity to address the space cooling challenge effectively.

2 Introduction

Globally, buildings consume a third of energy, 50% of electricity and account for 20% of energy-related GHG emissions. Almost 99% of AC and refrigeration loads worldwide are met by electricity. The associated annual electricity demand (and CO_2 emissions to certain extent) has tripled between 1990 and 2016 and touched 10% of global electricity use in 2018. This demand for AC and refrigeration is estimated to triple again to 6200 TWh by 2050 in the baseline scenario (of International Energy Agency) with 70% of this rise attributable to residential users. Another report[3] states "the energy required to deliver access to cooling globally could reach 19,600 TWh by 2050 without efficiency measures". This growth will take place essentially due to rises in population in developing economies that are in hot-climate regions (India, China, Pakistan, South East Asia and the Middle East). The cooling energy consumption of

size for room ACs in 2019 was estimated at 6.7 million units. https://www.motilaloswal.com/site/rreports/636596385051621278.pdf.

[3] 2019 Chilling Prospects: Tackling Sustainable Cooling for All by SE4ALL and Kigali Cooling Efficiency Program.

typical buildings in hot and hot/humid climates is up to three times higher than in moderate climate zones.

Presently, conventional on-site cooling systems (see figure below) are used mostly which comprise of either window unit in each room in small buildings, or centralized air-conditioning in large buildings with water-cooled or air-cooled chillers which are located on the rooftop or basements. In all the cases the cooing agent to cool the air is produced and distributed at the user end. The efficiency of on-site air-conditioning system is roughly 67% of that of a centralized DCS which produces chilled water in a central chiller plant and deliver to buildings through insulated distribution network and energy transfer stations (ETSs) at each building (Figs. 1 and 2).

The central chiller plant consists of cooling equipment, pumps, heat-rejection equipment, chemical treatment unit, controller and other devices such as cold storage, pumping stations and control systems. Typical ETS is a plate heat exchanger which exchanges the “chillness” of the chilled water from the DCS (normally at 5 °C) and cools the water in the building’s air-conditioning system which comprises of air handling units (AHUs), fan coil units (FCUs) and distribution/regulation valves. In the ETS the chilled water at 5 °C from the DCS gets heated up to 12–14 °C and returns to the centralized chiller. Cold water networks of the DCS and of individual

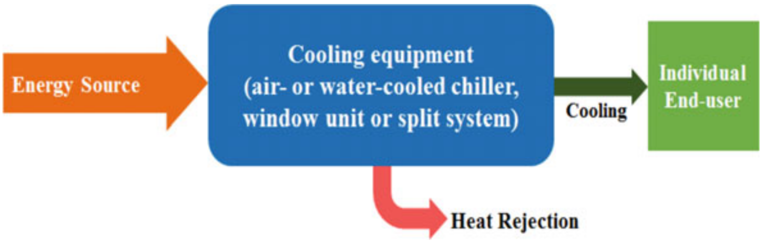


Fig. 1 Building air-conditioning systems: conventional on-site systems

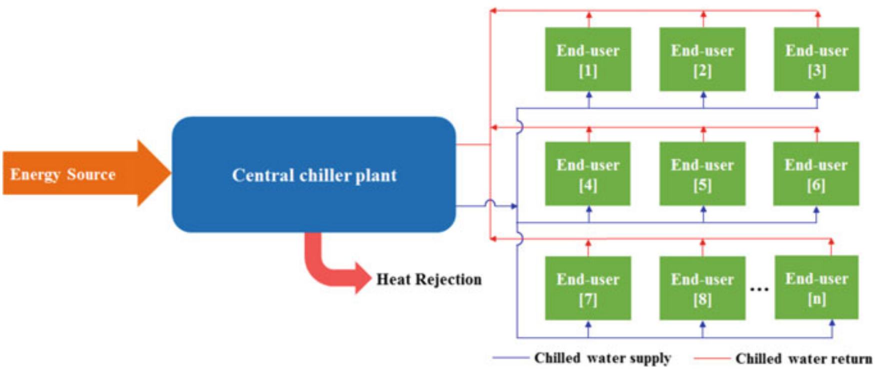


Fig. 2 Building air-conditioning systems: district cooling system (DCS)

buildings are not mixed—they exchange "chillness" in the ETS. The central chillers typically use R134a as refrigerant gases.[4]

DCS can use either regular water or seawater. DCS can be more than twice as effective as conventional decentralized chillers. The key advantages/benefits of DCS are:

- Low overall power demand and energy consumption: Overall Power demand and energy consumption in a DCS is almost half of the total cooling power requirement compared to distributed standalone cooling systems installed in each building. The largest electricity load in a typical building is the cooling load. With DCS taking that load, the total power demand and energy consumption in a building is significantly reduced. Consequently, the electricity distribution network for the locality can be much cheaper.
- Reduced cooling capacity: DCS can be designed for 60–70% of the combined cooling load of the individual buildings because of load diversity and variability in a larger system.
- With thermal energy storage, DCS can reduce peak hour power consumption and run the chillers during off-peak hours at lower power cost

Lower Capex and Opex for Individual Buildings:

- Reduced environmental impact: 50% lower carbon emissions; and the reduced emissions at the DCS location is handled better than individual building's air-conditioning systems
- Reliable service (>99.7%) owing to high standard industrial class equipment, backup chillers, professional operation and maintenance support
- DCS eliminates the refrigerant use in individual buildings
- Longer life span: DCS have a typical life span of 30 years or more (the pipe network could last well over 50 years) compared to on-site air-conditioners which have a life of 10–15 years
- Space savings in buildings: The space used for air-conditioners in the building is available for other uses
- Reduction in Heat Island effect
- Lower noise level in the occupied areas
- Better aesthetic of the area
- Additional green rating points for the buildings

[4] Montreal Protocol of 1987 mandated progressive elimination of CFC and HCFC refrigerants which was causing ozone layer depletion. The alternate refrigerants used now are HFCs. R134a is the most popular HFC refrigerant today. HFCs have much higher global warming potential than CO_2–1430 times higher! Hence the Kigali Amendments to the Montreal Protocol in 2016 laid out a roadmap for progressive reduction of HFCs by 80% by 2050. In India it has to start from 2028 onwards. Cost of R134a has already started going up owing to production curtailments in some countries. Alternatives to HFC are HFO and Ammonia. HFO is fast emerging as a viable option.

3 DCS and the Electric Grid

Space cooling loads in hot climates are subject to large seasonal and daily variations which create strain on electricity grids. While, air-conditioning represents on average 14% of peak electricity demand worldwide, in hot regions such as Middle East (GCC countries), this demand is approximately 50% of peak load and up to 70% of electricity consumption. In South Asian countries, the energy demand from residential and commercial buildings accounts for 60% of total energy consumption and nearly half of it is for space cooling.

As mentioned above, India is projected to add 55–120 million room ACs by 2030 which will take the total stock to 85–150 million units. Load of 100 million ACs (1.5 ton) would constitute about 150 GW on the electric grid. Managing these distributed units will be a herculean task for the grid operators particularly in the April to June quarter when the whole country will be experiencing hot weather and most of the ACs will be in operation. Associated power generation, transmission and distribution network investment could be prohibitive.

With DCS, the cooling load will be almost two-third. DCS with thermal storage facility will allow the system to produce ice/chilled water when the electricity is cheap on the grid or when solar plants are generating during the day. The ice/chilled water can be stored in the thermal storage facility for several hours. This can be of great help to balance the load on the grid by shutting-off (or partially running) the electric chillers during peak electricity demand periods on the grid.

There are some studies that indicate that solar energy could completely meet the cooling load by 2050. In most offices, commercial centers, educational institutions etc., cooling load is during the day when solar energy can be locally produced near the DCS locations as well as on the roof of the buildings in the DCS network.

