Chapter 11
Smart Grid: Energy Backbone of Smart City and e-Democracy

Jignesh G. Bhatt and Omkar K. Jani

Abstract In broad context, e-Governance is a functional subsystem under e-Democracy, since Governance and hence, entire Government itself is an important section of democracy itself. Hence, smart city development is in fact, the transformation of approach in their futuristic contexts towards responsibilities, interests and rights of all its stakeholders; such as citizens, government, administration, services, utilities, etc. Globally, consistent focus for financial growth and quality of life has ultimately resulted into unprecedented rise in consumption of electrical energy. Electrical power management in India has become a critical issue with rising population, increasing life expectancy, economic growth and, more importantly, due to vibrantly changing and difficult to predict weather. Electrical power supply has always been a resource in deep scarcity in India, so 24 * 7 electricity is an issue causing concern. Efficient decision-making at different levels rely upon reliable availability of electricity, which has been an integral element of citizens' life, therefore stable and sustainable power management, especially supply reliability is a need of today. Government of India has launched a Smart City Mission for building 100 Smart Cities, in which 24 $\times$ 7 availability of electricity has been one of the major focus. Historically, electricity generation, transmission and distribution decisions have been the exclusive domain of utility companies, domain experts, bureaucrats or sometimes political interventions, but now a paradigm shift could be observed towards citizens' participation and active involvement. Sufficient electricity being the mandatory element of a smart city necessitates an inclusive and participatory management of this resource. Smart electricity management in upcoming smart cities encounters challenges in the urban electricity

J.G. Bhatt (✉)
Department of Instrumentation and Control Engineering, Faculty of Technology, Dharmsinh Desai University, Nadiad 387 001, Gujarat, India
e-mail: jigneshgbhatt@gmail.com

O.K. Jani
Solar Energy Division, Gujarat Energy Research and Management Institute (GERMI), Pandit Deendayal Petroleum University (PDPU) Campus, Gandhinagar 382 007, Gujarat, India
e-mail: omkar.j@germi.res.in

T.M. Vinod Kumar (ed.), *E-Democracy for Smart Cities*, Advances in 21st Century Human Settlements, DOI 10.1007/978-981-10-4035-1_11

management through smart grid via integration of ICT and e-Democracy. Smart Grid as an energy backbone of smart city is immensely vital and serving at the core of Smart City realization. Evolving e-Democracy, smart grid includes highly interactive participation of citizens in energy consumption domain, based on humanitarian and customer centric approach. Different types of prosumers (producers + consumers), their different energy requirements at different timings, different types of energy resources and their switching feasibilities considering different aspects have been integrated. Under National Smart Grid Mission, Government of India has launched Restructured Accelerated Power Development and Reforms Programme for funding Smart Grid initiatives and Gujarat has been one of the leading states of India as far as self-reliance and reforms like solar city, smart grid, etc. are concerned. Renewable Power Plants and Smart Grid Pilot Projects implemented in Gujarat have been proved models and case studies for other locations. Moving ahead from our earlier contributed chapter "E-Governance for Photovoltaic Powergrid: Solar City Gandhinagar, Gujarat, India", in the book *E-Governance of Smart Cities*, in this chapter, we now present citizen-centric approach of design-implementation of smart grid with case study of pilot project at Naroda, Ahmedabad.

Keywords e-Democracy · Electricity · Smart city · Smart grid · Smart electricity management · Collaborative planning · Electricity scarcity · Information and communication technologies (ICT) · Internet of things (IoT)

Abbreviations

2G	2nd generation
3G	3rd generation
4G	4th generation
AMI	Advanced metering infrastructure
BAS	Building automation system
CT	Communication technology
DDU	Dharmsinh Desai University, Nadiad, Gujarat, India
DISCOM/DisCom	DIStribution COMpany/Distribution Company
DR	Demand response
EA 03	Electricity Act 2003
GEB	Gujarat Electricity Board
GEDA	Gujarat Energy Development Authority
GENCOM/GenCom	GENeration COMpany/Generation Company
GenCos	Generation Companies
GERC	Gujarat Electricity Regulatory Commission
GERMI	Gujarat Energy Research and Management Institute, Gandhinagar, Gujarat, India
GIS	Geographic information system
GoG	Government of Gujarat
GoI	Government of India

GPS	Global positioning system
GPRS	General packet radio service
GSM	Global system for mobile communication
GUI	Graphical user interface
HAN	Home area network/home automation network
HTLS	High temperature low sag
ICT	Information and communication technology
IOT/IoT	Internet Of Things/Internet of Things
IPDS	Integrated power development scheme
ISGF	India Smart Grid Forum
ISGTF	India Smart Grid Task Force
IT	Information technology
JNNSM	Jawaharlal Nehru National Solar Mission
LTE	Long-term evolution
MNRE	Ministry of New and Renewable Energy, Government of India
MoP	Ministry of Power, Government of India
NLDC	National Load Dispatch Center
NSGM	National Smart Grid Mission
PGCIL	Power Grid Corporation of India Limited
PLC	Programmable logic controller
PLCC	Power line carrier communication
PMU	Phasor measurement unit
Prosumer	Producer + consumer
PV	Photo voltaic
PXIL	Power Exchange India Limited
RAPDRP/R-APDRP	Restructured accelerated power development and reforms programme
RE	Renewable energy
REMC	Renewable Energy Monitoring Center
RET	Renewable energy technology
RLDC	Regional Load Dispatch Center
SCADA	Supervisory control and data acquisition
SG	Smart grid
SGCT	Smart Grid Communication Technology
SGKC	Smart Grid Knowledge Center
SoS	System of systems
SLDC	State Load Dispatch Centre
SLPMU	State level project monitoring unit
UGVCL	Uttar Gujarat Vij Company Limited
UI	Unscheduled interchange
VAR	Volt-ampere reactive
WAMS	Wide area monitoring system
WBAS	Wireless building automation system

11.1 Introduction [1–5]

One of the major and most significant changes observed globally in world development is 'Urbanization'. Adil and Ko [1] have indicated that the growth of Decentralized Energy Systems (DES) have been directing towards a new frontier in urban energy planning and design of local energy systems. As affordability of RET, particularly solar PVs and solar thermals, have been rising, cities and urban regions are transforming into venues, not only for energy consumption, but also for energy generation and distribution. This is clearly establishing a need for systemic and paradigmatic change in local energy infrastructure.

Focusing upon the importance of high quality, reliable, efficient and uninterrupted electrical power and its importance for energizing core services of smart cities, Al-Ali [2] have outlined the need for IoT and cloud computing for interconnecting and synchronizing basic application services of smart cities which have been now transforming from conceptual models to developmental stages. While observing growing developments in AMI, Arasteh et al. [3] have noted that smart cities have now been getting equipped with IoT based electronic devices in order to increase their smartness further.

Bansal et al. [4] have estimated that approximately 500 million people would have been living in cities by 2030, which is around 60% of the world's population. Cities contribute to economic growth by turnover of financial resources, workforce, etc. and have potential to provide higher opportunities of wealth creation, improved health-medical supports, quality education and much better standard of living with enhanced infrastructure facilities. High-level integration of existing technologies to deliver a smart energy network, enhanced electricity transmission, energy efficient transportation, and low carbon building footprints, will make it easier to manage the unfolding urbanization, and could have much positive impact on energy use and consumption. Policy interventions and government investments are important determining tools to its success.

Bhatt et al. [5] presented descriptions on "E-Governance for Photovoltaic Powergrid: Solar City Gandhinagar, Gujarat, India", in the book *E-Governance of Smart Cities*. In this chapter, the authors presented technological development and e-Governance aspects of solar PV based electrical powergrid in the upcoming smart city-solar city Gandhinagar, Gujarat state, India.

Proceeding further from earlier contribution, in this book chapter, the authors have presented interesting descriptions on 'Smart Grid'—the technological development serving as energy backbone of the upcoming smart city. Beginning with introductory details including historical perspective and present situation, need analysis has been included. Subsequent section describes the relationship among electricity, urbanization and human settlement with useful literature cited. In the next section, by including conceptual details and salient features and merits of smart grid, smart grid development in India has been discussed; wherein various government initiatives and other information have also been included. In the same section, smart grid developments in state of Gujarat have been discussed along with

UGVCL's approach (as methodology) and case study of UGVCL's smart grid pilot project at Naroda, Ahmedabad has been included. Next section is based on e-Democracy and citizens' participation consisting subsections like internet based e-tools and mobile based M-tools, followed by separate sections on experiences and lessons learnt. Various relevant issues and challenges have been identified and mentioned in the subsequent section. Finally, sections like vision and roadmap, technological inputs and useful conclusions have been included to mark end of the chapter with acknowledgement and list of cited references.

11.1.1 Historical Perspective [6]

In India, electricity reforms started with the re-evaluation of Electricity Supply Act, 1948 and the Indian Electricity Act, 1910, which led to the Electricity Act, 2003. The EA 2003 has been brought about to facilitate private sector participation and to help cash strapped state electricity boards to meet electricity demand. EA 2003 envisages competition in electricity market, protection of consumer interests and provision of power for all. The act recommends the provision for national electricity policy, rural electrification, open access in transmission, phased open access in distribution, mandatory SERCs, license free generation and distribution, power trading, mandatory metering, and stringent penalties for theft of electricity. One more welcome step that the Indian electricity market has taken is the implementation of ABT, which brought about the effective day-ahead scheduling and frequency sensitive charges for the deviation from the schedule for efficient real-time balancing and grid discipline.

To promote power trading in a free power market, CERC approved the setting up of Indian Energy Exchange (IEX) which is the first power exchange in India, in June 2008. IEX has been modeled based on the experience of one of the most successful international power exchanges, Nordpool. At present, two power exchanges are operating in India, namely, IEX and Power Exchange India Limited (PXIL). These exchanges have been developed as market based institutions for providing price discovery and price risk management to the electricity generators, distribution licensees, electricity traders, consumers and other stakeholders. The participation in the exchange operations is voluntary. At present, exchanges offer day-ahead operations whose time line is set in accordance with the operations of RLDCs. Power exchanges coordinate with the NLDC/RLDCs and SLDCs for scheduling of traded contracts' to get up-to-date network conditions. Currently, about 96% of the market transactions in India are in the form of bilateral (long and short terms) contracts. The rest is dealt by two power exchanges.

The Indian power sector has come a long way since the introductions of second wave of reforms vide the EA 03. This gave a major boost to the power sector by creating conducive environment for enhanced private sector participation, which resulted in a large increase in generation capacity as well as investments in T&D as well as the introduction of a power market and power trading activities. In addition to this, the focus was shifted on reforms aimed at providing affordable, good quality and reliable power to consumers, making the electricity industry commercially viable and promoting efficiency improvements.

11.1.1.1 Generation

Power Generation has gained the most due to the entry of private players. The magnitude of capacity being added each year has increased manifold when compared to previous planning periods. Also, with the use of new and more advanced technologies, efficiencies of thermal power plants have been improving and emission levels falling. Operational requirements related to scheduling and dispatches are driving the implementation of automation across the power system and for the generators. All new plants now have sophisticated operational IT systems and the existing generation fleet is slowly upgrading to match. RE based electricity generation has gained prominence over the years. Several fiscal and policy measures have been introduced to promote RE. On an average, over 3000 MW of RE installed capacity has been added every year with major contribution from the wind and solar energy segments. Solar energy is gaining momentum through the union government's JNNSM and similar state level policies. Given the economics of coal and gas, fuel security issues and environmental concerns that are being faced, generation from RE is increasingly assuming a central role in the entire power system.

11.1.1.2 Transmission

The transmission sector in India is moving towards higher voltage levels of 1200 kV and is introducing a higher level of automation and grid intelligence. PGCIL has already installed PMUs for WAMS on a pilot basis in select regions and is now pursuing a plan to install PMUs nationwide. Significant technological advancements such as increasing the capacity of transmission corridors through the use of Static VAR compensation and re-conductoring of lines using HTLS wires are also being taken up. Power system operation is also under evaluation as a result of the disturbance in July 2012 and it is expected that policy reform will lead to more system control being given to the load dispatch centers and the phase out of the current UI mechanism designed to discourage DisComs and GenCos from deviating from published schedules. The UI mechanism is expected to be replaced by an ancillary services market, which would be managed by the power exchanges, thus further liberalizing power markets and providing greater transparency on costs and prices of services. Managing these systems will require real-time monitoring and control only possible with robust state-of-the-art information and communication systems.

11.1.1.3 Distribution

The electricity distribution sector in India is currently in the worst shape, plagued by high network and financial losses in almost all states. There is an urgent need to bring in new technologies and systems to arrest these leaks. R-APDRP introduced by the GoI has been aimed at reducing the network losses to 15%. Part-A of the program is aimed at creating IT Infrastructure and automation systems within utility operations, which until its introduction was largely missing in most of the distribution utilities in the country. Part B is aimed at strengthening the physical network. The R-APDRP is still under implementation and completion is expected during the 12th Five Year Plan. Once completely implemented, the program would provide a strong foundation for evolution to smart grids in the power distribution segment.

For the distribution sector, smart grids will mean the introduction of DR programs, managing the expected introduction of electric vehicles and integrating distributed energy resources in a way that can help the DisComs balance local supply and demand and reduce peak time consumption. Building to Grid (B2G) or development of "Green Buildings" which could be incentivized to manage their consumption and even distributed energy resources to match grids conditions will also play their part in helping DisComs to manage supply and demand. For realizing all these changes, AMI as well as reliable communication technology infrastructure is essential.

11.1.2 Present Situation [7–9]

India is the 3rd largest producer of electricity in the world. Indian power system is today one of the largest synchronous grids in the world with approximately 250 GW capacity, >3 million km^2 area covered and serving ~240 million consumers. It is largely dominated by government owned utilities (central and states—29 states and 7 union territories own majority of power utilities); private sector role is about 27% in generation, <1% in transmission and about 5% in distribution. Transmission Grid in India is one of the largest in the world, comprising ~1,03,000 ckms lines of 765 kV/400 kV and ~132,000 ckms lines of 220 kV capacity, with 1200 kV AC and 800 kV HVDC networks being under development (Fig. 11.1).

India operates with very high T&D losses—about 26.5% nationally (>40% in many states!). ~400 million + people have no access to power. Large parts of the country experiences power cuts for several hours every day—customers keep storage (invertors)/standby generation facilities. Power quality being poor, consumers require voltage stabilizers, UPS, inverters, etc. The world loses ~$89.3 billion, while India loses ~US$ 10–15 billion annually in power theft.

