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

V. Thakur (✉) · A. Mogha
Grid Automation, TATA Power DDL, New Delhi, India
e-mail: varun.thakur@tatapower-ddl.com

A. Mogha
e-mail: abhinav.mogha@tatapower-ddl.com

R. K. Pillai et al. (eds.), *ISUW 2021*, Lecture Notes in Electrical Engineering 843,
https://doi.org/10.1007/978-981-16-8727-3_5

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).

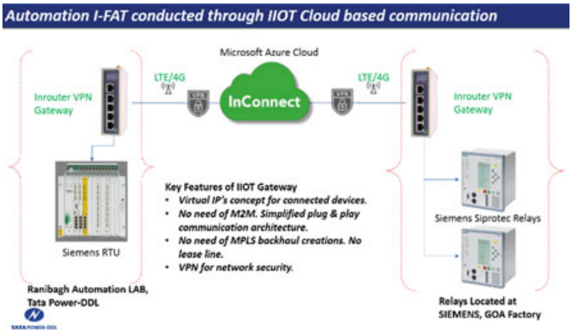
IIOT major components:

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.

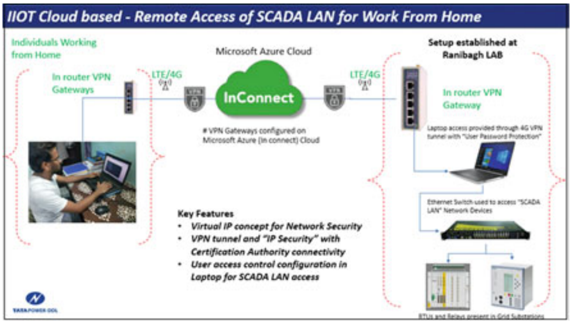
Remote Integrated Factory Inspections were conducted through Internet of thing (IOT) based FAT for turn grid and bay extension activities wherein IEDs/Relays were located at SIEMENS, GOA factory and RTU was at Tata Power-DDL, Ranibagh Lab, Delhi location. Real time automation integration testing was 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

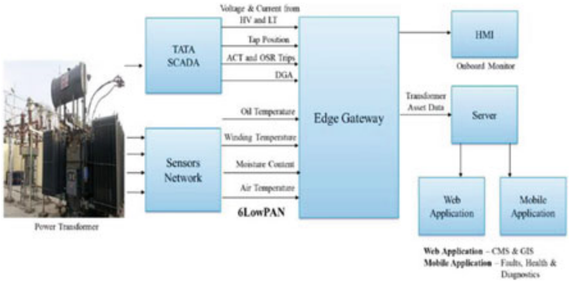
IIOT based Transformer Asset Health Monitoring system POC has been carried out to measure—Transformer Efficiency or Residual Life Assessment or Real time PTRs performance measurement.

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.***



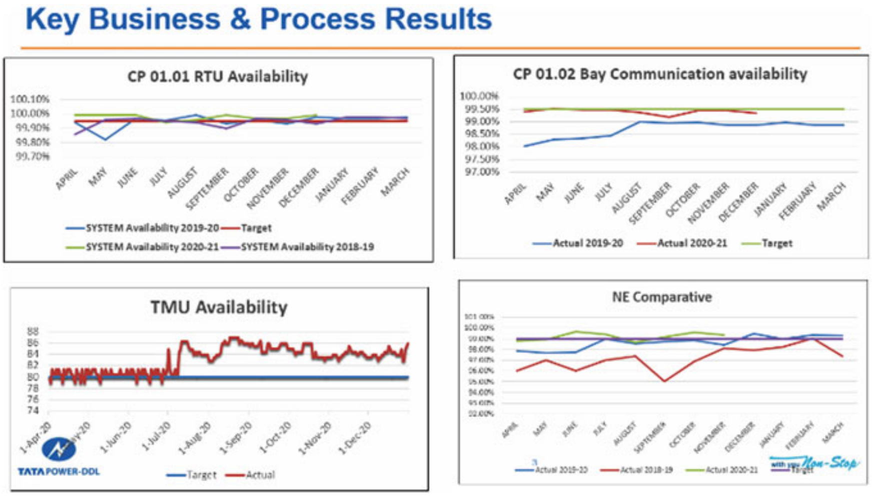
Critical processes and Assets health can now be monitored more accurately using IIOT enabled digital data collection. These digital transformations takes the guesswork out of processing and allow utilities to achieve high Operational Efficiencies and Profitability with optimized resources while maintaining 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.

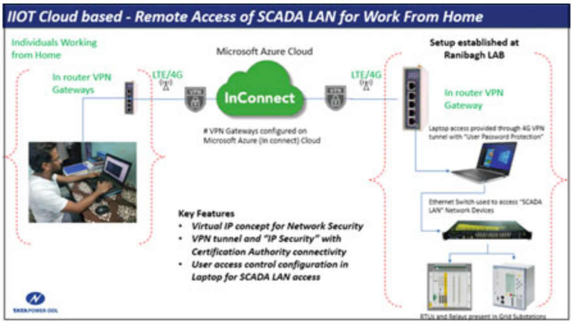
A transformation promising to change how companies work—improving connectivity, efficiency, reliability and safety.

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