4 Cooling as a Service

Electricity, water and cooking gas are supplied to buildings as a service by utilities. On the same model, cooling can also be provided to individual buildings as a service. This model has been successfully implemented in several parts of the world including in the GIFT City in Gujarat. Besides all the advantages of the DCS mentioned above, individual flat/building owners need not invest in buying ACs or centralized AC systems. This is a huge savings and a portion of that could be made as a deposit with the DCS utility—similar to the deposit for getting electricity or gas connections. Every residential colony, street, office complex, commercial centre and market should have DCS and the electricity to run the DCS may be generated from solar panels that are installed on the building roofs and other common areas in the locality. New infrastructure being constructed and under panning must be mandated to build with DCS as the integral part. Existing buildings may be mandated to implement DCS in next 10–15 years in all urban areas phase-wise starting with commercial centers, government offices, hospitals and educational campuses to residential areas.

In the low-income communities, it may be explored to create common sleeping rooms and entertainment areas which are cooled.

5 Gift City—First DCS in India

Gujarat International Finance-Tec (GIFT) City is located between Ahmedabad and Gandhinagar and is India's first smart city. The total planned area is 42 million SqFt of commercial space, 14 million SqFt of residential space and 6 million SqFt of social space. GIFT City has a currently installed DCS capacity of 10,000 TR[5] with 2 sets of electric chillers of 5000 TR each (2500 TR × 2 nos; series—counter flow arrangement). The DCS has a thermal storage with capacity of 10,000 TR-Hour. The DCS is in commercial operation since April 2015.

Presently DCS supplies chilled water to twelve commercial/social buildings in GIFT City which are operational at different HVAC loads of the respective buildings. The total design cooling load demand of the twelve buildings is around 15,500 TR. As against the total connected HVAC load the DCS capacity to serve the total load requirement is around 10,000 TR.

If each of these buildings had their own air-conditioning systems, they would have built systems for total of 19,500 TR and would have taken more than 23 MW power connection as against the total power demand for DCS is 9 MW at full load.

There is a plan to build 500 kW of solar PV system in GIFT City that would power the DCS plant independent of the grid at peak hours.[6] This flexibility of DCS load could save money for GIFT City as the chiller plant can be run when electricity prices are low on the power exchange and store the chilled water in the thermal storage unit (Fig. 3).

[5] Cooling capacity is measured in Ton of Refrigerated (TR) or Refrigeration Ton (RT) which is equivalent to 12,000 BTUs per hour. TR is the unit measure for the amount of heat removed and is defined as the heat absorbed by one ton of ice causing it to melt completely by the end of one day (24 h).

[6] GIFT City has electricity distribution license and is connected to the Gujarat's transmission grid. GIFT City has long-term PPA with a power generation company and they buy daily from the power exchange as well.

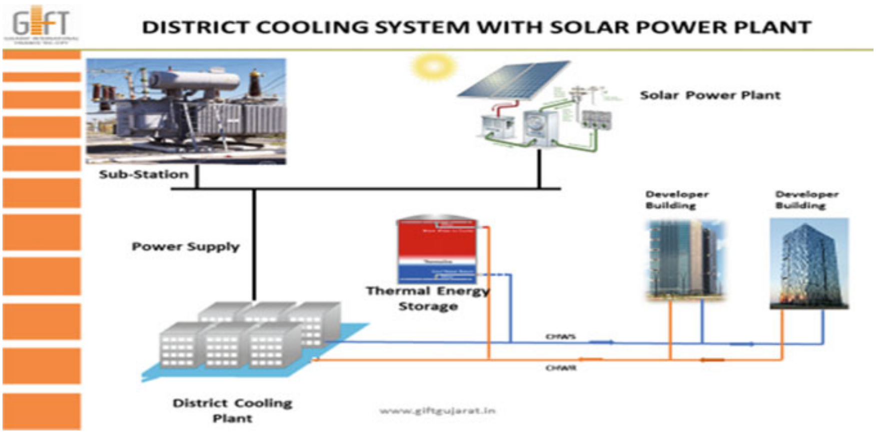


Fig. 3 District cooling system with solar power plant

6 Other DCS Initiatives in India

6.1 Amaravati District Cooling Scheme

The new state of Andhra Pradesh has a greenfield capital city planned in Amaravati with world-class and sustainable infrastructure features, inter alia, an elaborate and interconnected District Cooling Scheme to serve cooling loads of up to 100,000 TR. The Amaravati Government Complex (AGC) featuring the State Assembly, the High Court, 5 secretariat towers and two future mixed-use towers is planned among the initial developments in the capital city with a cooling requirement of 19,989 TR. The Andhra Pradesh Capital Region Development Authority (APCRDA), entrusted with developing the capital city, launched a Design, Finance, Build, Own, Operate and Transfer (DBFOT) tender for a District Cooling System (DCS) to be developed in a phased manner after being convinced of the significant benefits that a DCS could provide in meeting the cooling demand of AGC in a sustainable manner vis-a-vis the standalone cooling system it had planned earlier. This would make the AGC DCS as India's first cooling scheme developed through a Public Private Partnership (PPP) concession model (Fig. 4).

The various benefits that accrue from a DCS for meeting AGC's cooling needs compared to standalone water cooled or air-cooled systems are (Fig. 5):

The DFBOT global tender for DCS by APCRDA attracted several bids from which Tabreed (amongst the world's largest District Cooling utility based out of UAE) was selected as the winner with an investment commitment of INR 3750 million. The tender process successfully culminated into a 32-year cooling concession agreement between APCRDA and Tabreed, following which Tabreed started its operations in India through its country office set-up in the NCR in 2019. After the change in State

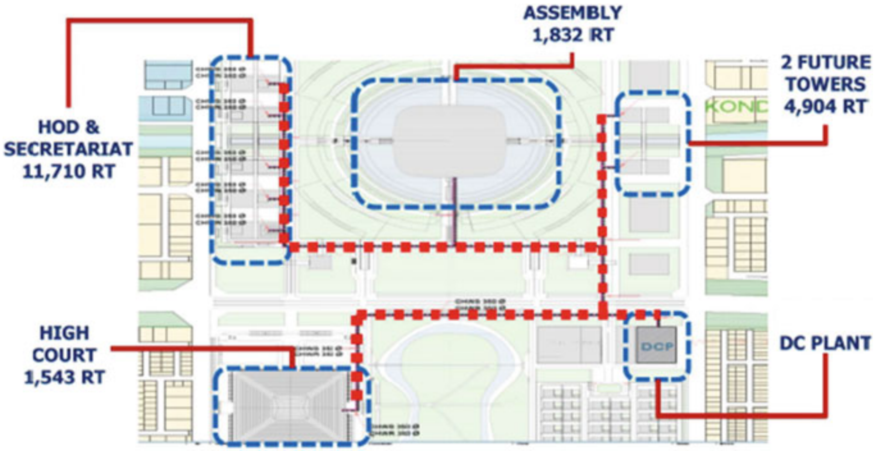


Fig. 4 Cooling requirements at AGC

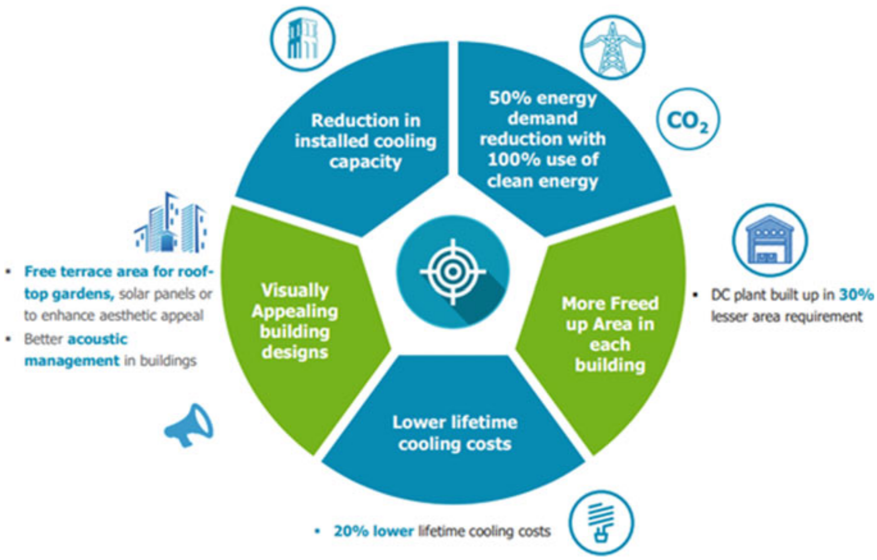


Fig. 5 Benefits of DCS

Government in 2019 and the lack of visibility in the development timelines of the AGC, the DCS project is currently on hold.