Over population in cities always create problems for the authorities such as electricity shortage, supply breakdowns, etc. As per the studies, approximately

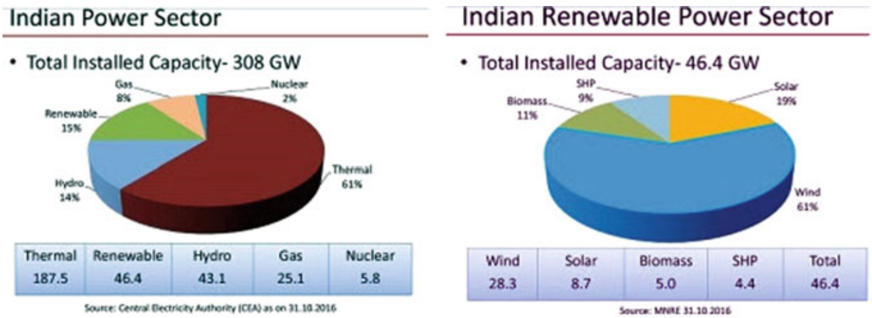


Fig. 11.1 Scenario of Indian power sector [8]

2.5 billion Indians have either unreliable or no access to electricity. By 2035, energy consumption will increase by 35% (World Energy Council 2010).

Not only availability of energy, but the challenge of converting from its existing form to useful form in the form of electricity needs to be properly tackled, if India wishes to turn her dream “power for all” in a reality. Majority of Indians still live in rural areas utilizing traditional ways for cooking and live below poverty line. Solar, wind and hydro power resources are available and applicable; however, suitable and efficient technologies are required to make such small installations to serve local striving due to insufficient and/or no power supply situations. While electrical power generation from renewables keep fluctuating due to various reasons including vibrant climatic situations, intermittent nature as well as difficulties to predict power production, the existing conventional electrical grid find it difficult to handle such variability due to unbalance and instability in electrical networks. Therefore, a new grid which shall resolve such renewable interconnection issues as well as ensure reliability, safety, security, profitability and public-private participation is required. Smart grid is emerging as a novel concept to provide insight to policies maker, grid operators and end users for sustainable energy efficiency.

11.1.3 Need Analysis [6, 10, 11]

The legacy conventional unidirectional power-only flowing electrical grid served well for over a century, now there are stringent requirements to upgrade, due to aging infrastructure as well as on account of upcoming challenges on technological, environmental and societal fronts. Therefore, not only Indian, but all national governments and relevant stakeholders have been planning substantial and significant developments for futuristic smart grids.

The urgency for Smart Grids in India emerges from the key challenges being currently faced. India operates the 3rd largest transmission and distribution network in the world, yet faces a number of challenges such as: inadequate access to electricity, supply shortfalls (peak and energy), huge network losses, poor quality and reliability and rampant, theft. The evolution towards Smart Grid would address these issues and transform the existing grid into a more efficient, safe, reliable and less constrained grid that would help provide access to electricity to all.

According NIST, the following are anticipated benefits and requirements of smart grids:

(i) Improving power reliability and quality.
(ii) Optimizing facility utilization and averting construction of back-up (peak load) power plants.
(iii) Enhancing capacity and efficiency of existing electric power networks.
(iv) Improving resilience to disruption.
(v) Enabling predictive maintenance and self-healing responses to system disturbances.

Smart Grid Drivers

(i) Increase in electricity demand and supply shortfall: India's increasing electricity demand especially during peak hours continues to outpace India's power supply. So, managing growth and ensuring supply is a major driver.
(ii) Loss reduction: In India, the AT&C losses are around 32% of installed generating capacity. Smart grid can make a substantial contribution in reducing these losses.
(iii) Increase in unit cost of electricity: With the increase in unit cost of electricity, there is a need for utilities to replace and renew aging transmission and distribution infrastructure with a pressure of using the assets wisely.
(iv) Managing human element: Human errors and deliberate errors can be lowered by using smart instruments like smart meters.
(v) Reliability: The smart grid can improve outage management performance by responding faster to repair equipment before it fails unexpectedly.
(vi) Efficiency: The smart grid can improve load factors and reduce system losses.
(vii) Renewable energy integration: In order to integrate renewable energy projects into the grid.
(viii) Grid improvement: Electricity demand in India is growing much faster than the transmission system in tremendous strain. The smart grid will improve the grid's resilience and robustness.
(ix) Technological advances: The advances in computing and telecommunications during the last half century have affected almost every facet of life. One reason the smart grid is taken seriously because advance computing and telecommunications made it possible.

11.2 Urbanization, Electricity and Human Settlement [1, 4, 12, 13]

Fistola and La Rocca [12] have outlined interesting relationship of technology and human settlement. The authors have stated that technology represents a basic element in the process of building up the urban artifact. Today the term "technology" is used to refer to ICT tools available. City and technology have very close relationship, since the first human action could have been made to resist to natural events or produce a human settlement. Technology has to be considered like a basic and fundamental factor inside the evolution process of the human beings, which can extend human senses in order to have a best perception of the environment and to develop capabilities to understand natural events, to carry on scientific development and to build common space for more people. Today, technology has a new acceleration, which can separate it from the human evolution process. The smart city has to consider the adoption of the ICT inside its process of development and not the addition of the technological equipment (like sensors) to the physical system of the city.

Joshi et al. [13] have described "smart city" as a futuristic approach to alleviate obstacles triggered by ever-increasing population and fast urbanization, to benefit the governments as well as the citizens. Smart cities are an endeavor to make cities more efficient, sustainable and livable by delivery of vital elements like quality of life and socio-economic development, etc. In other words, a smart city is a city that can monitor, integrate and control various functionalities of all critical infrastructures and can help in optimizing the resources maintaining security issues as well. The authors have identified six significant pillars for developing the framework as: Social, Management, Economic, Legal, Technology and Sustainability (SMELTS) to indicate how these factors can make the smart city initiative a successful project.

Bansal et al. [4] have mentioned that urbanization propelled by economic reforms is putting cities under perpetual pressure of population concentration and energy intensive growth model. The cities are often confronted with a multitude of key problems like high urban densities, traffic congestion, energy inadequacy, unplanned development and lack of basic services. Due to high land values, migrants often have no choice but to settle in shantytowns and slums, where they lack access to decent housing and sanitation, health care and education; thus adding to urban poverty. Urbanization is also contributing significantly to climate change as 20 largest cities consume 80% of the world's energy and urban areas generate 80% of greenhouse gas emissions worldwide. The challenges of rapid urbanization are to deal with the social, economic and environment development through more effective and comprehensive land administration functions, supported by efficient per capita infrastructure supply, resolving issues such as climate change, disaster management, insecurity, energy scarcity, environmental pollution, and extreme poverty. Urbanization must be able to support urban planning to achieve sustainable development in order to meet the growing energy and housing demands, reliable public transportation systems and be able to meet essential urban services without putting pressure on resources. Therefore, it needs to support innovative urban planning policies and strategies beyond traditional urban planning paradigms. Urbanization on the positive side provides an unparalleled urban planning opportunity to pre-address social and environmental problems, including reduction of greenhouse gas emissions combined with the retrofitting and upgrading of facilities and networks in existing urban centers, as well as smart urban planning of cities can provide better education, healthcare and high-quality energy services more efficiently and with less emissions because of their advantages of scale, proximity and lower geographic footprints. Thus “Smart Urbanization” is the key to safer cities of tomorrow. Building cities sustainably using smart growth principles, compact development planning form, using eco-city concepts, concept of low carbon electricity ecosystem etc., provides an opportunity to avoid future sources of greenhouse emissions, while developing more livable and efficient urban centers. It could also alleviate population pressure on natural habitats and biodiversity thus reducing the risks to natural disasters.

Bansal et al. [4] have mentioned that electricity is one the major energy consuming sectors and need to be stratified for smart urbanization. To make electricity efficient, larger-scale use of smart grids and superconductors are needed for transmission and distribution of electricity in dense urban settings. This would reduce their overall carbon footprints. Smart, information-rich energy network that uses superconductors for enhanced electricity transmission capacity and allows transportation needs to be met by multiple approaches not reliant on private vehicles. Widespread adoption of such technologies will make it easier to manage the unfolding urbanization, and could have much positive impact on energy use and consumption.

Adil and Ko [1] have suggested that centralized approaches to energy production, delivery and consumption constituted the original framework for provision of modern energy services. With the invention of high voltage AC power in late 19th century, electricity could to be transmitted over large distances through electric cables. Mass production, delivery and consumption of energy were expanded, stretched across the country through one nation-wide grid, designed as if to convey electricity perpetually to the energy-hungry masses of residential, commercial and industrial consumers. In addition, increasing resource conflicts tied to fossil fuels, depletion of the fossil fuel reserves, and anthropogenic climate change offer ample reasons for designing an alternate energy system that enables weaning off of carbon-intensive fossil fuels in meeting the world’s current and future energy needs. The alternate approach is decentralized; it is predicated on recognition of the finiteness of fossil fuels and their carbon-intensive character, deteriorating energy infrastructure and growing demand for energy. DES suggests a paradigm shift in the way energy is produced, delivered and consumed. DES conceived on the basis of RET offer a clean and inherently resilient approach towards reaching sustainable development goals. There are four major advantages of such DES over centralized energy systems: (i) the ability to offer low to zero-carbon emissions, (ii) offset capital-intensive investments for network upgrades, (iii) impart local energy independence and network security, and (iv) motivate social capital and cohesion.

As RET becomes more affordable and penetrate the energy markets, cities become the place for celebrating these benefits of DES.

11.3 The Smart Grid [9, 10]

A smart grid is an electrical grid with automation, communication and IT systems that can monitor power flows from points of generation to points of consumption (sometimes even down to the appliances level) and control the power flow or curtail the load to match generation on real-time basis. It involves two-way communication among the generating units, the control centers of distribution utilities and the consumers. The smart grid enables increased, predictability and control of generation and demand through consumer involvement, thus bringing flexibility in both generation and consumption, enabling the utility to better integrate intermittent renewable generation and reducing costs of peak power. A smart grid is cost-effective, responsive, and engineered for reliability of operations.

Interesting comparison of basic distinctive features of conventional and smart grid can be referred in Table 11.1. It could be observed from this comparative analysis that unlike conventional unidirectional electricity-only flowing conventional grid, smart grid is high speed, more accurate-efficient and customer-oriented bidirectional electricity + information flowing grid, which has potential to serve need based customized requirements of variety of customers and with useful intelligent features.

Murthy Balijepalli et al. [9] have described smart grid as a concept for transforming an electric power grid by using advanced communications, automated controls and other forms of information technology. It integrates new innovative tools and technologies from generation, transmission and distribution all the way to consumer appliances and equipment. This concept, or vision, integrates energy infrastructure, processes, devices, information and markets into a coordinated and collaborative process that allows energy to be generated, distributed and consumed more effectively and efficiently, with focus on sustainable options for customers. Smart grid enables devices at all levels within the grid (from utility to customer) to

Table 11.1 Comparison: conventional grid versus smart grid [10]

Conventional grid	Smart grid
Electromechanical	Digital
One way communication	Two way communication
Centralized generation	Distributed generation
Few sensors	Sensors through out
Manual monitoring	Self monitoring
Manual restoration	Self healing
Failures and blackouts	Adaptive and islanding
Limited control	Pervasive control
Few customer choices	Many customer choices

independently sense, anticipate and respond to real-time conditions by accessing, sharing and acting on real-time information.

Referring to IEEE P2030, Bhatt et al. [10] have described smart grid as power, communications, and information technologies for an improved electric power infrastructure serving loads while providing for an ongoing evolution of end-use applications. IEEEP2030 also defines Smart Grid as "System of Systems" (SoS) as the smart grid is a complex system made up of interrelated systems.

As mentioned in Bhatt et al. [10], SG facilitates for active participation of consumers with timely access and control to their energy usage. Consumers can bid their energy resources at the electric market. SG supports real-time power quality monitoring and active diagnostics to respond power quality deficiencies and reduces loss to customers due to insufficient quality of power. SG possesses the capability to anticipate and respond to system disturbances by continuous self-assessment to take corrective action. Constantly changing customer choices-behavior, increased integration of renewables, varieties of DR programs, etc. all are likely to increase the fluctuations in the ratio of produced and consumed power. Hence, utilities must make strong efforts to deal with the increasing volatility and vibrancy in classification, affordability, feasibility and final choices of power production, demand, distribution and consumption. Important features, such as Real Time Pricing (RTP), require intensive monitoring of the consumers' power consumption patterns along with close real-time asset monitoring and timely provision of control actions. This necessitates data prioritization and delay-responsiveness using communication links with sufficient reliability, data rates and latency.

Futuristic conceptual architectural diagram of Fig. 11.2 provides interesting illustration of how a smart city would evolve with smart grid. It could be observed from the diagram that the smart grid provides level playing field to different types of

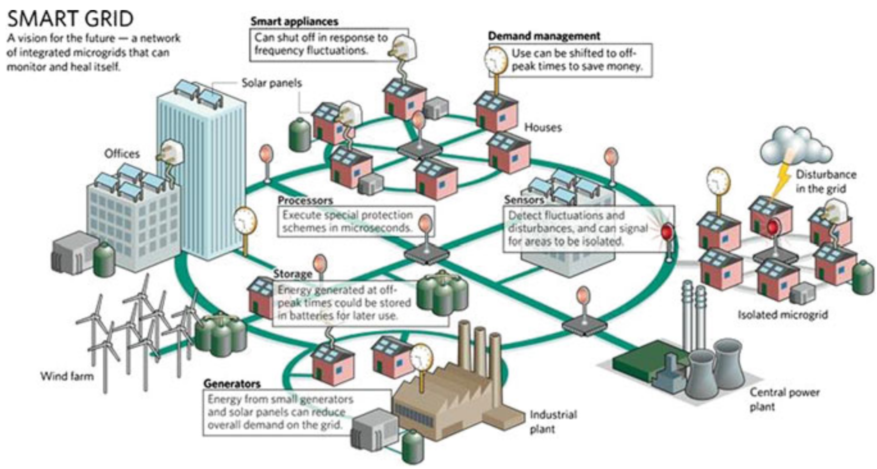


Fig. 11.2 Futuristic conceptual architectural diagram of smart city with smart grid [10]

energy sources as well as different types of prosumers, as in this novel setup, a consumer would also be a producer of electricity as well.

Figure 11.3 presents the SG architecture with associated systems and sub-systems. Overall SG architecture could be split into three major systems—smart infrastructure system, smart management system and smart protection system.