6.2 District Energy in Cities Initiative of the United Nations Environment Program

The **District Energy in Cities Initiative** is a global, multi-stakeholder partnership that assists developing countries and cities to accelerate their transition to lower-carbon and climate resilient societies through promoting modern district energy systems. In India, the initiative is coordinated by the United Nations Environment Programme (UNEP), in collaboration with Energy Efficiency Services Limited (EESL), ICLEI-Local Government for Sustainability (South Asia) as well as contributions from its 60 global partners. It provides technical assistance and capacity building activities to local governments and stakeholders for developing modern district energy approach, particularly for district cooling that can be scaled up in the country (Fig. 6).

The Initiative has completed five years of work in District Cooling Systems. It has been working to unlock investments and build momentum and policy support for district energy (particularly district cooling and tri-generation) at city and state-level, within industry and with relevant national ministries. Specific milestones achieved by this initiative till date are listed below:

(a) Report on "National District Cooling Potential and Policy recommendations" which is under review with National Steering Committee and expected to be launched in January 2021 by Energy Efficiency Services Limited (EESL) who are the National coordinators for District Cooling System (DCS) related work.
(b) Pilot City Rajkot has incorporated DCS in Smart City Plan and awarded the tender for EPC work on district cooling network.
(c) Pilot City Amaravati has successfully tendered and awarded a DCS project in the government complex (currently on hold).
(d) Tools and methodologies have been developed and will be used as a standard for how to support cities on District Energy Systems (DES). They have been developed following a deep research of how 45 champion cities globally have prepared DES projects. The methodology goes beyond just supporting demo projects but also to stakeholder coordination, energy mapping, local policies, energy master planning, MRV etc.

Fig. 6 United Nations Environment Program

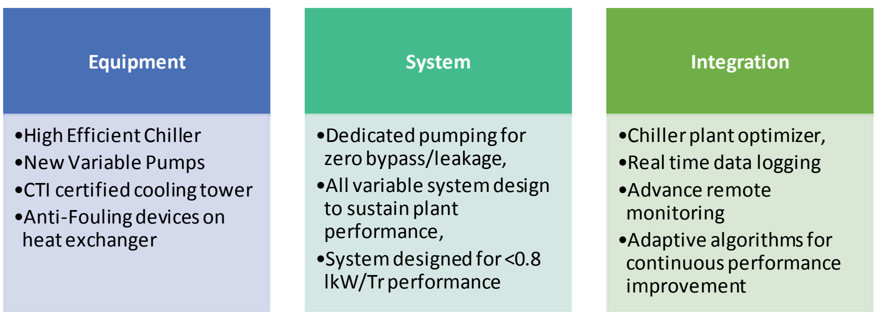
(e) As a part of pilot city methodology, UNEP is supporting Thane and Rajkot cities in GIS energy mapping, master planning and local policies for district cooling.
(f) Developing virtual platform which will capture the case studies, training material, and learning, tools, methodologies etc. on district cooling projects across the world and India.
(g) Prepared rapid assessments of district cooling in five cities (Thane, Coimbatore, Rajkot, Pune and Bhopal).
(h) Organized numerous training workshops and webinars with different stakeholders on district cooling over last five years.

6.3 Chiller Plant Optimization Case Study at Taj Palace, New Delhi

Until 2014, 52–58% of total electrical consumption was from HVAC and in HVAC also 40–45% was contributed by Chillers/Heat machines and its connected accessories like pumps and cooling tower. A comprehensive energy evaluation of the entire HVAC system including the building load and energy pattern was conducted by AdvanTEC team of experts at Carrier. Key drivers for conducting this evaluation/audit were:

i. To minimize operating cost
ii. Upgrade existing system with latest technologies and futuristic designs
iii. Best/optimum performance at plant system level, benchmarking the global standards
iv. Environment safety and Government regulation—Reduction in Carbon Footprint

Basis the evaluation, the new Carrier Heat Machine 23XRV, coupled up with plant system manager with advanced controls and other plant room equipment were integrated into the system. In addition various interventions were also undertaken at three different levels—Equipment, System and Integration.



The entire project execution was performed by the Carrier team which resulted in 26% increase in the productivity of the plant room, leading to saving of over 1 million kWh of electricity over a period of 9 months. By the end of the 2015–16 financial year, the hotel had achieved monetary savings of INR 9 million by reducing electricity consumption. The system uses various techniques such as cooling tower staging, cooling tower fan speed control, condenser water pump speed control, secondary water pump speed control, chiller staging, chilled water reset, etc. to work in fully automatic mode using Carrier Advanced Plant Room System Optimization solution. The control system also conducts plant room energy diagnostics to determine possible areas of plant waste and to provide accurate information on waste prevention and correction.

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New Revenue Opportunities For Utilities

Akshay Kumar, Bindeshwary Rai, Reena Suri, and Reji Kumar Pillai

Abstract In 2020, India has moved up from 76 to 74th positions on a Global 'Energy Transition Index (ETI)' with improvements on all key parameters of economic growth, energy security and environmental sustainability. With solar panels getting cheaper and its efficiency getting higher, renewable energy is playing a major role in energy transition. Alongside renewable energy, battery technologies are showing tremendous growth in terms of higher efficiency, longer life and cheaper price with compact form factor. This would accelerate the transition and also opens a window for introduction of vehicle to grid technology to play a vital role, where electric vehicle's batteries would act as virtual power plants. With constantly declining prices and increasing efficiencies of solar panels and batteries, a large section of customers could generate, store and consume their own electricity. Today, the primary revenue for electric utilities is from the sale of energy (kWh) to their customers which is going to be seriously impacted in the near future. Since these changes are already on the horizon, it is important for utilities to consider **New Revenue Streams** for growth and sustainability. This White Paper suggests various opportunities for revenue generation for utilities from the **Digitalization of the Power Sector** and **Unlocking Existing Infrastructure and Services**.

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1 New Revenue Opportunities Enabled by Digitalization of the Power Sector

During the lockdown in 2020, electric utilities, like all other organizations, quickly adopted to *paper-less* and *contact-less* operations. This alone has pushed forward the digitalization process in utilities. The level of automation and digitalization that would have taken another decade in power utilities would now happen in next 2–3 years. Most processes have become paper-less. The culture of remote working and use of third-party owned digital platforms for meetings and collaborations have instilled confidence in utilities to adopt cloud technologies and applications hosted on the cloud. So, many systems that utilities used to buy earlier will now move to the services model for a monthly or quarterly fee. Availability of digital data of all assets, processes and operations in near real-time will enable utilities with better visibility and control; and they can now deploy analytical tools to optimize their operations. This is a quantum leap from their paper-based operations in the pre-Covid era. Covid-19 has presented never before opportunities for innovation and transformation with profound implications that are gainful in the long term. We are building data driven smart utilities which will open up new business opportunities for organizations providing tools and services to host and manage the enormous amounts of data utilities are expected to generate in the coming days.

While the typical physical assets of utilities depreciate, the digital assets will constantly appreciate. Here, we are presenting few ideas on how these digital assets can be monetized through appropriate business models.

Physical Assets Depreciate

- Power Plants
- Transmission and Distribution Network Equipment
- Offices, Buildings, etc.
- Computer and Communication Hardware

Digital Assets Appreciate

1. Customer Data
2. Billing and Collection Systems
3. AMI Data and Energy Consumption Profile
4. GIS Maps indexing electrical network and customers covering all buildings and roads in a city
5. Automation Systems—SCADA/DMS, DA and SA, DR, DERMS
6. Outage Management System and Mobile Workforce Management System
7. Call Centers and Call Data Archives

1.1 Customer Data

All the homes, business establishments and industries in cities, towns and villages are electricity customers. The electricity distribution utility has the full data of all their customers. They also know the size of the house or building, connected load, power consumption and their contact information. This is a very valuable data for other infrastructure and services providers, product marketing companies and a host of other businesses.

The customer information can be monetized by utilities by sharing that with responsible organizations under agreements. For example, a new agency that won the license for city gas distribution (CGD) in a town require customer data of all residents in the town to approach them. The electric utilities can share the customer data with the CGD company helping them kick start their operations in their new territory (Fig. 1).

Key Findings

- Digital data can be shared easily: removes spatial and inter-domain barriers
- Cross-pollination over several sectors

The market opportunities

- Share with Service Providers in other Domains: Water and City Gas Distribution, Municipal Agencies, Renewable Energy Development Agencies
- Large aggregation allows for better and more integration of renewables into the grid on the supply side and more effective Demand Response tools on the demand side
- Big data analytics can use power system data for various cross sectoral themes—environment, lifestyles, wealth, health, etc.
- Analytics both real-time and stored/archived data from equipment, systems and operations could yield valuable insights
- The use of AI and M2M communications to determine optimal energy use, lifestyle, comfort, energy efficiency etc.

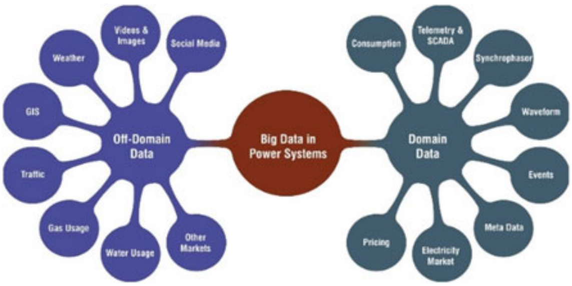


Fig. 1 Types of big data in power sector

1.2 Billing and Collection System

Most electric utilities now a days have state of the art Billing and Customer Relationship Management (CRM) systems and the customers have multiple options to make their payments. There are also Customers Care Centers at strategic locations and interactive customer portals. Utilities have regular interactions with their customers for meter reading, bill distribution, payment collection, attending to complaints, sharing information on planned outages etc. Large number of customers regularly use the customer portals.

All water and gas consumers are electricity consumers also. The Billing and CRM systems of electric utilities can be used for collection of water and gas bills, house taxes and other municipal dues. At certain places it can even be extended to private utilities such as cable TV, internet, telephone, etc. This not only reduces the overall collection cost, but also facilitates higher compliance in terms of timely payment. Similarly, it can also cover multiple Government to Citizen G2C) payments like monetary awards, senior citizens benefit, subsidies, and scholarships.

Moving billing and payment collection of different domains like electricity, gas, water, tv, internet, house tax and other municipal fees to common platform with a one bill would considerably reduce the cost of business operation for all domains. The customers would love the combined bills as they can pay for all utilities in one bill on one payment platform or location.

This could be an additional revenue opportunity for the electric utilities (Fig. 2).

Key Findings

- State of the art Billing and Collection Systems deployed in utilities cover all customers (residents in their service area) and are capable of extending to other domains in a city

The market opportunities

Fig. 2 Digital payment and collection platforms [2]

- Extension of the billing and collection system to water and city gas distribution, house tax collection, other municipal/city taxes
- Can even be extended to other service providers such as cable TV, internet, telephone, etc. in semi-urban and rural areas
- Considerable savings in cost of doing business to other domain owners
- Additional revenue stream for electric utilities

1.3 Smart Meter Data and Energy Consumption Profile

Smart metering or Advanced Metering Infrastructure (AMI) enables two-way communication between the customer and the control center of the electric utility. AMI facilitates remote monitoring and control of energy consumption as well as other electrical parameters in real time. Through analysis, data from the smart meters can be utilized by utilities to learn, predict and forecast the energy consumption of a customer. AMI system is capable of.

- Meter data validation
- Extracting tamper and missing information due to communication failure, meter fault etc.
- Energy audit and accounting of all customers on a feeder or connected to a distribution transformer in near real time
- Peak demand estimation
- Consumer profile analysis for demand estimation and energy usage
- Forecast and build predictive models for demand management or demand response program planning

AMI data of millions of customers is a gold mine for data analytics applications. Advanced analytical tools could yield new insights on the distribution network planning. The data will be valuable for several other domain owners (Fig. 3).

Key Findings

- AMI data is a very valuable resource depicting energy consumption profile of millions of customers
- Could help better estimation of demand leading to savings in power purchase cost

The market opportunities

- Sharing of AMI data with a variety of industry players for development of innovative applications and services
- Authentic load research for many stakeholders in the sector

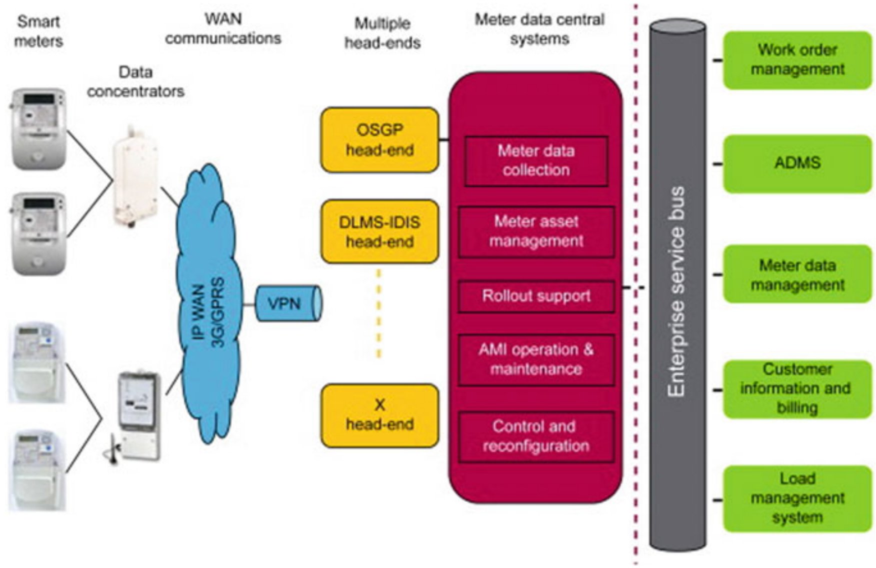


Fig. 3 Ease of analysis from AMI data for utilities

- New revenue stream for electric utilities

1.4 GIS Maps

R-APDRP and IPDS programs in India facilitated creation of GIS maps in distribution utilities in India. During the past ten years, distribution utilities created GIS maps of their electrical network and indexed all their customers on the maps in 1900 towns. These digital maps depict all the buildings and roads in a city; and are periodically updated.

Other infrastructure and services providers in a city could leverage these digital maps to plan their operations. The Digital Door Number (DDN) framework can be created on these maps and that can be linked for all services. Further it can be leveraged to interlink the built-up area information obtained from the geotagging exercise with the utility bills. This will result in the creation of a property wise database for electricity bills, gas bills, built-up area, etc. and enable estimation of energy performance indicators (EPI) at the building and city levels.

The simplest example of how a good GIS system can help beyond a single domain is avoiding damages to each other's assets. If one knows the routing of underground power cables, then the same can be synergized by other utilities that would need to dig up roads (like water, sewage, telecom, etc.—thus one should, in the future, never interrupt other services for adding new connections/ lines/ pipes) (Fig. 4).