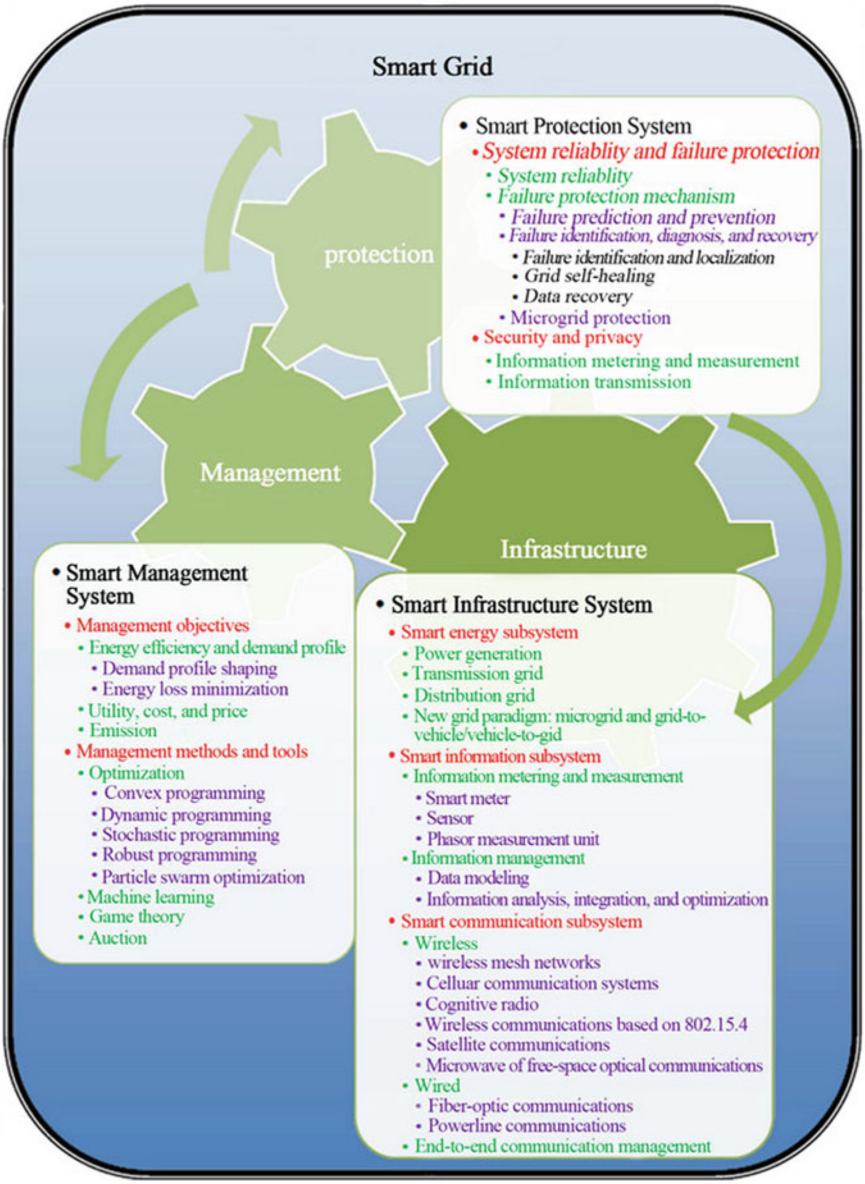


Fig. 11.3 Technical smart grid architecture with associated systems and sub-systems [10]

(a) *Smart infrastructure system* is the energy, information, and communication infrastructure underlying of the SG that supports (i) advanced electricity generation, delivery, and consumption, (ii) advanced information metering, monitoring, and management and (iii) advanced communication technologies. The smart infrastructure system has been further split into three subsystems: smart energy subsystem, smart information subsystem, and smart communication subsystem.
(b) *Smart management system* is the subsystem in SG that provides advanced management and control services. The smart management system has also been split further into two subsystems: management objectives, and management methods and tools.
(c) *Smart protection system* is the subsystem in SG that provides advanced grid reliability analysis, failure protection, and security and privacy protection services. The smart protection system has also been split further into two subsystems: system reliability and failure protection; and security and privacy.

11.3.1 Key Characteristics and Benefits [9, 11]

Key Characteristics:

(i) *Superior citizen involvement in e-Governance*:
Involves consumers by engaging them as active prosumer (producer + consumer) participants in the electricity market
Provides timely information and control options to consumers
Real time monitoring, automated outage management and faster restoration enables consumers to enjoy improved reliability
In-house displays, IoT based equipments, programmable control thermostats, portals and energy information tools like mobile apps enable consumers to track and manage their energy usage and identify opportunities to reduce and conserve electricity

(ii) *Improved power quality*:
Provides high quality of power and reduces the occurrence of distortions of power supply
Respond to local and system-wide inputs and have much more information about broader system problems

(iii) *Enable demand response*:
Dynamic pricing mechanisms incentivize consumers to alter their usage during different times of day based on pricing signals, enabling them to optimize their electricity bills through better energy management
Extends within home, so that consumer appliances, devices, etc. can be controlled remotely allowing for demand response

(iv) *Market empowerment*:
Provides greater transparency and availability of energy market information
Enables more efficient, automated management of market parameters
Provides level playing opportunities to new market products

(v) *Enhanced automation*:
Incorporate extensive measurements, rapid communication, centralized advanced diagnostics, and feedback control that quickly return the system to a stable state after interruptions or disturbances

(vi) *Clean and green*:
The energy conservation and improvements in end-use efficiency enabled by the smart grid reduce half of the emissions
Deploy and integrate distributed resources and generation including renewable resources
Facilitates distributed generation, especially the roof top solar generation, by allowing movement and measurement of energy in both directions

(vii) *Self-healing and resilient*:
Performs real time self-assessment to detect, analyze and respond to sub-normal grid conditions
Detects and addresses emerging problems on the system before they affect service

(viii) *Asset optimization and operational efficiency*:
Enables better asset utilization from generation to the consumer end points

(ix) *Integration of advance and low carbon technologies*:
Enables 'Plug and Play" scalable and interoperable capabilities
Permits higher transmission and distribution system penetration of renewable generation, distributed generation and energy storage
Integrates "smart" appliances (IoT based) and consumer devices like hybrid cars, electric vehicles, etc.

Benefits:

Benefits extended by smart grid to its various stakeholders have been included in Table 11.2. It could be observed that smart grid provides win-win situation for all the stakeholders without many tradeoffs. Overall financial implications could be reduced by generation of renewable energy by consumers and thereby reaching the final break-even point easily.

11.3.2 Smart Grid in India [14–19]

Indian power sector is expanding at a fast pace. India has a power sector characterized by deficient generation and high distribution losses. The first power exchange of India was introduced in June 2008. Smart grid activity has been reported in some distribution pockets mostly by private players. Many utilities in

Table 11.2 Benefits of smart grid [11]

Stakeholders	Benefits
Residential and small commercial consumers	(i) Improved system reliability (ii) Individual control over energy used and monthly bills (iii) Customers are transformed from passive ratepayers to active, engaged participants in electricity markets (iv) A more reliable grid will limit the risk of outages
Large industrial and commercial customers	(i) A smart grid will provide additional benefits from more detailed information and better reliability (ii) A smart grid will allow large customers to integrate their production, shortage and efficiency investments easily into wholesale market operations
State governments	(i) State governments can benefit from higher reliability and lower duration of outages (ii) Greater information and control over distribution system will also allow grid operators to assist with emergency situations, such as fires and storms, by turning off power selectively or by restoring power faster and more efficiently (iii) State governments are also consumers of electricity and can take advantage of consumer-related benefits of smart grids (iv) Environmental benefits
Utility grid operators	(i) Grid operators will benefit from direct cost reductions, enhanced system reliability, and higher customer satisfaction (ii) More efficient deployment of field staff as a result of better information on grid conditions (iii) Improvement in efficiency of billing, customer connections, and many other utility processes (iv) Reductions in working capital needs and bad debt expenses (v) Reduction in theft and energy losses (vi) Improved and more efficient customer service, more efficient planning and maintenance of the system, and more efficient use of back office resources

power sector have now smart grid activity with high priority in their research and development agenda.

The efforts for the development and deployment of smart grids in India are presently being carried out through India Smart Grid Task Force (ISGTF) and India Smart Grid Forum (ISGF) under the aegis of Ministry of Power (MoP). 14 smart grid pilot projects have been carried out by different state utilities.

11.3.2.1 Government Initiatives [11, 14–16]

(a) *Smart Cities Mission* [14]

Smart Cities Mission is an urban renewal and retrofitting program by the Government of India with a mission to develop 100 smart cities all over the country making them citizen friendly and sustainable. Ministry of Urban Development is responsible for implementing the mission in collaboration with the state governments of the respective cities. The government of India has a vision of developing 100 smart cities as satellite towns of larger cities and by modernizing the existing mid-sized cities. Smart cities are projected to be equipped with basic infrastructure to offer good quality of life through smart solutions. Assured water and power supply, sanitation and solid waste management, efficient urban mobility and public transport, robust IT connectivity, e-Governance and citizen participation along with safety-security of its citizens are some of the likely attributes of these smart cities.

Smart Cities Mission of the Government is a bold, new initiative. It is meant to set examples that can be replicated both within and outside the Smart City, catalyzing the creation of similar Smart Cities in various regions and parts of the country. The core infrastructure elements in a smart city would include:

(i) adequate water supply
(ii) assured electricity supply
(iii) sanitation, including solid waste management
(iv) efficient urban mobility and public transport
(v) affordable housing, especially for the poor
(vi) robust IT connectivity and digitalization
(vii) good governance, especially e-Governance and citizen participation
(viii) sustainable environment
(ix) safety and security of citizens, particularly women, children and the elderly
(x) health and education

Solar PV and Smart Grid serve as essential subsystems of any smart city in form of "Reliable Energy Backbone" to supply continuous power and seamless connectivity for all smart applications conceived under a smart city.

(b) *National Smart Grid Mission (NSGM)* [15]

Government has approved the National Smart Grid Mission (NSGM), an institutional mechanism for planning, monitoring and implementation of policies and programs related to Smart Grid activities. Major activities envisaged under NSGM are development of smart grid, development of micro grids, citizen engagements, training and capacity building, etc. NSGM entails implementation of a smart electrical grid based on state-of-the art technology in the fields of automation, communication and IT systems to monitor and control power flows from points of generation to points of consumption.

A smart Grid Vision and Roadmap for India was approved by the Ministry of Power in August 2013 which also envisaged the launch of National Smart Grid Mission (NSGM) having its own resources, authority, functional and financial authority to plan and monitor implementation of the policies and programmes prescribed in the roadmap.

(c) *India Smart Grid Task Force (ISGTF)* [11]

The Government of India formed the India Smart Grid Task Force in 2010 as an inter-ministerial group and will serve as the government focal point. It is a body composed of officials from different government departments and is primarily meant for understanding and advocating policies in smart grid technologies.
Major functions of the ISGTF are:

(i) To ensure awareness, coordination, and integration of diverse activities related to smart grid technologies
(ii) To promote practices and services for R&D of smart grids
(iii) To coordinate and integrate other relevant intergovernmental activities
(iv) To collaborate on an interoperability framework
(v) To review and validate recommendations from the ISGF

Corresponding to NSGM, each of the states also has a State Level Mission which is chaired by the Power Secretary of the state. The administrative/operation and maintenance expenses in this regard have been borne by respective states. NSGM provides support for training and capacity building to State Level Project Monitoring Units (SLPMUs) for smart grid activities.

(d) *India Smart Grid Forum (ISGF)* [11]

The Government of India also formulated the India Smart Grid Forum in 2010 as a non-profit, voluntary consortium of public and private stakeholders with the prime objective of accelerating development of smart grid technologies in the Indian power sector. The ISGF has roles and responsibilities complementary to the ISGTF.

The goal of the forum is to help the Indian power sector to deploy Smart Grid technologies in an efficient, cost-effective, innovative and scalable manner by bringing together all the key stakeholders and enabling technologies.

The India Smart Grid Forum will coordinate and cooperate with relevant global and Indian bodies to leverage global experience and standards where ever available or helpful, and will highlight any gaps in the same from an Indian perspective.

India Smart Grid Forum (ISGF) is a public-private partnership initiative of the Ministry of Power (MoP), Government of India for accelerated development and deployment of smart grid technologies in the Indian power sector.

11.3.2.2 DRUM, R-APDRP and Smart Grid Pilot Projects in India [11, 16–20]

(a) Distribution Reform, Upgrades and Management (DRUM) [11]

The Ministry of Power, Government of India, and the U.S. Agency for International Development (USAID)—India jointly designed the Distribution Reform, Upgrades and Management (DRUM) Project with the purpose of demonstrating "the best commercial and technological practices to improve the quality and reliability of 'last mile' power distribution in selected urban and rural distribution circles in the country." The project is in synch with the Indian Government's policy on power sector reforms, the Electricity Act of 2003, and the Re-Structured Accelerated Power Development and Reforms Program (R-APDRP) scheme.

The overall programmatic goal of the DRUM Project is to demonstrate commercially viable electricity distribution systems that provide reliable power of sufficient quality to consumers and to establish a commercial framework and a replicable methodology adopted by India's financial institutions for providing non-recourse financing of DRUM activities and programs.

(b) *Restructured Accelerated Power Development and Reforms Programme (R-APDRP)* [11, 17]

Ministry of Power, Govt. of India, as a part of Reforms in the Power Sector, has launched the RAPDRP in the XI Five year Plan. The focused objectives of the program have been on the actual demonstrable performance in terms of AT&C loss reduction, establishment of the reliable and automated sustainable systems for collection of base line data, adoption of information technology in the areas of electricity accounting, customer care and strengthening of distribution network of state power utilities. To achieve these objectives, it is proposed to strengthen and upgrade distribution network and adopt Information Technology systems and services. Various IT systems are planned to be implemented in the distribution companies across the nation under first phase of the programme. The basic infrastructure is being created under RAPDRP/IPDS in large towns, over which the smart grid development can be superimposed. IT implementation and SCADA being carried out will be leveraged for smart grid.

R-APDRP is one of the largest IT initiatives by electric utilities anywhere in the world—in one integrated project, all state owned distribution utilities in India are building IT Infrastructure. The Govt. of India has proposed to continue R-APDRP during the XI Plan with revised terms and conditions as a Central Sector Scheme.

Proposed Coverage and Scheme

R-APDRP has been proposed to cover urban areas—towns and cities with population of more than 30,000 (10,000 in case of special category states). In addition, in certain high-load density rural areas with significant loads, works of separation of agricultural feeders from domestic and industrial ones, and of High Voltage Distribution System (11 kV) will also be taken up.