Use Case

The Karnataka state police department has been using shared GIS data for pilot project for crime analytics and real-time monitoring as shown in figure below. *[Source—India: A Vision for National GIS].*

Key Findings

- All electrical assets (medium voltage and low voltage lines, substations) and customers are mapped on a digital map and the utilities update this system on regular basis to capture changes/addition to the electrical network as well as new customers/buildings
- This digital map can be effectively used by other infrastructure services providers for planning as well as operation and maintenance of their systems
- Very useful for planning the laying of water supply and sewerage lines, telecom cables, gas pipe lines etc.; also useful for planning of road networks

The market opportunities

- Share the maps with other stakeholders in a city for a mutually agreed fee

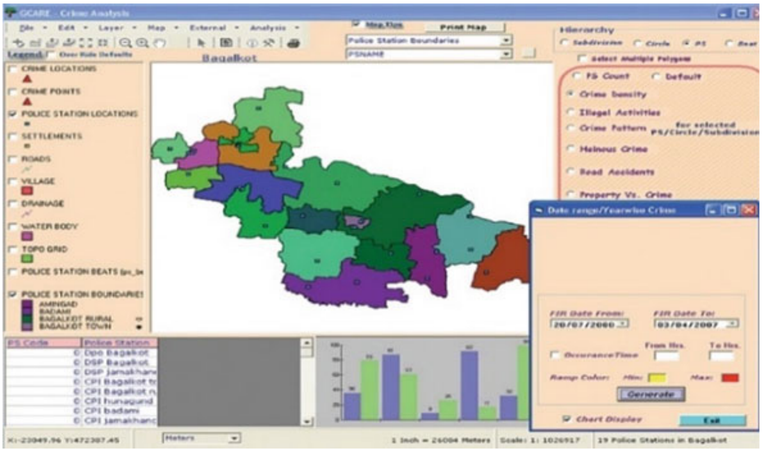


Fig. 4 Karnataka state GIS map [4]

1.5 Automation Systems—SCADA/DMS, DA and SA, DERMS

Under the R-APDR/IPDS programs of the Ministry of Power, Supervisory Control and Data Acquisition System (SCADA) and Distribution Management System (DMS) were implemented in about 78 towns in India with population of 400,000 and above. In the coming days all major towns will implement advanced SCADA/DMS and Distribution Automation (DA) and Substation Automation (SA) systems. Utilities with larger share of renewable resources will have to go for Distributed Energy Resources Management Systems (DERMS). The field infrastructure and dedicated communication bandwidth for these automation systems of the electric utility can be shared with the water and gas distribution utilities to automate their networks at marginal cost.

The automation systems have Remote Terminal Units (RTU) installed on the electrical network in the field with dedicated communication bandwidth to the control center. The same communication bandwidth can be shared by the automation system of water and gas distribution networks. It can also be leveraged for security and traffic cameras and other sensors monitoring noise, pollution etc (Fig. 5).

Key Findings

- Field infrastructure and dedicated communication bandwidth of electric utilities for automation systems can be shared with other infrastructure domains

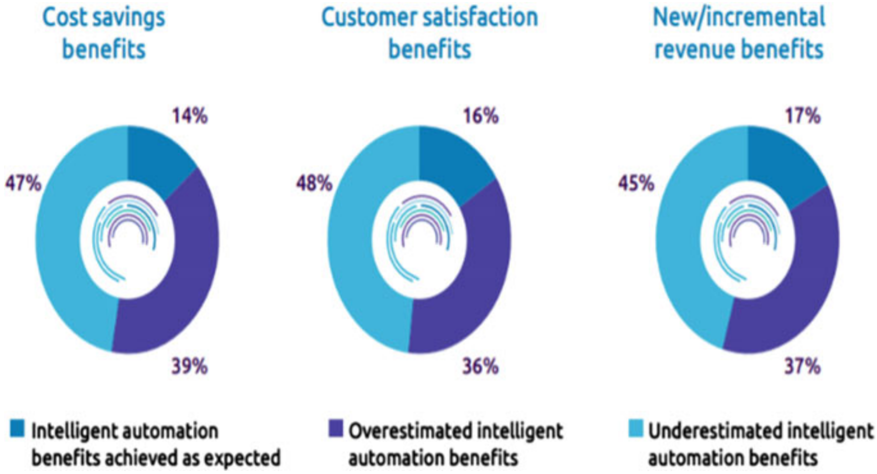


Fig. 5 Benefits of automated systems

- Latest trend is building own communication networks by electric utilities

The market opportunities

- **Common SCADA** with water and gas distribution utilities
- Sharing the **communication infrastructure** for security cameras, traffic cameras and other smart city applications
- Communication network (spare fibers) can be leased to telecom operators

1.6 Outage Management System (OMS) and Mobile Workforce Management System (MWFM)

Utilities recognize that, when it comes to service outages, the bar has been raised. Customers, regulators, media and the public have significantly higher expectations from the utilities regarding the reliability of their service, the speed of outage restoration, and the quality of information and communication they receive from their utility.

A next-generation Mobile Workforce Management (MWFM) solution unifies the field and the office on a single, mobile platform to manage utility crews and all types of work they perform on the field. MWFM provides the ability to create, receive, schedule, dispatch, and execute work orders. It is also integrated with the Customer Information (CIS) & Billing Systems, Outage Management Systems (OMS), Work and Asset Management (WAM) systems and Geographic Information Systems (GIS), as well as extensions to AMI systems and hardware devices, when needed.

Use Case

According to Tata Power DDL, the total AT&C losses stand at 7.79% as of April 2020 which is an unprecedented reduction of around 85% from an opening loss level of 53% in July 2002. To ensure reliable power supply Tata Power-DDL has implemented technologies like Advance Distribution Management System (ADMS) and real-time Outage Management System (OMS) integrated with Geographical Information System (GIS) for instant services, Advanced Metering Infrastructure (AMI), Automated Demand Response (ADR), Smart Street light Management System to manage the grid more efficiently and convert it to an intelligent network (Fig. 6).

Key Findings

- OMS and MWFM are very powerful platforms that can be shared with other infrastructure and services providers in a city

The market opportunities

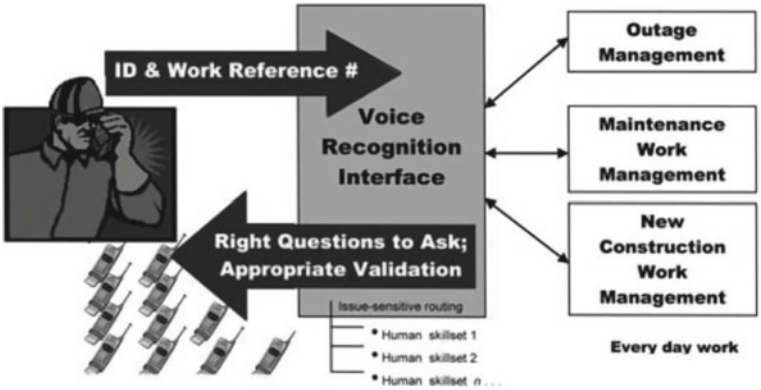


Fig. 6 Voice response technology for customer satisfaction [6]

- Revenue from sharing the OMS and MWFM with water and gas distribution agencies, white goods services agencies, other city service providers

1.7 Call Centers and Call Data Archives

A common command and control center that can handle the complaints from customers for all their grievances related to electricity, water, gas, internet etc. can be created. Now, there is a common 4-digit number (1912) all across India for electricity complaints. Electricity distribution utilities have setup state of the art Customer Care Centers in about 1900 towns in the country. These same call centers can be upgraded as common city command centers. The incoming calls can be diverted to the respective teams responsible for each domain and their crew. The IT and communication infrastructure and cost can be optimized significantly. It will also boost customer satisfaction to a great extent as they do not have to knock at different doors for each service. A state-of-the-art call center in the electricity distribution companies have data of all their customer calls which can be analyzed with advanced tools to identify recurring complaints and rectify them. Chatbots and Voicebots are today deployed in call centers that further optimizes the operations and cost while improving customer experience.

Use case

Offset Solar, a US-based solar company, generated $1.2 million revenue within six months using a simple homepage messenger chatbot (Fig. 7).

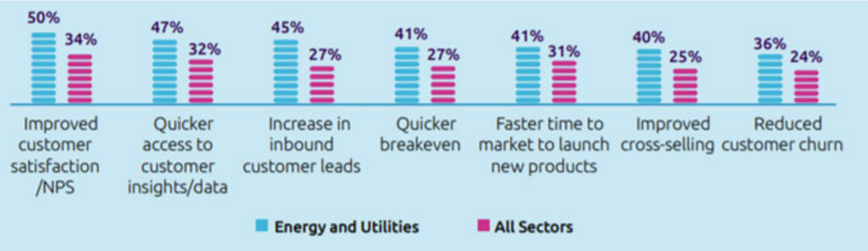


Fig. 7 Additional revenue by automated call centers [5]

Key Findings

- Customer Care Centers, Call Centers, Chatbots and Voice Bots of electric utilities are very valuable assets in a city/country
- India has 4-digit common number (1912) all across the country for electricity complaints/enquiries which can be extended to water, gas and other city services
- The incoming calls on 1912 can be diverted through IVR to the respective teams responsible for each domain
- The IT and communication infrastructure and cost can be optimized significantly

The market opportunities

- Revenue from sharing the Customer Care Centers, Call Centers, Chatbots and Voice Bots with other stakeholders
- Analytics of data from the customer calls and interactions with Chatbots and Voice Bots can be useful information for different stakeholders to optimize their business operations
- Call Centers of electric utilities can be made City Command and Control Centers at marginal cost

2 New Services and Revenue Opportunities from Unlocking Existing Infrastructure and Services

A set of paradigm shifts is forcing electric utilities to rethink their approach to services businesses and services policies to generate more revenue streams, and promote growth and operational efficiency

Growing customer expectations mean electric utilities must actively manage customer participation, such as demand side management programs, and provide network access to prosumers (consumers how are also energy producers). Mass adoption of electric vehicles (EVs) is poised to alter demand growth and put pressure on grid stability. Today, technology is being built into every asset, operation and interaction, transforming businesses into smart enterprises.

Based on the energy consumption of the existing customer base, utilities can enhance the customer experience by introducing new technologies at the same time increasing their revenue.

By ensuring various schemes and policies of the government, utilities can identify new streams of serving the customer and collaborating with new technologies to generate additional revenues.

New Business Areas

1. Selling Rooftop PV (RTPV) Systems and promoting “Prosumers”
2. Selling Energy Efficient (star-rated) and “*Smart*” Appliances
3. Promotion of Electric Cooking and sale of Cooking Appliances
4. Selling Electric Vehicle Chargers
5. Selling Batteries for Energy Storage and other Applications
6. Sharing of Communication Bandwidth
7. Smart Home: Grid Interactive Buildings and Appliances
8. Maintenance Services to Large Buildings and Complexes
9. Unlocking the Value of Substation Land: Commercialization of Surplus Land by Conversion of existing Substations to Gas Insulated Substations (GIS)
10. Unlocking the Value of Lamp Poles and Transmission Towers
11. Cooling as a Service—District Cooling Systems

2.1 Selling Rooftop PV (RTPV) Systems

During 2013 to 2016 all the state electricity regulatory commissions in India had issued net metering policies that allowed the consumers to be prosumers.

Today, the payback time for RTPV systems in most parts of India is 3–4 years. Presently 1 kW PV system cost is around Rs 35,000 to 40,000 and is expected to go down to Rs 20,000–25,000 by 2025. This would further reduce the payback period and could create a RTPV revolution which utilities can benefit if driven correctly.

Utilities can also generate additional income by selling and installing RTPV systems for their customers. They could also sign up for annual maintenance contracts for RTPV systems. This would create job opportunities and additional revenues (Fig. 8).

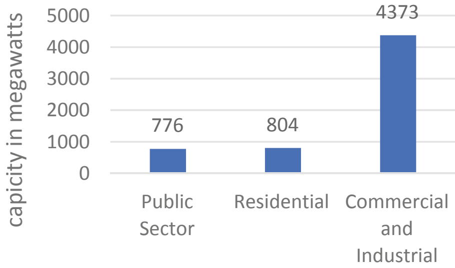


Fig. 8 Total installed solar rooftop capacity in India as of June 2020 [7]

Key Findings

- RTPV has become economically attractive to most categories of customers
- Customers are not familiar with RTPV systems and models available in the market; neither aware of the formalities to avail net-metering/gross metering benefits
- Utilities should TEST and CERTIFY good quality RTPV Systems and offer services to their customers for procurement and installation of RTPV systems as well as its annual maintenance
- A study by BRPL-CEEW in 2019 estimated a net benefit to the utility to the tune of Rs 0.22 per kWh of RTPV power generated in Delhi
- Time has come to unleash a RTPV revolution in the country and utilities can benefit from this huge opportunity—being part of this revolution and leading it is the way forward rather than being a "Kodak of Tomorrow"

2.2 Selling Energy Efficient (Star-Rated) and Smart Appliances

Energy efficiency measures are the foundation of a smart and efficient buildings and homes. The building automation and IT solutions can reduce the baseline load of a building and lower the overall electricity use. Use of smart appliance enabled by WiFi can support the utilities through demand response (DR) programs.

Currently, the efficiency standards of the Department of Energy (DoE), USA cover more than 60 categories of products, from dishwashers to vending machines to lighting technologies. Implementing these standards reduced the national energy bill by about $80 billion in 2015. The benefits of efficiency standards are significant and widespread, including product innovation, billions of dollars in energy savings for consumers, and significant reductions in carbon emissions as well as reduction in emissions of mercury and nitrogen oxide from power plants.

Star Labelling Program in India: Bureau of Energy Efficiency (BEE) has 10 mandatory and 13 voluntary labeled appliances. Total electricity savings from energy efficiency programs in 2017–18 was estimated at 86 Billion Units (BU) which was 7.14% of total electricity consumption in the country. This helped save US$ 7.5 billion and a reduction in CO_2 emissions of around 108 MTOE annually (Fig. 9).

Key Findings

- Many utilities are already promoting replacement of old Air-Conditioners and Refrigerators with new star-rated appliances
- Should promote "***smart***" appliances which can be connected to the WiFi network and remotely controlled
- The range should cover geysers, washing machines and electric cooktops
- This can be clubbed with energy efficiency programs and incentives

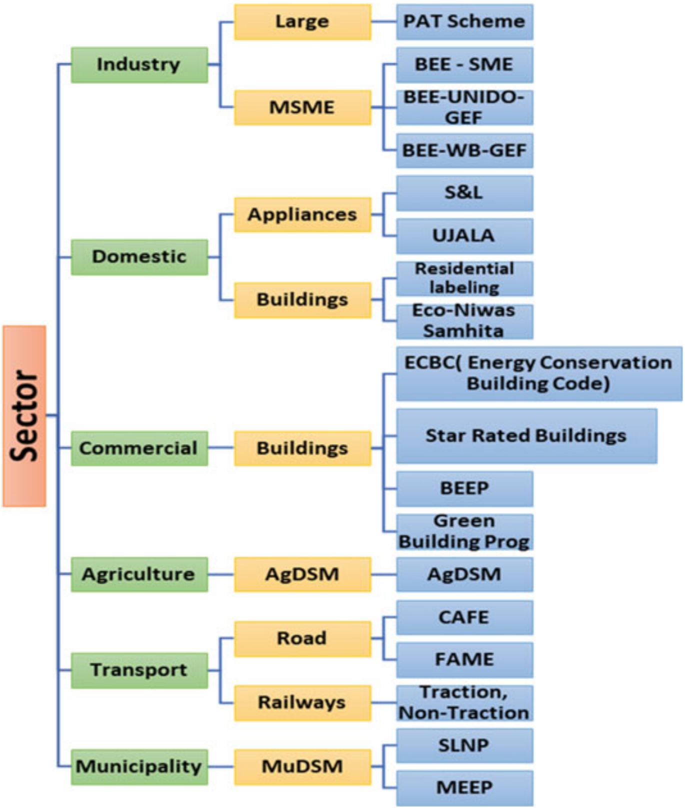


Fig. 9 Energy efficiency schemes in India

- Promote innovative and sustainable business models that will be WIN–WIN for both the Utility and the Customers

2.3 Promotion of Electric Cooking

Government of India (GoI) has undertaken several targeted programs in the recent past to provide access to clean cooking energy to urban and rural households as well as to electrify all the households in the country. Pradhan Mantri Ujjwala Yojana launched in 2016 provided credit-linked subsidized LPG connections to over 100 million households making the total LPG connections to over 200 million households. While DDUGJY program completed electrification of all the 619,000 villages by April 2018, another very successful program SAUBHAGYA has electrified almost all (>99%) households by March 2019.