Projects under the scheme shall be taken up in Two Parts. Part-A shall include the projects for establishment of baseline data and IT applications for energy accounting/auditing and IT based consumer service centers. Part-B shall include regular distribution strengthening projects. The activities to be covered under each part are as follows:

(c) *Smart grid pilot projects in India* [18–20]
Ministry of Power (MoP) injunction with India Smart Grid Task Force had shortlisted 14 smart grid pilot projects and one smart city R&D platform at under mentioned geographical locations: (Ref. Fig. 11.4)

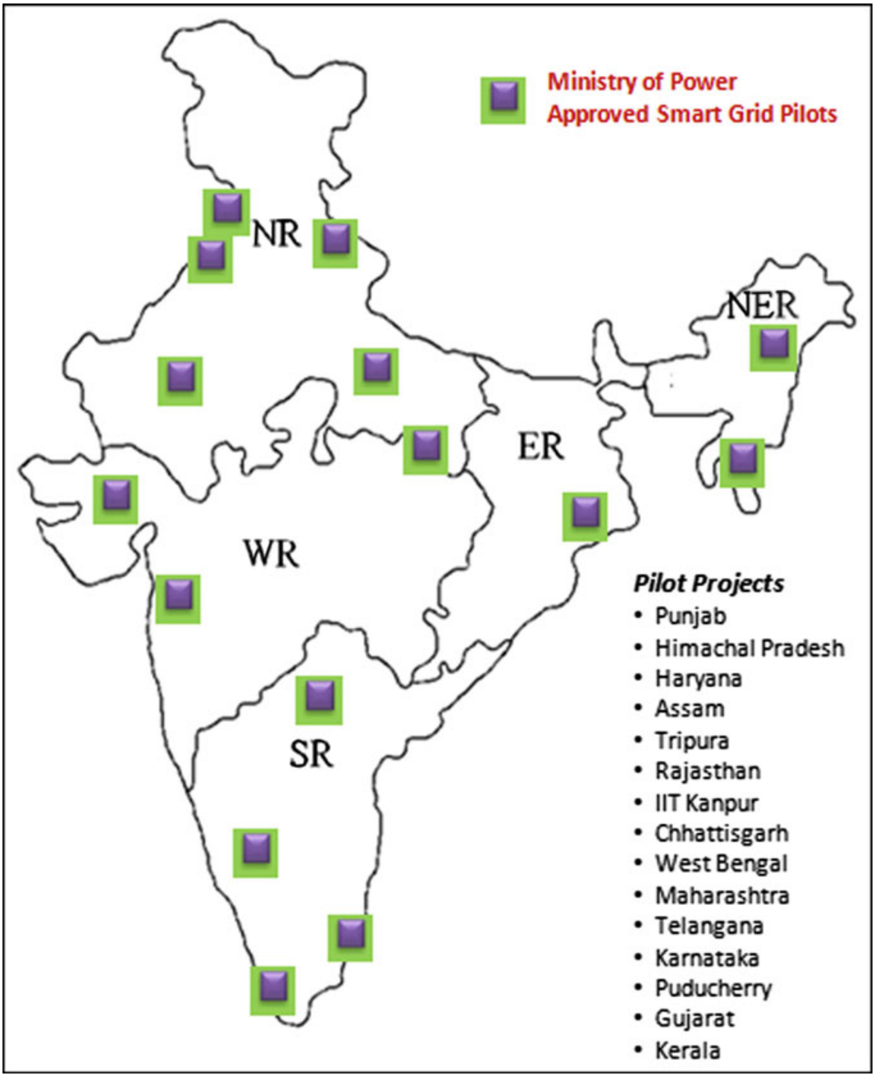


Fig. 11.4 Approved smart grid pilot projects in India [18–20]

(i) APDCL, Assam
(ii) CESC, Mysore
(iii) CSPDCL, Chhattisgarh
(iv) HPSEB, Himachal Pradesh
(v) JVVNL, Rajasthan
(vi) KSEB, Kerala
(vii) MSEDCL, Maharashtra
(viii) PED, Pondicherry
(ix) PSPCL, Punjab
(x) TSECL, Tripura
(xi) TSSPDCL, Telangana
(xii) UHBVN, Haryana
(xiii) UGVCL, Gujarat
(xiv) WBSEDCL, West Bengal
(xv) IIT Kanpur

Most of these projects have been part funded by MoP (50% project cost as grant from GoI) with combined costs of approximately about US$ 80 million. Most of these projects have been either executed or on the verge of completion with active involvement/participation of 20,000 or more citizens.

11.3.3 Smart Grid in Gujarat [20–22]

With duly implemented IT systems under ‘E-Urja’ program to manage their business functions, Gujarat DisComs have been leading among all utilities across the nation in terms of reduction of losses and IT systems implementation. To utilize the opportunity provided by Govt. of India under R-APDRP scheme, Gujarat DisComs have been further strengthening their distribution network and IT systems and integrating them with existing ‘E-Urja’ systems Fig. 11.5.

11.3.3.1 Methodology: UGVCL’s Approach [23, 24]

Incorporated in 2003, as a part of power sector reforms pursuant to the unbundling of erstwhile Gujarat Electricity Board (GEB), Uttar Gujarat Vij Company Limited (UGVCL) commenced its commercial operations in 2005, pursuant to notifications of the Government of Gujarat as an independent distribution licensee engaged in distribution and retail supply of electricity. As shown in Fig. 11.6, northern districts Banaskantha, Patan, Mehsana, Sabarkantha and central districts of Ahmedabad and Gandhinagar are covered by UGVCL electrical supply.

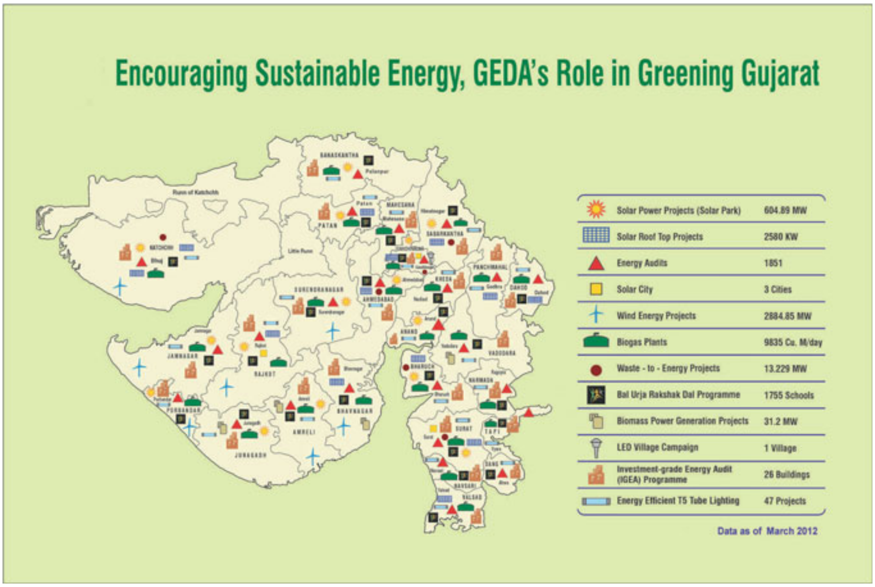


Fig. 11.5 Renewable energy map of Gujarat, India [22]

11.3.4 Case Study: UGVCL's Smart Grid Pilot Project at Naroda, Ahmedabad [25–27]

UGVCL's smart grid pilot project is located at Naroda of Sabarmati circle in Ahmedabad city, Gujarat, India. The pilot project covers approximately 20,524 customers of industrial, commercial and residential type and accounting for input energy of around 1700 MU. The functionalities of Peak load management, Outage Management, Power Quality Management are being planned by implementing Automated Metering Infrastructure (AMI). Some additional functionality like load forecasting, asset management and integration of renewables have also been underway. The approved project cost is around Rs. 82.70 Crore, out of which GoI is funding Rs. 41.35 Crore. Powergrid is approved consultant for the project.

Benefits Envisaged

(i) Peak load management/DSM
(ii) Reduction in AT&C losses
(iii) Savings in remote connect/disconnect and peak power purchase cost by reduction of peak load
(iv) Reduction in transformer failure rate

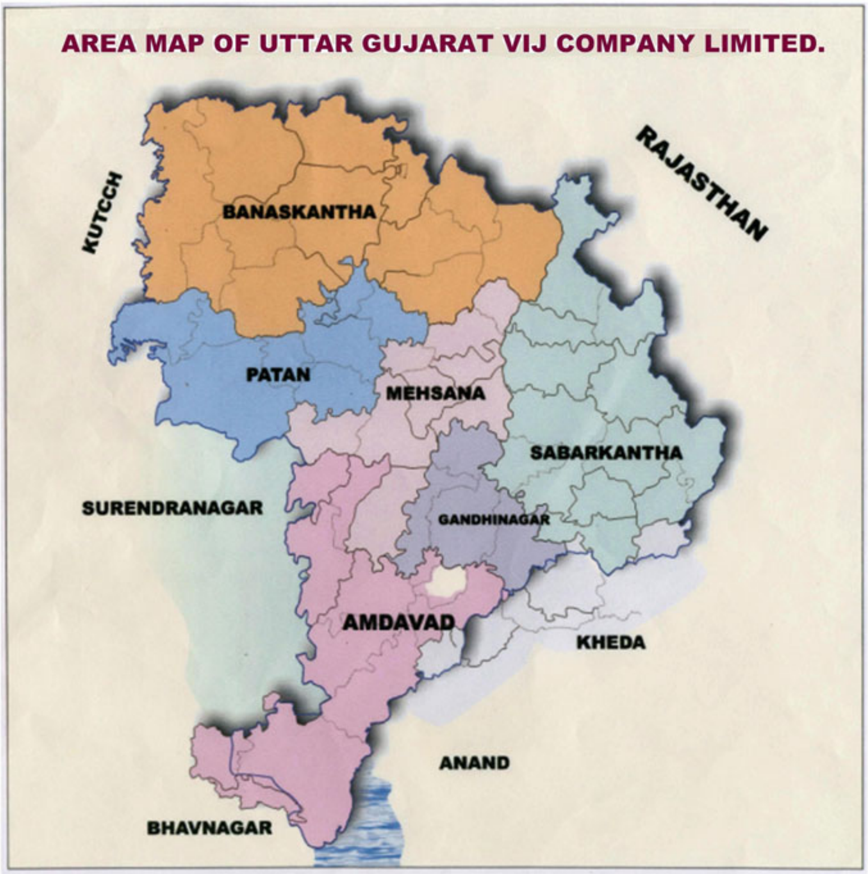


Fig. 11.6 Power area map of UGVCL, Gujarat state, India [24]

(v) Reduction in number of outages
(vi) Reduction in cost of meter reading, cost of payment collection, etc.

In Figs. 11.7 and 11.8, transit and hybrid maps of the UGVCL's smart grid pilot project have been shown. The pilot project site is in the heart of the Ahmedabad city and well connected by road and train transports. The project site is also quite near to river Sabarmati and domestic as well as international terminals of Ahmedabad airport. It could also be observed that the variety in types of consumers offers good opportunity for trail based pilot run of this novel technological-humanitarian experiment.

Fig. 11.7 Transit map of UGVCL's smart grid pilot project, Naroda, Ahmedabad city, Gujarat state, India [26]

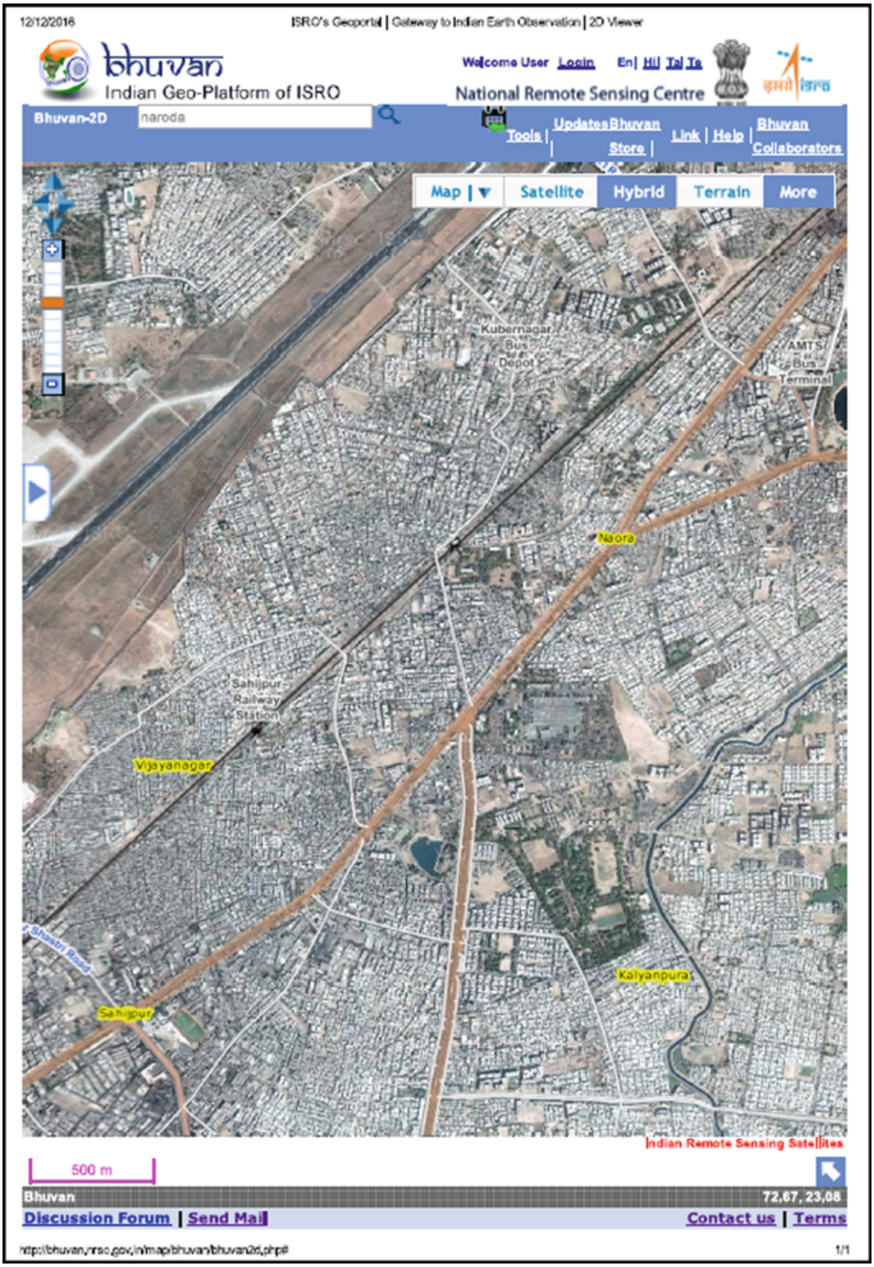


Fig. 11.8 Hybrid map of UGVCL's smart grid pilot project, Naroda, Ahmedabad city, Gujarat, India [27]

11.4 e-Democracy and Citizens' Participation

11.4.1 Internet Based e-Tools [23, 28]

11.4.1.1 UGVCL Consumer Support Website [28]

(a) Consumer support services
In addition to official website http://www.ugvcl.com, UGVCL has launched a distinct website http://ugvcl.in for providing consumer support.
This new secured customer support website is designed and maintained by Tata Consultancy Services (TCS) Limited since year 2010. All the new updates like billing rates, updated contact information, tenders, online bill payment, online complaint booking-follow-up, etc. have been availed through this website. Snapshot of registration/login page of this new customer support has been shown in Fig. 11.9. Snapshot shown in Fig. 11.10 has been displaying zone-wise UGVCL offices with their addresses nearby registered consumer address with toll-free 24 * 7 helpline number.