Electricity being the cleanest fuel at user-end and with surplus electricity generation capacity and having electrified all households, it is prudent to promote electric cooking. In February 2021, Government of India launched GO ELECTRIC program which will promote electric vehicles and electric cooking.

Today a variety of electrical appliances are available for cooking almost all items in any cuisine. Cost-wise also electric cooking will be cheaper for customers. With smart plugs that can be remotely controlled, customers can avail subsidized tariff for cooking when power is surplus on the grid.

Emissions from cooking is a significant contributor to CO_2; Electric Cooking will help achieve NDC targets.

Utilities should uprate the electricity connections to minimum 3 to 5 kW for all households and promote electric cooking that will improve the load factor and income of the utilities.

Key Findings

- Electricity is the cleanest fuel at the user end and increasing share of electricity is being generated from clean resources
- Millions of women and children in rural areas in developing countries use firewood/biomass and cow dung for cooking leading to pollution and serious health issues
- Electric cooking leads to economic efficiency in myriad ways:

a. Houses are already connected to the grid–no additional infrastructure is required to electrify the kitchens

b. Huge amount of energy (and money) being wasted in transporting gas cylinders to households—1500 million LPG cylinders were handled in 2019–2020
c. Billions of dollars spent every year in subsidy for cooking gas and kerosene
d. Healthcare expenses to treat respiratory diseases in millions can be avoided

- Electric pressure cooker, oven, hot plate, kettle, induction cooktop and air fryer—the combination of these appliances can cook almost every item in all cuisines
- Electric cooking can also help the grid in load balancing—there is surplus electricity on the grid during many timeslots in a day and can offer cheap electricity to millions of cooking appliances that will improve the load on the grid. With Time of Use (ToU)Tariff and Smart Plugs, most cooking load can be shifted to non-peak hours at lower tariffs
- Electricity connection capacity to all households should be enhanced to 3–5 kW so that cooking and cooling load can be met efficiently
- Electric Cooking is an Idea whose time has come!

2.4 Selling Electric Vehicle Chargers

The utilities can collaborate with Electric Vehicle (EV) manufacturers in order to provide charging solutions to their customers. Promotion of EV and home charging stations by utilities would allow them to generate new revenue streams.

The electric vehicle charging stations market is projected to reach USD 27.7 billion by 2027 from an estimated USD 2.5 billion in 2019, at a CAGR of 34.7%. Increasing investments made by governments across the globe to develop charging infrastructure creates opportunities for utilities to expand their revenue streams.

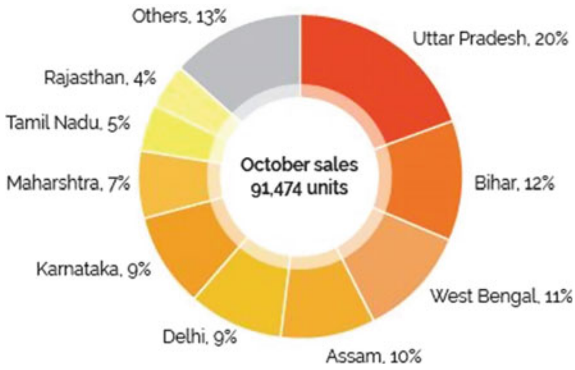
Use Cases

Jaguar Land Rover (JLR) has recently entered into a partnership with Tata Power to set up and provide EV charging solutions at 27 outlets of JLR and also at customers' residence in India (Fig. 10).

Key Findings

- Most EV owners likely to buy EV Chargers for home charging
- Utilities could partner with EV manufacturers and set-up home charging facilities (mostly AC Slow Chargers)
- AC Chargers with Vehicle-to-Grid (V2G) functionality would help load balancing on the grid

Fig. 10 Cumulative EV sales [8]



- Large number of EVs connected to the grid could be aggregated as virtual power plants (VPP) and support the grid in many ways
- Selling EV chargers and giving new electricity connections for EV charging to customers is new revenue opportunity for utilities

2.5 Selling Batteries for Energy Storage and Other Applications

Lithium-ion batteries (LiBs) have emerged as the best choice for grid-level energy storage systems because of their rapid response, modularization, and flexible installation. It can also be shifted from location to location easily. LIB's performance related to energy density, energy efficiency and cycle life has significantly improved in the recent past while the cost came down by over 90% in the last ten years.

In India there are about 100 GW of Diesel Generator (DG) sets for backup power supply in buildings, data centers and other emergency requirements. Due to the high levels of carbon emission many states have banned the use of DG sets. With the present cost of diesel, the electricity from DG sets is above Rs 30/kWh. The cost of electricity from a LiB based battery energy storage system (BESS) can be much cheaper, particularly if the batteries are charged when cheap electricity is available on the grid. Typical DG sets are used for few hours in a month whereas the BESS can be leveraged for multiple grid services.

BESS can offer voltage and frequency support as well as peak load shaving, load shifting and deferral of distribution system upgrades. Energy storage is becoming cost competitive with peaking power plants partially due to the ability to offer flexible grid services. The need for flexible grid services is increasing as the renewable penetration is increasing. BESS will also help RTPV integration with distribution grid.

Selling and maintaining of BESS is a very attractive business opportunity for utilities.

Key Findings

- Energy Storage System (ESS), particularly Lithium-ion Batteries (LiB) is fast becoming popular for several applications at customer end:

a. DG Set Replacement
b. Solar and Wind Power Applications
c. EV Charging
d. Data Centers
e. Stand-by Power for all new Infrastructure—lifts, emergency lights, computers and WiFi routers

- Utilities can offer LiBs to Customers and lease it back for grid support (large batteries):

a. Ancillary Services
b. Network Upgrade Deferrals
c. Smoothening of Power from Solar PV
d. Other Emergency Situations

- Smaller batteries at customer premises can be aggregated through battery aggregation systems and run as Virtual Power Plants (VPP)

2.6 Communication Bandwidth

Traditionally utilities created their own communication infrastructure for the power system operations. In the old days they had power line carrier communication (PLCC) systems on high voltage lines which they upgraded to digital PLC and also laid fiber optic cables as part of the ground wire (OPGW). Now the latest trend is to lay fiber along with power cables to create utility owned and controlled communication systems. Power cables are now available with fiber optic cables integrated inside at marginal cost.

Installing fiber optic cables is relatively economical for power utilities since they already own rights-of-way (ROW) and power poles or cable trenches. This gives the utility company the ability to install fiber optic cables alongside their existing power lines. Having own telecom network enable the utility to automate the electrical network and offer smart metering and other services to customers. Fiber optic cables along with power lines can connect all the distribution transformers, capacitor banks, EV charging stations, RTUs and FRTUs of SCADA/DMS and distribution automation systems etc. and help remotely monitor and control them.

The spare band width and spare fibers can be leased to other users or telecom operators.

Key Findings

- The latest trend in utilities is to build own telecom network by utilities

a. Electric cables with in-built fiber optic cables are now available at marginally higher cost—no additional right of way required; laying cost also saved; only fiber termination cost is extra
b. PLC/RF Mesh may be used for last mile connectivity

- Utilities own communication network for smart metering and network automation
- The spare fibers can be leased to third parties and telecom service providers
- Utilities could offer internet and cable TV services in underserved-communities

2.7 Smart Homes: Grid Interactive Buildings and Appliances

Countries are trying to decarbonize the electricity sector by increasing renewable generation and other significant changes are underway with the penetration of DERs, electric vehicles, smart grid-interactive appliances and demand management solutions in buildings. The grid is evolving from the linear system with a uni-directional energy flow to an increasingly complex and interconnected system through which energy and data flow to and from various entities (buildings, utilities, third-party service providers).

Globally about 40% of total energy generated is consumed in buildings. As the electric grid transforms into a more distributed two-way power system, and buildings incorporate new technology, including electric cars and smart appliances that can be remotely controlled, big opportunity is emerging to integrate homes and grid connected resources behind the meter to offer flexibility services to the grid. Technologies that transform a building into a grid-interactive smart building are a becoming affordable and by making buildings a dynamic grid asset that can generate and/or store and use energy efficiently.