(b) *Complaint related services* [23, 28]
Snapshot of online complaint booking screen has been shown in Fig. 11.11 along with facility to track status and follow-up past unresolved complaints, if any. Snapshot of online energy theft reporting screen has been shown in

Fig. 11.9 UGVCL consumer support website—registration and login [28]

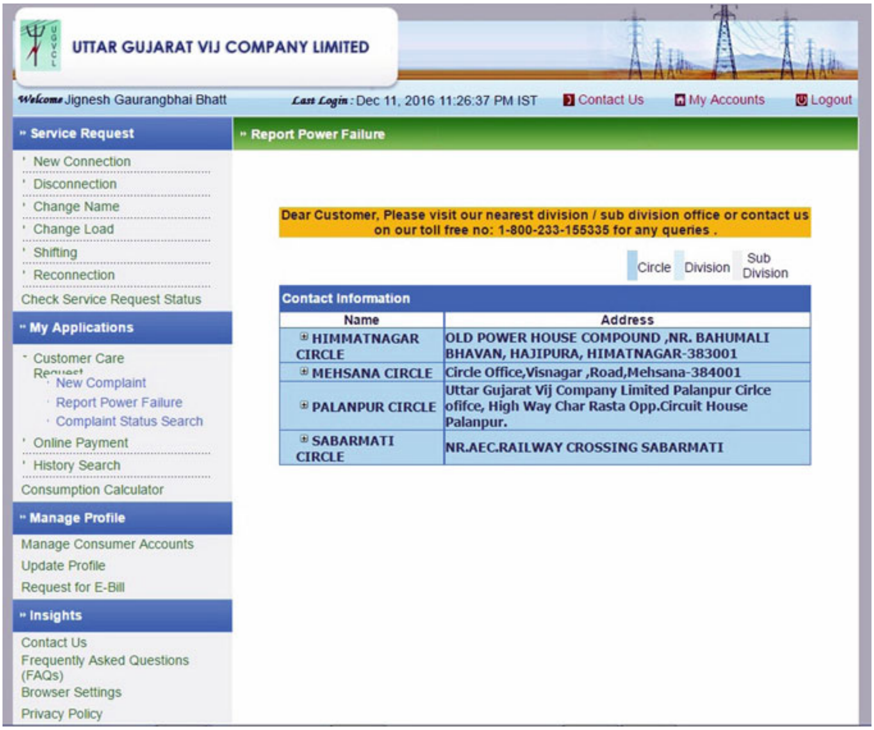


Fig. 11.10 UGVCL consumer support website—contact information display for different circles covered [28]

Fig. 11.12, wherein consumers can report unlawful stealing of electricity to prevent unauthorized unbilled usage.

(c) *Bill related services* [23]

Online facilities to estimate the billing amount have been provided by UGVCL to its consumers, which is available as “Bill Calculator” in old website and “Consumption Calculator” in new website as displayed in snapshots shown in Figs. 11.13 and 11.14 respectively.

(d) Online bill payment facility

Online bill payment facility has been provided in new website by UGVCL to its customers as displayed in snapshot shown in Fig. 11.15. UGVCL has availed common payment gateways to help customers for e-payments.

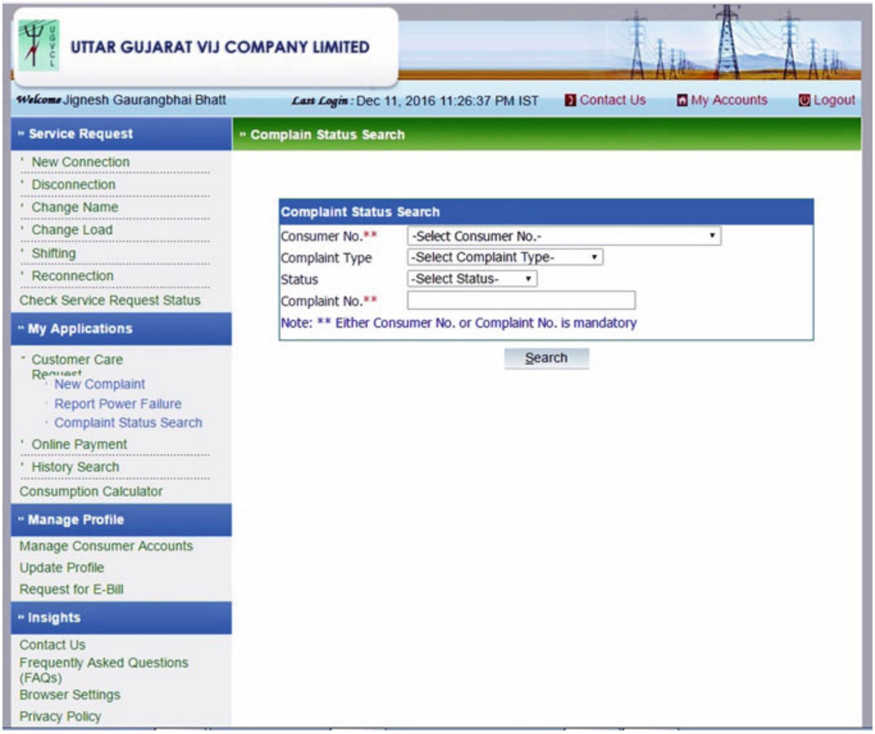


Fig. 11.11 UGVCL consumer support website—complaint section [28]

11.4.2 Mobile Based M-Tools [24, 29, 30]

11.4.2.1 UGVCL App [29]

In recent times, internet access and payment transactions are more preferred via mobile as compared to desktop and laptop computers due to obvious reasons including convenience, etc. UGVCL has also availed all major services for customer supports using android based mobile app which could be downloaded from Google Play Store. Snapshots of UGVCL mobile app have been included in Figs. 11.16 and 11.17a, b, which enables the basic facilities of bill payment and complaint to the consumers.

11.4.2.2 Solar PV Potential App by GERMI [24]

GERMI has also developed an app for estimation of production of electricity generation by solar PV for given geographic location. This app could be

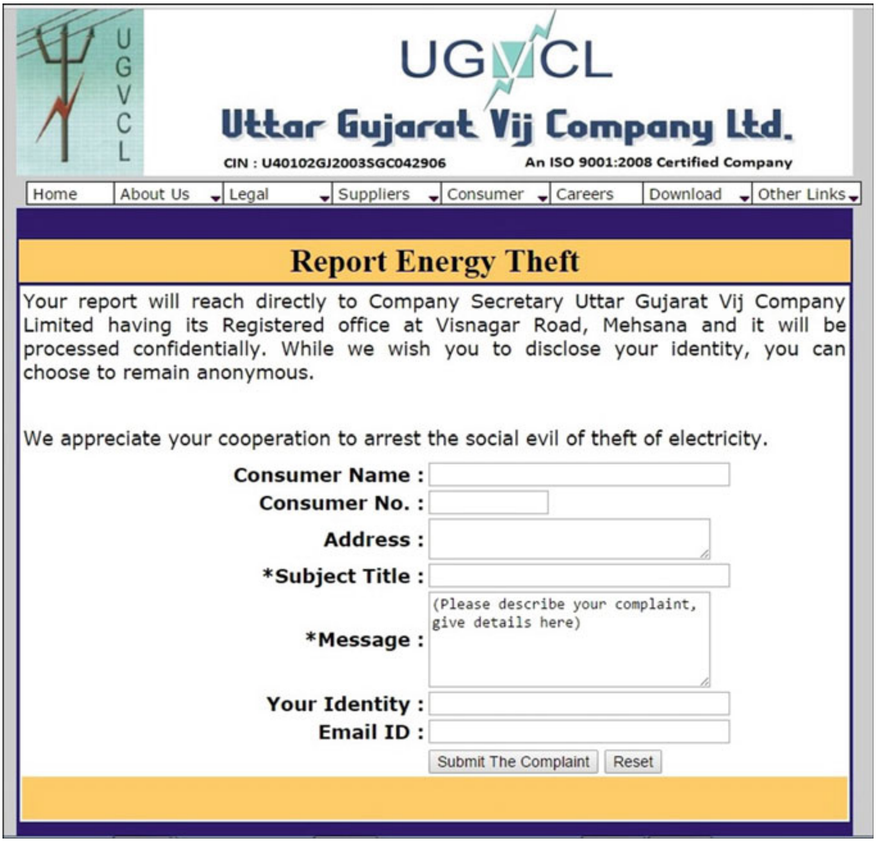


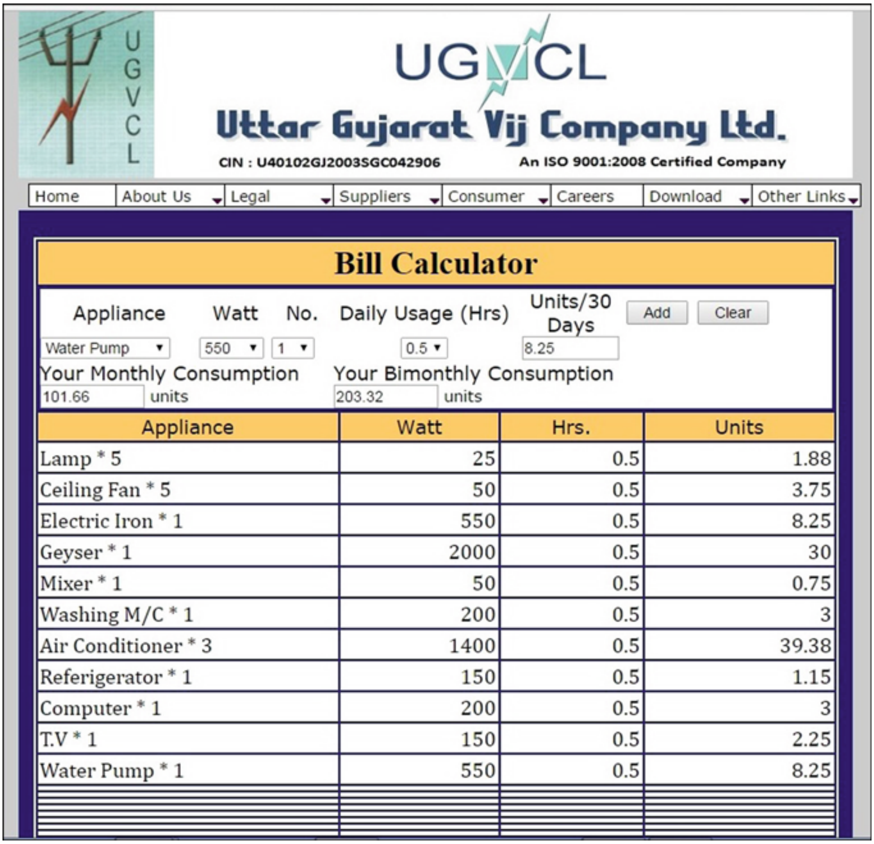
Fig. 11.12 UGVCL consumer support website—reporting energy theft [23]

downloaded from Google Play Store. Snapshots of GERMI mobile app have been included in Figs. 11.18, 11.19a, b and 11.20a, b.

11.5 Challenges [7, 11, 31, 32]

(i) "*To provide energy storage solutions, which would allow excess power to be used in less favorable weather conditions*" has been identified as a major challenge by Pillai and Forum [7].

(ii) "*To generate and sustain high rate of growth in power sector*" to support economic growth and employment generation.
Estimated demand in India has been estimated to rise up to 900 GW by 2032, almost quadrupling the existing capacity with per capita consumption is one-fourth of the world average at present. 79 million households are yet



Appliance	Watt	Hrs.	Units
Lamp * 5	25	0.5	1.88
Ceiling Fan * 5	50	0.5	3.75
Electric Iron * 1	550	0.5	8.25
Geyser * 1	2000	0.5	30
Mixer * 1	50	0.5	0.75
Washing M/C * 1	200	0.5	3
Air Conditioner * 3	1400	0.5	39.38
Referigerator * 1	150	0.5	1.15
Computer * 1	200	0.5	3
T.V * 1	150	0.5	2.25
Water Pump * 1	550	0.5	8.25

Fig. 11.13 UGVCL consumer support website—bill calculator [23]

to be electrified as per 2011 census. To address the above needs, the Indian power system should grow ~8–10% per annum for next several decades. Managing such a rapidly growing power system of this much gigantic size is a challenge in itself.

(iii) "*To integrate renewables and EVs along with maintaining grid stability*" India is pursuing one of world's largest grid connected renewable energy programs, sustainable integration of such renewable resources to such large fast growing grid would be a difficult task. India launched the National Electric Mobility Mission with a target of 6 million EVs by 2020; successful rollout of EVs along with maintenance of grid stability shall be quite complex problem.

(iv) "*Reduction of T&D losses*" continues to be top priority of both Government and utilities.

Fig. 11.14 UGVCL consumer support website—consumption calculator [28]

(v) "*Evolution of policies and regulations*"
As no defined standards and guidelines exist for the regulation of smart grid initiatives in India, and presently available policy and regulatory frameworks have been typically designed to deal with the existing networks and utilities, while moving towards smart grid, new policy and regulatory frameworks must evolve to encourage incentives for investment. The new framework should be such that it should match the interests of the consumers with the interests of the utilities and suppliers, ensuring that the societal goals are achieved at the lowest cost to the consumers.

(vi) "*Cost minimization*"
Cost is clearly one of the biggest hurdles in implementing smart grids and to make them a good sensible business case. Replacement of non-compatible equipments is expensive and difficult as it would result in pre-mature retirement of such equipments. High initial costs of implementing smart grids should be justified in terms of higher equipment availability, better quality of supply and greater use of green energy. Further, careful societal cost-benefit analysis, beyond return of investment calculations, would also be needed for such justification.

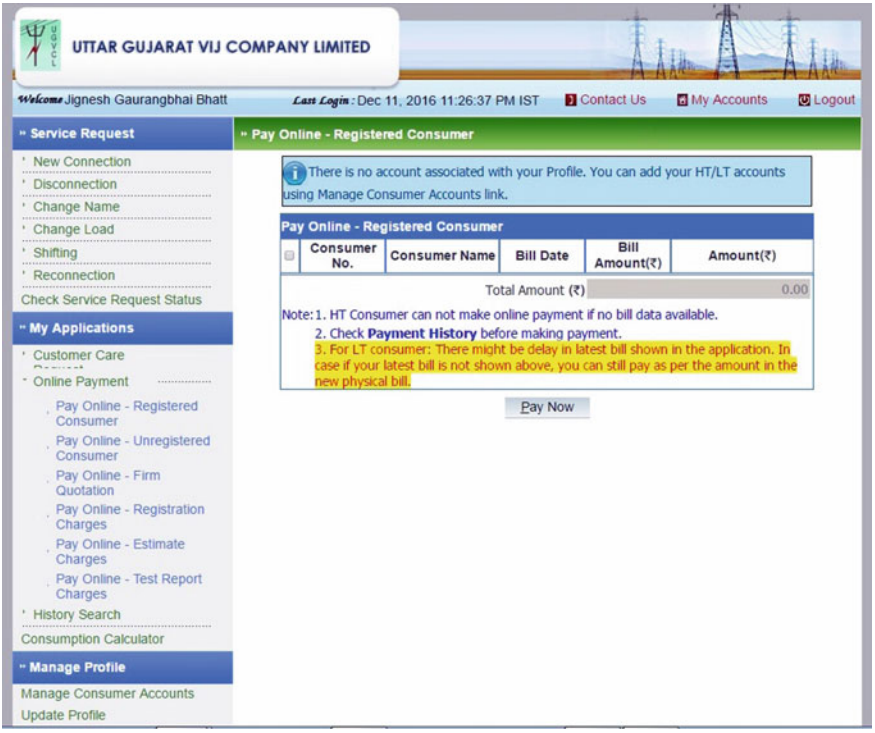


Fig. 11.15 UGVCL consumer support website—online bill payment section [28]

(vii) "*Lack of awareness*"

Sufficient spreading of awareness shall be required among prosumers regarding operational and economic aspects while ushering into this new low carbon environment. Similar and relevant awareness should also be spread into all the stakeholders including utilities, government, etc.

(viii) "*Cyber security and data privacy*"

Keeping the smart grid network secured from malicious hacking attacks shall be one of the most critical challenges. As the consumption data can provide sufficient insight regarding citizens' behavior and choices, invasion of privacy and security of such data shall be a serious concern. Resolution of issues relevant to such matters should be in transparent manner minimizing any negative impact on a customer's perception. Fan et al. [32] have identified various such challenges that must be addressed in order to have fully robust, secure and functional smart grid network.

(ix) "*Last mile connectivity*"

Last mile connectivity is the major challenge in smart grid applications and these field trials to determine the most appropriate communication solutions. Especially, in remote-rural areas of villages and difficult to reach or

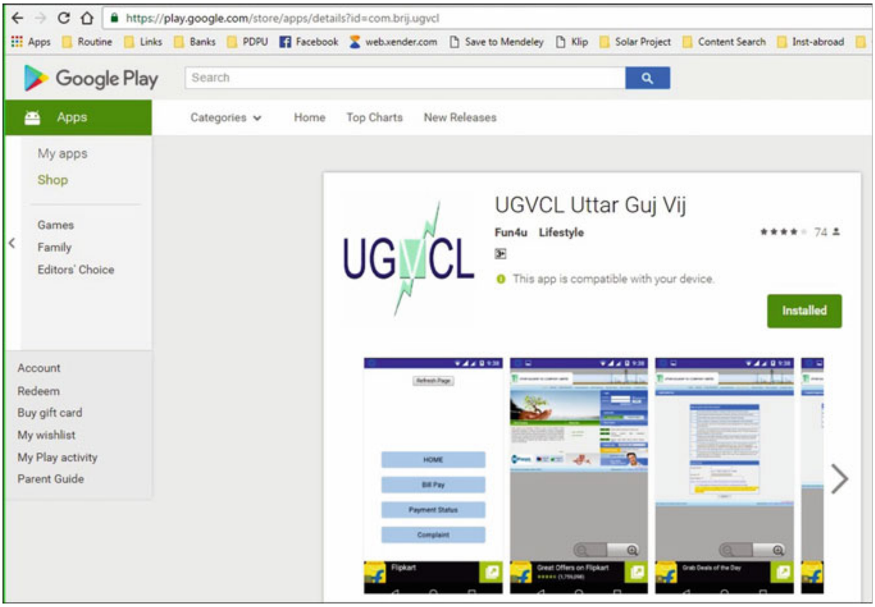


Fig. 11.16 UGVCL android app at Google play store [29]

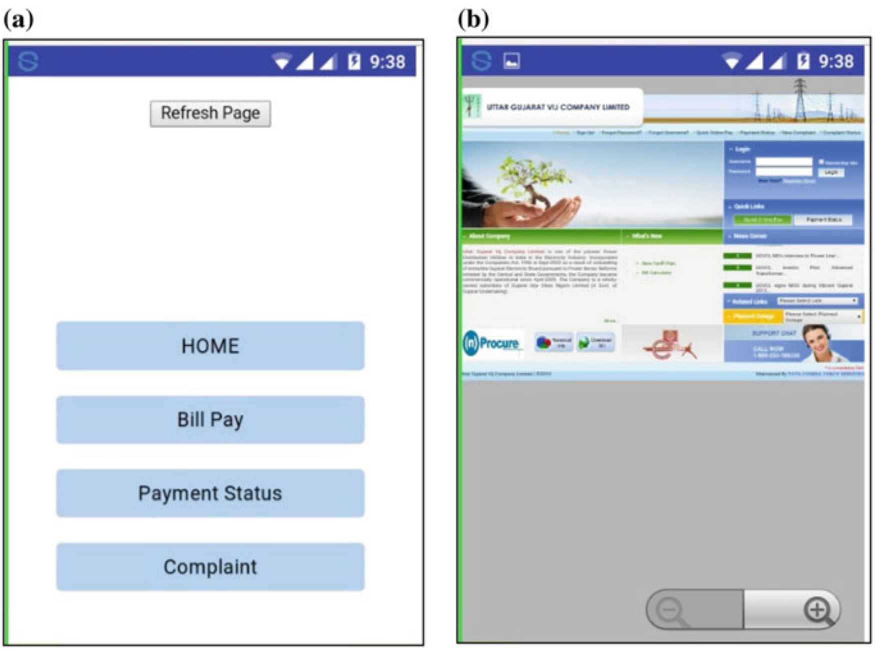


Fig. 11.17 **a**, **b** UGVCL android app snapshots [29]

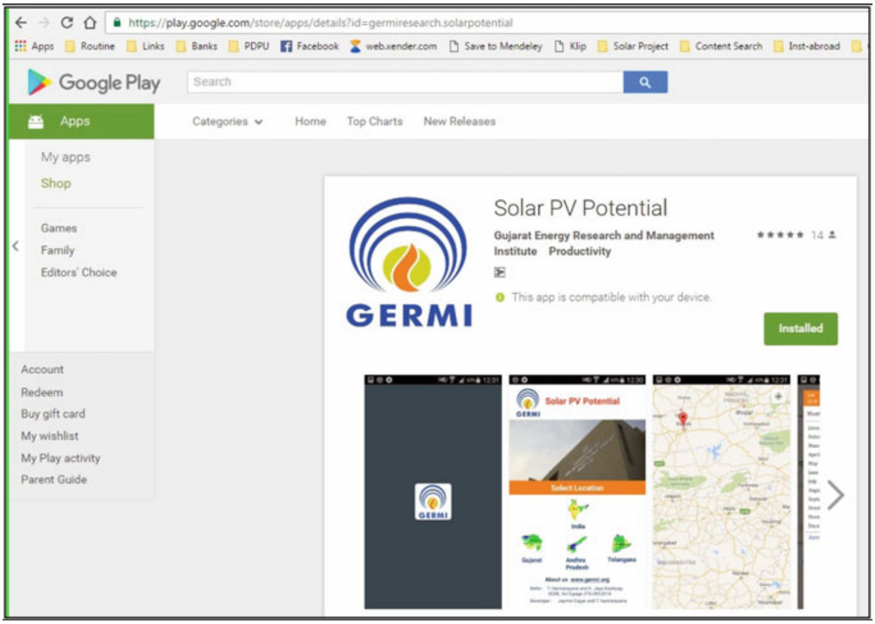


Fig. 11.18 GERMI's Solar PV Potential android app at Google play store [30]

inaccessible locations of cities in India, providing reliable and seamless connectivity for data is still remains a dream to realize!!

In (Babel), the authors have identified and summarized similar challenges especially in Indian context, which could be learnt in Fig. 11.21.

Barriers identified in [11] are similar to challenges identified in [31] in Fig. 11.21 and summarized in Table 11.3.

11.6 Vision, Way Forward and Roadmap [7, 11]

Vision

To transform the Indian power sector into a secure, adaptive, sustainable and digitally enabled ecosystem that provides reliable and quality energy for all with active participation of stakeholders.

Way forward

(i) Regulatory changes to support dynamic pricing
(ii) Time of Use pricing mechanism to be worked upon and finalized
(iii) Replacement of ageing assets

(a) (b)

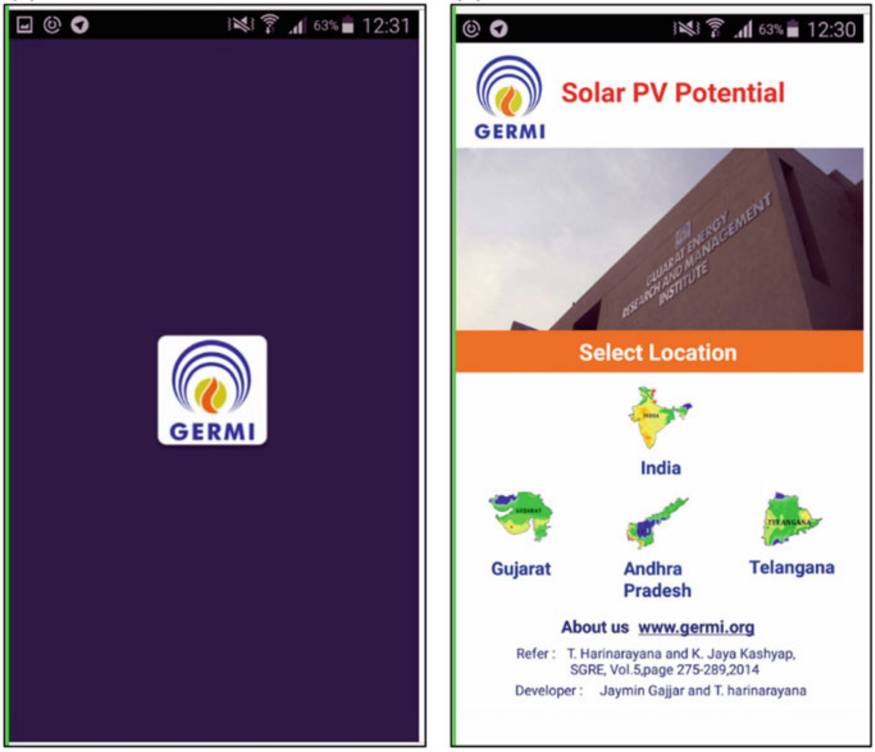


Fig. 11.19 **a**, **b** GERMI's Solar PV potential app snapshots [30]

(iv) To encourage consumer engagement both in communicating effectively with the consumer and in delivering high quality implementation
(v) To develop a communication infrastructure supporting Smart Grid activities at sub-transmission and distribution level required
(vi) Challenges around data privacy, cyber security and inter-operability need to be dealt by creating and adopting appropriate standards in the respective fields
(vii) Assessing and prioritization of benefits from AMI (smart meter) through use-cases.