Utilities should offer the service of making the buildings and campuses grid interactive.

According to IEA's projections the Indian power system is likely to quadruple to 1600 GW by 2040 and the power system would require up to 85% flexibility.

Key Findings

- Globally buildings consume 40% electricity generated
- Buildings are becoming smart and can be made grid interactive

- Large buildings and campuses with Rooftop/in-premise Solar PV, Electric Vehicles and Battery Energy Storage Systems can be made Grid-Connected Smart Microgrids that could

a. Island from the grid during peak hours
b. Buy electricity from the grid when prices are low and store it in the BESS/charge EVs and sell back to the grid during peak hours
c. Provide Ancillary Services (voltage and frequency support) to the grid

- Smart Homes/Buildings with Smart Appliances could provide Demand Response (or load relief) to the grid when required
- Utilities can evaluate appropriate equipment, smart appliances and systems to facilitate this transformation to smart homes/grid interactive buildings for mutual benefit
- Utilities could offer this as a new business to large buildings and campuses

2.8 Unlocking the Value of Substation Land: Commercialization of Surplus Land by Conversion of Existing Substations to Gas Insulated Substations (GIS)

Economic growth will propel demand for electricity as well as cost of land. Land availability and high cost of land as well as the right of way to construct high voltage transmission lines to urban areas are major constraints in capacity expansion of transmission and distribution networks. Old substations built 30–40 years ago outside the cities have now become prime commercial properties. Those substations require refurbishment and capacity enhancement which can be achieved by converting them to Gas Insulated Substations (GIS). By converting the Air Insulated Substations (AIS) to GIS, 70–80% of the land can be made available for commercial purposes.

Railway stations, metro stations, airports, sea ports and bus stations are commercializing the surplus land around them and utilizing the money generated for improving the existing facilities. Same way, electric utilities should be allowed to commercialize their land assets and utilize the money generated to improve and expand their networks.

Use Cases

Gurgaon Palwal Transmission Ltd is a 130 km long inter-state transmission line built in the urban landscape of Gurugram and its neighborhood. A vertical substation was developed as a compact, multi-storied structure. This futuristic substation houses the 400 kV GIS equipment on the ground floor, the 220 kV GIS on the first floor and the open 220 kV switchyard on the roof. This entire 400/220 kV GIS substation occupies just 3.8 acres, thus, reducing the land required by as much as 75 percent. The project built multi-circuit monopole towers across the transmission path, using micro piling to create the foundations. In addition to space-saving, another remarkable advantage of these vertical substations is the reduced carbon footprint.

Key Findings

- Large substations built 30-40 years ago outside the cities are now prime commercial properties
- Old substations require urgent refurbishments and capacity enhancement
- Conversion of these substation to Gas Insulated Substations (GIS) could release up to 80% of the land that could be commercialized
- Only a portion of the price of the land commercialized is required for the conversion to GIS and to enhance the capacity

2.9 Unlocking the Value of Lamp Poles and Towers

Utilities own millions of lamp poles and towers of different sizes which is today largely under-utilized. This is a gold mine that can be unlocked to create additional revenues. Since the lamp poles already have electricity, they can be leveraged for installation of WiFi routers, security cameras, EV charging points, sensors for pollution and noise monitoring, navigation systems for drones etc.

Latest trend is to go for smart poles that are multifunctional light poles equipped with electronic components, software controls and smart sensors that can receive and transmit data. Smart pole comprises LED lights with advanced controls to remotely control lighting; and built-in sensors and communication units. They have the potential to incorporate numerous add-on capabilities and functions, and can be easily upgraded with new and evolving technologies and devices.

Smart poles could also act as nodes for capturing traffic data, weather and pollution levels.

Use Cases

In March 2018, Tata Communications announced its plan to install 15,000 smart street lights in Jamshedpur. Wipro Lighting partnered with Schréder Lighting to market “smart city products and beyond” in India and meet premium lighting requirements. It will leverage the latter’s expertise in IoT-based smart street lights and smart poles.

Key Findings

- Millions of lamp poles that utilities own is an undervalued asset which can be deployed for:

a. Installation of EV Charging Points
b. Installation of 4G/5G/WiFi Antennas
c. Installation of Navigation Systems for Drones—Passenger Drones and Delivery Drones
d. Installation of Pollution and Noise Monitoring Sensors
e. Installation of Security Cameras
f. Advertisements

- Lamps can be converted to solar powered lamps with integrated sensors and cameras for the above—lot of innovation is going on in this domain
- Above possibilities offers additional revenues to utilities

2.10 Maintenance Services

Outsourcing maintenance services is becoming an increasingly prevalent method for companies to maintain their assets in numerous industries, from aviation to IT and manufacturing as carrying out such functions in-house is expensive.

Utilities have skilled technicians who could undertake complete maintenance of large buildings and campuses with the help of contract employees for miscellaneous tasks. Utilities would be able to efficiently do the service and maintain the reliability and trust of their customers.

This could generate huge revenues for utilities.

Key Findings

- All large buildings outsource electrical maintenance services to third parties
- Utilities have skilled employees and better access to supply chain for undertaking such services efficiently
- Customers will have more trust with utilities taking over the responsibility to maintain their buildings and campuses—particularly in case of Schools, Colleges, Hospitals, IT Parks etc.

2.11 Cooling as a Service—District Cooling Systems

Electricity, water and gas are supplied to buildings as a service against monthly payments. Same way, cooling can also be provided as a service to buildings and homes.

Chilled water produced at a central chiller can be supplied to buildings through insulated pipes where air handling units will cool the air passing over chilled water pipes for air conditioning the buildings/rooms. This is called District Cooling Systems (DCS) which are successfully implemented in several cities around the world including GIFT City in Gujarat. Nationally only 5% people have room air-conditioners (ACs) while urban India has room ACs in 10% households. The traditional model of more efficient equipment and appliances for space cooling is not going to help as the demand is expected to surge exponentially in the coming years. The 2050 scenarios show that space cooling could reach 28% of India's electricity demand and 44% of peak load. The way forward is DCS and providing cooling as a service. DCS is highly energy efficient and will significantly reduce electricity consumption in buildings, reduce heat in the street/neighborhood as well as avoid the capex by each building/flat owner to buy window air-conditioners.

DCS is normally built with large chilled water storage tanks that could provide cooling service to the buildings for several hours. This thermal storage system is a good flexibility resource for the electric grid as well. During off-peak hours the chiller plant can produced chilled water and store it and give load relief to the grid during peak hours.

Use Case

Gujarat International Finance Tec- City (GIFT City) has the country's first public DCS which is successfully operating for last 7 years. With much higher energy efficiency, DCS has fundamental cost and space saving benefits, including load variety, streamlined processes, advanced technology and better employee economies. It reduces the capital investment needed for the additional infrastructure for power generation, transmission and distribution and would create additional revenue streams through the service provided.

Key Findings

- Summer temperature in North India is constantly on the rise—during the past 3-decade maximum temperature in Delhi has gone up from 42 to 48 °C; at this rate by 2030, temperature in most parts of North India will be above 50° C making it impossible for people to live, work and commute. Nationally only 5% people have room air-conditioners; Urban India has 10% (over 30% in Delhi)

- Room air conditioners spew out heat and create heat islands—making it further difficult to for those without access to cooling. Incremental improvement in efficiency of room air conditioners and other appliances will be over shadowed by the sheer increase in the number of new units added every year
- District Cooling Systems (DCS) is successfully implemented in several cities around the world including GIFT City in Gujarat where cooling is provided as a service against monthly bills.
- DCS is highly energy efficient and economical; reduces the electrical load of individual buildings; it also can be combined with thermal storage.
- Electric Utilities should seriously consider Cooling Service with DCS as a new business opportunity

3 Conclusion

ISGF had the opportunity to discuss the ideas presented in this paper with regulators and utility CEOs in different forums in the recent past. All of them were interested in taking up few of the ideas on pilot basis in 2021 itself. It is recommended that regulators may accord approvals to utilities to try some of these ideas on pilot basis and depending on the success factor and customer acceptability may scale up the same.

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