Roadmap
Distribution

(i) Appropriate policies and programs to provide access for electricity for all, Electrification of 100% households by 2017, 24 $\times$ 7 quality supply on demand to all citizens by 2027

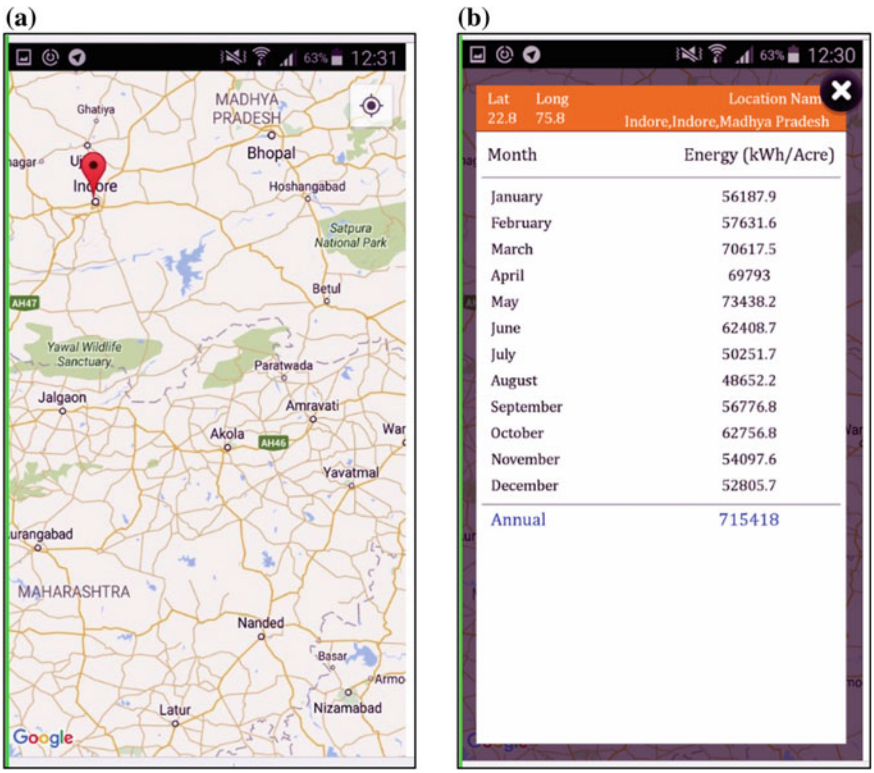


Fig. 11.20 GERMI's Solar PV Potential app: **a** geographical location and **b** solar power generation potential [30]

(ii) Based on outcome of smart grid pilots, full rollout of smart grids in pilot project areas by 2017; in major urban areas by 2022 and nationwide by 2027

(iii) Completion of existing complementary or building block projects such as R-APDRP. Planning for integration of such systems into future smart grid deployments

(iv) AMI roll out for all customers in a phased manner based on size of connection, geography and utility business case. Starting with consumers with load >20 KW by 2017, 3-phase connections by 2022 and all consumers by 2027. Development of innovative and sustainable financing/business models for smart meter roll outs

(v) Working with other stakeholders, building of National Optical Fiber Network by connecting all the 2,50,000 g Panchayats in the country by Optical Fiber Cable and including the telecom link at the nearest 33/11 kV substation to support smart grid in distribution by 2017

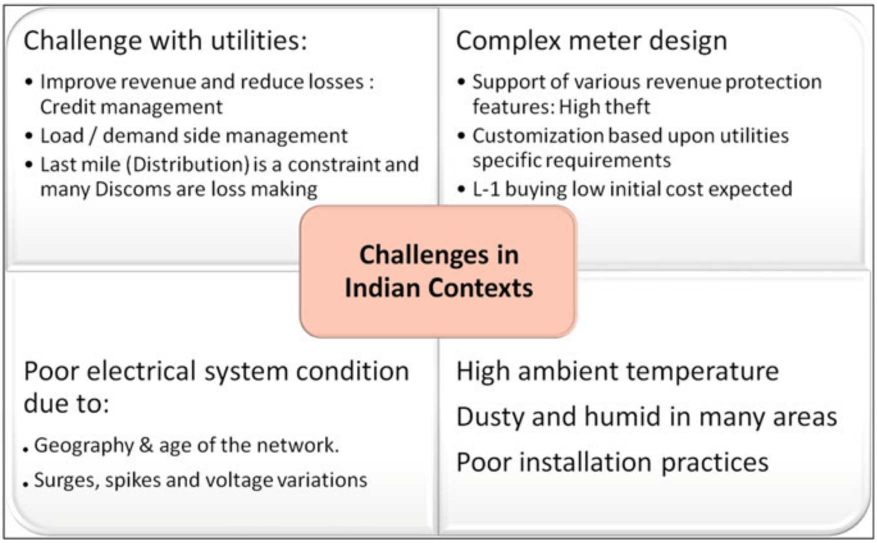


Fig. 11.21 Challenges in Indian Contexts [31]

Table 11.3 Barriers to implement smart grids in India [11]

Barriers	Details
Political and regulatory	In many cases utilities don't get business case for the smart grid as there are regulatory and policy barriers in place that either create reverse incentives or fail to create sufficient positive incentives for private sector investment
Technology maturity and delivery risk	Technologies have significant technology risks associated with them because agreed standards have not emerged. In addition, there are only a handful of examples of large scale implementation of more than 50,000 premises and therefore there continues to be significant delivery risks priced into the estimates
Business case	Where policy makers and utility executives are aware of the role that smart grids can play, they are often unable to make the business case for the smart grid investments
Lack of awareness	There is lack of awareness among stakeholders about role of smart grids in enabling a low-carbon future
Poor financial health of utilities	In India, debt burden utilities find it difficult to invest in smart grid initiatives
Skills and knowledge	In the longer term, a shortfall is expected in critical skills that will be required to architect and build smart grids
Cyber security	Digital communication networks and more granular and frequent information on consumption patterns raise concerns in some quarters of cyber in-security and potential for misuse of private data

(vi) Enabling programs and projects in distribution utilities to reduce AT&C losses. Below 15% by 2017, below 12% by 2022, and below 10% by 2027

(vii) Conversion of existing EHV sub stations in all urban areas and sub transmission and medium voltage substations in metro cities to advanced (such as) Gas Insulated Substations (GIS) in a phased manner through innovative financing models

(viii) Development of Microgrids, storage options, virtual power plants (VPP), vehicle to grid (V2G), solar to grid (PV2G), and building to grid (B2G) technologies in order to manage peak demand, optimally use installed capacity and eliminate load shedding and black-outs

(ix) Push for mandated roof top solar power generation for large establishments with connected load >20 kW

(x) EV charging facilities to be created in all parking lots, institutional buildings, apartment blocks etc.; and quick/fast charging facilities to be built in fuel stations and at strategic locations on highways

(xi) Microgrids in 1000 villages/industrial parks/commercial hubs by 2017 and 10,000 villages/industrial parks/commercial hubs by 2022. Islanding facility from main grids during peak hours to be availed

(xii) Optimally balancing different sources of generation through efficient scheduling and dispatch of distributed energy resources (including captive plants in the near term) with the goal of long term energy sustainability

(xiii) Improvement in power quality and quantum across the board

Transmission

(i) Development of a reliable, secure and resilient grid supported by a strong communication infrastructure that enables greater visibility and control of efficient power flow between all sources of production and consumption by 2027

(ii) Implementation of WAMS, using PMUs for the entire transmission system. Installation of a larger number of PMUs on the transmission network by 2017 or sooner, as guided by the results of initial deployments. Indigenization of WAMS technology and PMU development and development of custom made analytics for synchrophasor data by 2017

(iii) Setting up of Renewable Energy Monitoring Centers (REMCs) and Energy Storage Systems to facilitate grid integration of renewable generation

(iv) Installation of 50,000 km of optical fiber ground wire (OPGW) over transmission lines by the year 2017 to support implementation of smart grid technologies

(v) Enabling programs and projects in transmission utilities to reduce transmission losses to below 3.5% by 2017 and below 2.5% by 2022

(vi) Implement power system enhancements to facilitate evacuation and integration of 30 GW renewable capacity by 2017, 80 GW by 2022, and 130 GW by 2027, or as mutually agreed between MoP and MNRE

Policy, standards and regulations

(i) Formulation of effective customer outreach and communication programs
(ii) Development of state/utility specific strategic roadmap(s) for Smart Grid deployments. Required business process reengineering, change management and capacity building programs
(iii) Policies for grid-interconnection of consumer generation facilities (including renewable) where feasible. Policies for roof-top solar, net-metering/feed-in tariff as well as peaking power
(iv) Policies supporting improved tariffs such as dynamic tariffs, variable tariffs, etc., including demand response programs. Bulk consumers; extending to all 3-phase (or otherwise defined) consumers by 2017
(v) Policies for implementing energy efficiency in public infrastructure and EV charging facilities starting and Demand Response ready appliances by 2017.
(vi) Finalization of frameworks for cyber security assessment, audit and certification of utilities
(vii) Development of business models to create alternate revenue streams by leveraging the Smart Grid infrastructure to offer other services (security solutions, water metering, traffic solutions etc.) to municipalities, state governments and other agencies.
(viii) Build upon the results of smart grid pilot projects and recommend appropriate changes conducive to smart grid development in Acts/Plans/etc.
(ix) Development of Indian Smart Grid Standards. Active involvement of Indian experts in international SG development bodies

Other initiatives

(i) Tariff mechanisms, new energy products, energy options and programs to encourage participation of customers in the energy markets that make them "***prosumers***"—producers and consumers—by 2017
(ii) Create an effective information exchange platform that can be shared by all market participants, including prosumers, in real time which will lead to the development of new and enhanced energy markets.
(iii) Investment in research and development, training and capacity building programs for creation of adequate resource pools for developing and implementing smart grid technologies in India—can also become a global leader and exporter of smart grid knowhow, products and services

11.7 Technological Inputs

11.7.1 Hybrid Communication Technologies [32–35]

Fan et al. [32] have opined that optimization of energy consumption in future intelligent energy networks (or Smart Grids) will be based on grid-integrated near-real-time communications between various grid elements in generation, transmission, distribution and loads.

Wired networking technologies such as RS485, Modbus, PLCC, BACnet, LonWorks, EIB/KNX, etc. and wireless networking technologies such as ZigBee, Wi-Fi, WiMax, GSM, GPRS, 3G-4G, LTE, etc. have been utilized for development of communication and integration of various smart grid applications.

Wired networking technologies are popular due to their superior reliability, security and latency performances. However, frequent rewiring of existing facilities may be difficult and expensive, further it also affects the aesthetic of the building; hence in such cases power line and wireless networks have been preferred to enhance coverage and improve scalability. Bhatt [33] have suggested that wireless technologies are demonstrating their relative strength as compared to wired technologies on account of their salient features and obvious merits.

In Roy et al. [34], the authors could observe sufficient potential in pure wireless as well as hybrid technology solutions (combined of wired and wireless) to serve critical need based applications of smart grid and therefore, those of a smart city.

Overall, need based customizable, mixed or hybrid technology solutions which are effectively combining wired and/or wireless both type of technologies based on actual requirements could evolve the best and optimum solution(s) for given smart application(s).

Güngör et al. [35] have addressed critical issues on smart grid technologies primarily in terms of information and communication technology (ICT) issues and opportunities. Main objective of the authors is to provide a contemporary look at the current state of the art in smart grid communications as well as to discuss the still-open research issues in this field. The paper provides a better understanding of the technologies, potential advantages and research challenges of the smart grid to provoke future research interests.

11.7.2 IoT, HAN and BAS [2, 3, 5, 36−44]

As described by Arasteh et al. [3], an IoT prototype is subject to smart and self-configuring objects that are connected to each other through a global network infrastructure. IoT is mostly considered as real objects, broadly scattered, with low storage capability and processing capacity, with the target of improving reliability, performance and security of the smart city and its infrastructures. In the IoT context, devices can be integrated based on the geographic location and evaluated by using an analyzing system. An IoT infrastructure could be utilized for the monitoring of intended domains using sensor services for the collection of particular data. IoT is not only likely to affect the various aspects of the smart city citizens' life like health, security, and transportation, it could play an important role at the national level for making policy decisions in important aspects such as energy saving policies, pollution control, economic considerations, reliability enhancement, etc.

Al-Ali [2] have suggested that the concept of Smart Cities is becoming a reality as it evolves from conceptual models to developmental stages. Resilient, reliable, efficient and seamless energy and electrical power flow are essential parts to energize and power the services of smart cities such as smart hospitals, smart buildings, smart factories, smart traffic and transportations. All of these smart services are expected to run without interruptions by the use of smart energy and electrical power grids which are considered among the most important pillars for such cities. To keep the services of smart cities interconnected and in sync, the Internet of Things (IoT) and cloud computing are key in such transfers.

The World Wide Web (WWW) is evolving from a traditional host that contains text, images, audios and videos to a physical host that enables users to control physical objects. Home appliances, remote CCTV cameras and factory floors can be monitored and controlled using Internet of Things (IoT) using communication media. The physical web concept is emerging nowadays. An IoT communication network is utilized in energy generations and consumptions in residential areas.

The world is becoming an integrated global community through multiple technologies and numerous areas of applications and services. IoT concepts are leading to a world where real, digital and virtual things are converging to make our cities smarter and more intelligent. Nowadays, traditional web technologies are empowered by IoT to connect physical objects (things) such as home appliances and smart grid devices with a unique address for each thing. This has been made possible with the help of IPV6 protocol which has 2^{128} unique IP addresses compared to 2^{32} addresses used by IPV4. Using IPV6, billions of objects can be connected, monitored and controlled at the same time. In terms of communication networks, the consumption domain is divided into three different networks: Home Area Network (HAN), Business Area Network (BAN) and Industrial Area Network (IAN).

Many communication protocols are utilized in these networks, such as ZigBee, PLCC, Z-wave, Wi-Fi, WiMax, 3G/GSM and LET. Each renewable energy resource is considered as an object and it is assigned a unique IP address. Using bidirectional communication, it becomes possible to monitor each object as control is carried out via its unique IP address. Such IoT networks are scalable and more devices and appliances such as local batteries storage, home appliances, smart meters, etc. can also be included as objects to join the same network with functionalities of remote monitoring and control.

Shrihariprasath and Rathinasabapathy [36] have presented an effective implementation of an intelligent remote monitoring system for solar Photovoltaic (PV) Power Conditioning Unit (PCU) for using in a greenhouse environment. The proposed smart remote monitoring system is based on internet of things and its

GPRS based design could be installed to remotely monitor solar PV PCU in real time and to solve management problems, maintenance and shortens MTTR.

Perera et al. [37] presented and interesting survey of one hundred IoT smart solutions in the marketplace and examine them closely in order to identify the technologies used, functionalities, and applications. Based on the application domain, the authors have classified and discussed those solutions under have different categories such as (i) smart wearable; (ii) smart home; (iii) smart city; (iv) smart environment; and (v) smart enterprise. This survey is intended to serve as a guideline and a conceptual framework for future research in the IoT and to motivate and inspire further developments. It also provides a systematic exploration of existing research and suggests a number of potentially significant research directions.

Domingues et al. [38] have presented that a BAS consists of a system installed in buildings that controls and monitors building services responsible for heating, cooling, ventilation, air conditioning, lighting, shading, life safety, alarm security systems, and many more. A BAS aims at automating tasks in technologically-enabled environments, coordinating a number of electrical and mechanical devices interconnected in a distributed manner by means of underlying control networks. These systems may be deployed in industrial infrastructures such as factories, in enterprise buildings and malls, or even in the domestic domain. Building automation has been receiving greater attention due to its potential for reducing energy consumption and facilitating building operation, monitoring and maintenance, while improving occupants' satisfaction.

Bhatt and Verma [39] have presented simple, user-friendly, re-usable and customizable design and implementation of wired security system and wired building automation system. Indicating clear trend of legacy stand-alone security systems transforming into intelligent-computerized-network based building automation systems, the authors have developed web-based GUI for live run-time monitoring and control of a residential building as major outcome.

Bhatt and Verma [40] have presented the design of a three-layer BAS for a residential building using PC based controller. GUIs for live remote monitoring via CCTV camera, critical events alarm annunciation through SMS and distribution of audio-video entertainment using intranet/internet are some of the important features of the design.

In Patel et al. [41, 42] have presented an alternative design of Programmable Logic Controller (PLC) originally aimed at industrial safety and emergency shutdown-trip systems, however its present commercially available modern and cost-effective versions could also be used in BAS as well as HAN with suitable customizations.

Bhatt [43], Bhatt and Verma [39] have described that building automation system (BAS) is a data acquisition and control system that incorporates various functionalities provided by the control system of a building. In general, the BAS are also known by other names such as: energy management control systems (EMCS), building management systems (BMS), building energy management systems (BEMS), facility management systems (FMS) and so on. Modern BAS is a computerized, intelligent network of electronic devices, designed to monitor and control the lighting, internal climate and other systems in a building resulting in optimized energy usage, safety, security, information, communication and entertainment facilities. BAS maintains the internal climate of building within a specified range by regulating temperature and humidity regulates lighting based on parameters like occupancy, ambient light and timing schedule, monitors system performance and device failures and generates audio-visual-email and/or text notifications to building operation and maintenance (O&M) staff. The BAS reduces building energy consumption and, thereby, reduces O&M costs as compared to an uncontrolled building. A building controlled by a BAS is often referred to as an Intelligent Building. Home automation or domotics is possibly the system having the highest level of functional similarity to building automation. But the former has significantly different characteristics. While the BAS focuses on financial benefits, the domotics focuses on comfort and mental peace. Domotics are of comparatively quite smaller scale, with low costs of equipment as well as commissioning and maintenance.

Bhatt and Verma [39] have described that Home area network (HAN) is the network within the premises of a house or building enabling devices and loads to communicate with each other and dynamically respond to externally sent signals (i.e. price). This type of network, characterized by a low data rate requirement, provides the communication infrastructure behind the meter. As a result, smart grid applications are extended into the home premises and energy management systems (EMS) capabilities are enabled. Further benefits derived from the realization of such HANs are anticipated for customers, utilities and society as a whole. Overall, Energy savings and user satisfaction are two major design considerations for modern HAN systems. Interesting descriptions on useful developements of remote monitoring and control applications of solar PV could be found in Bhatt et al. [5].

Ejaz et al. [44] have presented that the drastic increase in urbanization over the past few years requires sustainable, efficient, and smart solutions for transportation, governance, environment, quality of life, and so on. The Internet of Things offers many sophisticated and ubiquitous applications for smart cities. The energy demand of IoT applications is increased, while IoT devices continue to grow in both numbers and requirements. Therefore, smart city solutions must have the ability to efficiently utilize energy and handle the associated challenges. Energy management is considered as a key paradigm for the realization of complex energy systems in smart cities. Along with a brief overview of energy management and challenges in smart cities, a unifying framework for energy-efficient optimization and scheduling of IoT-based smart cities has been presented in the article which is illustrated in Fig. 11.22.

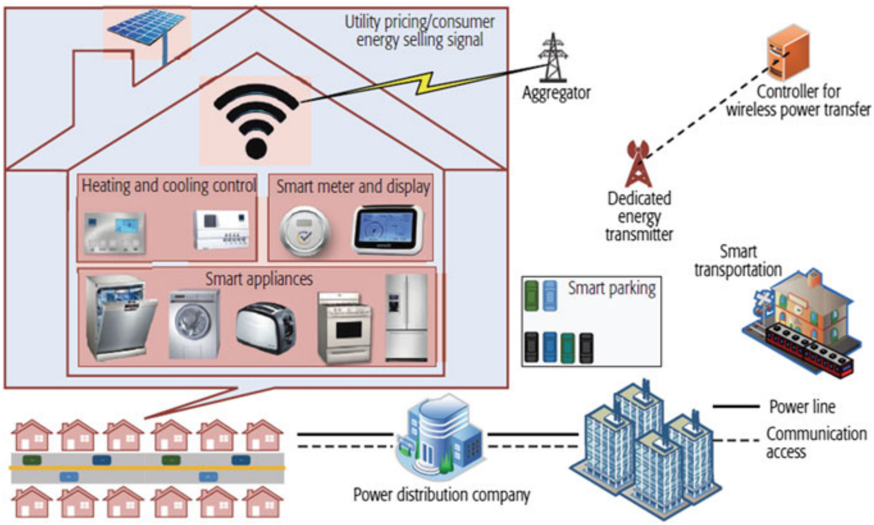


Fig. 11.22 IoT-based illustration of smart cities focused on smart homes [44]

11.8 Experiences and Lessons Learnt

Cities are prime movers of global economy and platforms for providing opportunities in employment, goods and services, commerce, culture and enhanced quality of convenient life with better services, health-education facilities, etc. They have some mega issues like poverty, poor health, social issues and environmental degradation. The cities are often confronted with a multitude of key problems like high urban densities, traffic congestion, energy inadequacy, lack of basic services, water-soil-air pollution, aging infrastructure and environmental impact on climate change coupled with poor urban governance.

Reliability of critical power infrastructures has been the area of major focus today, wherein smart grids are expected to play game changing role. As energy backbones of smart cities, smart grids are deployed with intelligence, automation, citizens' active participation. Smart grids have started attracting attention of global research community and demonstrating excellent growth potential.

Distributed energy sources and demand response programs contribute to environmental, economic and social aspects of urban sustainability; they are now viewed from different perspectives. Most of the available studies and literature on smart grid subject mainly takes only technocratic approach, while novel upcoming approaches have been now found based on their social impacts, including policy regulations, e-Democracy, etc.

11.9 Conclusions

Transformation from legacy conventional grid to smart grid is now necessity and reality by effective applications of ICT and e-Democracy. The role of smart grids as energy backbones of smart cities, involving high interactive participation of citizens in energy management, based on humanitarian and customer centric approach has been discussed. After presenting the historical perspectives and present situations of electrical power sector in India, interesting relationships of electricity, urbanization and human settlement have been presented. An interesting case study of one of the most successful Indian smart grid pilot project by UGVCL at Naroda, Ahmedabad, Gujarat, India has been included with brief details regarding citizen participation tools based on internet and mobile. Experiences, issues, challenges along with vision and future roadmap have been shared to mark the end of the chapter.

Rapidly rising urbanization has led to many critical issues like scarcity of electricity. Developing countries like India have been aggressively invest in both strengthening their existing legacy electricity grids and also by building smart grids and renewables.

Comprehensive study of renewables' socio-technical co-assessment, their responses and combined impacts upon urban planning and energy policies—have been indeed interesting domains of research. Transition to smart grids necessitates detailed investigation and comprehensive evaluation regarding co-evolution of renewables and social responses together in cities and further how they could be related to urban planning-policies and citizen-centric e-Governance.

Acknowledgements The authors thankfully acknowledges the support received with appreciations to all the faculty members, Management and office bearers of Gujarat Energy Research and Management Institute (GERMI), Gandhinagar—382 007, Gujarat, India, Pandit Deendayal Petroleum University (PDPU), Gandhinagar—382 007, Gujarat, India, and Dharmsinh Desai University (DDU), Nadiad—387 001, Gujarat, India for their kind cooperation, active support and timely help in development of this book chapter. Useful contributions and cooperation received from UGVCL, GEDA, Govt. of Gujarat, Govt. of India and all the cited sources of references are also hereby thankfully acknowledged.

The authors also take this opportunity to express their sincere thanks to Editor Prof. TM Vinod Kumar and his entire team including Springer staff for their valuable guidance, excellent cooperation and timely help extended.

References

1. Adil AM, Ko Y (2016) Socio−technical evolution of decentralized energy systems: a critical review and implications for urban planning and policy. Renew Sustain Energy Rev 57:1025−1037. doi:10.1016/j.rser.2015.12.079
2. Al-Ali AR (2016) Internet of things role in the renewable energy resources. Energy Procedia 100:34−38. doi:10.1016/j.egypro.2016.10.144

3. Arasteh H, Hosseinnezhad V, Loia V et al (2016) Iot-based smart cities: a survey. EEEIC 2016−Int conf environ electr eng. doi:10.1109/EEEIC.2016.7555867
4. Bansal N, Shrivastava V, Singh J (2015) Smart urbanization−key to sustainable cities. Real Corp 2015 2:551−560
5. Bhatt J, Jani O (2014) E−governance for photo voltaic powergrid: solar city Gandhinagar, Gujarat, India. In: E-governance of smart cities
6. ISGF (2013) India smart grid day. India Electr 2013:48
7. Pillai RK, Forum G (2015) Introduction to India smart grid forum, smart grid vision and roadmap for India. Smart Grid Projects and India Smart Grid Week 2015 Overview of Indian Power Sector Smart Grids−Challenges for India, pp 1−13
8. Urvish Dave (2016) Year in review for renewable energy sector across India−a new dawn in Renewable Energy! https://urvishdave.wordpress.com/2016/12/19/2016-year-in-review-for-renewable-energy-sector-across-india-a-new-dawn-in-renewable-energy/. Accessed 23 Dec 2016
9. Murthy Balijepalli VSK, Khaparde SA, Gupta RP, Pradeep Y (2010) SmartGrid initiatives and power market in India. IEEE PES Gen Meet PES 2010:1−7. doi:10.1109/PES.2010.5589947
10. Bhatt J, Shah V, Jani O (2014) An instrumentation engineer′s review on smart grid: critical applications and parameters. Renew Sustain Energy Rev 40:1217−1239
11. Smart Grid http://indianpowersector.com/wp-content/uploads/2013/04/Smart-Grid.pdf. Accessed on 09/01/2016
12. Fistola R, La Rocca RA (2014) New technologies for sustainable energy in the smart city: the WET theory. TeMA J L Use, Mobil Environ 7:29−42. doi:10.1007/s13398-014-0173-7.2
13. Joshi S, Saxena S, Godbole T, Shreya (2016) Developing smart cities: an integrated framework. Procedia Comput Sci 93:902−909. doi:10.1016/j.procs.2016.07.258
14. What is Smart City? http://smartcities.gov.in/writereaddata/What%20is%20Smart%20City.pdf. Accessed 12 Jan 2017
15. National Smart Grid Mission (NSGM). http://www.nsgm.gov.in/content/nsgm.php. Accessed 23 Dec 2016
16. India Smart Grid Forum (ISGF)−Smart City Project, UGVCL, Gujarat. http://www.indiasmartgrid.org/ProjectsDesc.php?id=56. Accessed 23 Dec 2016
17. Restructured Accelerated Power Development & Reforms Programme (R−APDRP). http://ipds.co.in/Forms/Know_More.aspx. Accessed 23 Dec 2016
18. Smart Grid Pilots in India. http://www.nsgm.gov.in/content/sg_pilots.php. Accessed 23 Dec 2016
19. Smart Grid Pilots−Snapshots. http://www.nsgm.gov.in/content/sg_snapshot.php. Accessed 23 Dec 2016
20. Updates on execution of Smart Grid Pilot Projects in India−IV. http://www.desismartgrid.com/2014/06/updates-execution-smart-grid-pilot-projects-india-iv. Accessed 23 Dec 2016
21. Gujarat Energy Development Authority (GEDA) website. http://geda.gujarat.gov.in/index.php. Accessed 12 Jan 2017
22. Renewable energy map of Gujarat. http://geda.gujarat.gov.in/state_renewable_energy_maps.php. Accessed on 12 Jan 2017
23. UGVCL website. http://www.ugvcl.com. Accessed 23 Dec 2016
24. Power area map of UGVCL. http://www.ugvcl.com/cprofile/pau.htm. Accessed 12 Jan 2017

25. Uttar Gujarat Vij Company Limited Smart Grid Pilot Project−PoC studies 23rd May 2016. http://www.ugvcl.com. Accessed 12 Jan 2017
26. Transit map of Naroda area, Ahmedabad city, Gujarat state, India. http://googlemap.com. Accessed 12 Jan 2017
27. Google map of Naroda area, Ahmedabad city, Gujarat state, India. http://googlemap.com. Accessed 12 Jan 2017
28. UGVCL Customer support website. http://www.ugvcl.in. Accessed 23 Dec 2016
29. UGVCL app in Google Play Store. https://play.google.com/store/apps/details?id=com.brij.ugvcl. Accessed 23 Dec 2016
30. Solar PV Potential app by GERMI in Google Play Store. https://play.google.com/store/apps/details?id=germiresearch.solarpotential. Accessed 23 Dec 2016
31. Babel BS, Smart metering : to help Indian utilities address the revenue challenge Ind′a's energy scenario, Accessed 02 Sept 2016
32. Fan Z, Kulkarni P, Gormus S et al (2013a) Smart grid communications: overview of research challenges, solutions, and standardization activities. IEEE Commun Surv Tutorials 15:21−38. doi:10.1109/SURV.2011.122211.00021
33. Bhatt J (2010) "Wireless networking technologies for automation in oil and gas sector". In: Yadav S (ed) Int Conf on Manag Pet Sect. Pandit Deendayal Petroleum University, Gandhinagar, India, p 25
34. Roy S, Jani O, Bhatt J (2013) A record note of workshop on smart meter and communication technology solutions. Gandhinagar, India
35. Güngör VC, Sahin D, Kocak T et al. (2011) Smart grid technologies: communication technologies and standards 7:529−539
36. Shrihariprasath B, Rathinasabapathy V (2016) A smart IoT system for monitoring solar PV power conditioning unit. In: IEEE WCTFTR 2016−Proc 2016 world conf futur trends res innov soc welf. doi:10.1109/STARTUP.2016.7583930
37. Perera C, Liu CH, Jayawardena S (2015) The emerging internet of things marketplace from an industrial perspective: a survey. IEEE Trans Emerg Top Comput 3:585−598. doi:10.1109/TETC.2015.2390034
38. Domingues P, Carreira P, Vieira R, Kastner W (2016) Building automation systems: concepts and technology review. Comput Stand Interfaces 45:1−12. doi:10.1016/j.csi.2015.11.005
39. Bhatt J, Verma H (2015) Design and development of wired building automation systems. Energy Build. doi:10.1016/j.enbuild.2015.02.054
40. Bhatt J, Verma H (2010) RS−485/MODBUS based intelligent building automation system using LabVIEW. In: 4th Int Conf Comput Appl Electr Eng Adv IIT Roorkee, Roorkee, India, p 5
41. Patel D, Bhatt J, Trivedi S (2015) Programmable logic controller performance enhancement by field programmable gate array based design. ISA Trans. doi:10.1016/j.isatra.2014.08.019
42. Patel D, Trivedi S, Bhatt J (2011) Design and implementation of field programmable gate array based programmable logic controller. In: Soni HB (ed) 2nd Int Conf Signals, System Autom, Universal Publishers, USA−G.H. Patel College of Engineering & Technology, Vallabh Vidyanagar, India, pp 332−336
43. Bhatt J (2013) Building automation system: Design and Development. Ind Autom 16:18
44. Ejaz W, Naeem M, Shahid A et al (2016) Efficient energy management for internet of things in smart cities efficient energy management for internet of things in smart cities