In the Framework of Project

SESEI Seconded European Standardisation Expert in India

Enabling Europe-India Cooperation on Standards

In Association with

IET The Institution of Engineering and Technology

Study Report on **Smart Energy**

"Smart Grids Smart Meters, LVDC and Microgrids"

cen CENELEC ETSI European Commission EFTA

TABLE OF CONTENTS

GLOSSARY OF ACRONYMS 4

1. FOREWORD 5

2. EXECUTIVE SUMMARY 6

3. BACKGROUND 7

4. INDIA POWER SCENARIO – SETTING THE CONTEXT 08

5. SMART ENERGY ECO-SYSTEM, MARKET DYNAMICS & POTENTIAL 10

i Smart Grid including Renewables Integration 10
(a) Transmission 10
(b) Distribution 10
(c) Renewable Integration 11
ii LVDC and Micro Grids 11
iii Smart Meters.. 12

6. POLICY INITIATIVES AND STANDARDIZATION 13

i. National Programmes in Smart Grids and Renewable Energy 13
ii Standards 15
(a) Smart Grid 15
(b) Communications and IoT 16
iii Standards Setting in India... 18
iv Cybersecurity.. 20
v Global Scenario... 20

7. OPPORTUNITIES AND CHALLENGES 23

i. Smart Grid including Renewables 23
ii. Transmission 23
iii. Distribution 25
iv. LVDC and Micro grids.. 26
v. Communication and Security 27

8. CONCLUSIONS AND RECOMMENDATIONS 31

GLOSSARY OF ACRONYMS

AMI	- Advanced metering infrastructure
C-DAC	- Centre for Development of Advanced Computing, India, www.cdac.in/
C-DOT	- Centre for Development of Telematics, http://www.cdot.in/
CEA	- Central Electricity Authority of India, www.cea.nic.in/
CERC	- Central Electricity Regulatory Commission, www.cercind.gov.in/
DA	- Distribution Automation
DISCOM	- Distribution Companies
DOT	- Department of Telecommunications, http://www.dot.gov.in/
DST	- The Department of Science & Technology, http://www.dst.gov.in/
EV	- Electric Vehicles
FAN	- Field Area Network
FDI	- Foreign Direct Investment
GOI	- Government of India
HAN	- Home Area Network
IED	- Intelligent Electronic Devices
ISGF	- India Smart Grid Forum, http://www.indiasmartgrid.org/
ISGTF	- India Smart Grid Task Force
ITS	- Intelligent Transport Systems
LPWAN	- Low Power Wide Area Network
MeitY	- Ministry of Electronics & Information Technology, http://meity.gov.in/
MoP	- Ministry of Power, https://powermin.nic.in/
NIST	- National Institute of Standards and Technologies, USA, https://www.nist.gov/
NLDC	- National Load Dispatch Centre
NSGM	- National Smart Grid Mission, http://www.nsgm.gov.in/
PLC	- Power line communication
PMU	- Phasor Measurement Unit
POSOCO	- Power System Operation Corporation Limited, https://posoco.in/
POWERGRID	- Power Grid Corporation of India Ltd, http://www.powergridindia.com/
PTMP	- Point to Multi point
PTP	- point-to-point
RE	- Renewable Energy
REMC	- Renewable Energy Management Centre
REMC	- Renewable Energy Management Centre
RLDC	- Regional Load Dispatch Centers
SCADA	- Supervisory control and data acquisition
SERC	- State Electricity Regulatory Commission
SLDC	- State Load Dispatch Centre
TEC	- Telecommunications Engineering Centre, http://www.tec.gov.in/
ToU	- Terms of Use
TPDDL/NDPL	- Tata Power Delhi Distribution Limited/North Delhi Power Ltd.
TSDSI	- Telecommunications Standards Development Society, http://www.tsdsi.org/
URTDSM	- Unified Real Time dynamic State Measurement
WAN	- Wide Area Network
WEF	- World Economic Forum, https://www.weforum.org/

FOREWORD

The SESEI project (Seconded European Standardization Expert in India) is a project co-funded by five European partners (EC, EFTA, CEN, CENLEC & ETSI), operating from New Delhi, India, with the objective to increase the visibility of European standardization in India and to promote EU/EFTA-India cooperation on standards and related activities.

The SESEI's mission is to enhance the visibility of European standardization activities, increase the cooperation between Indian and European standardization bodies and support European companies facing standardization related issues hampering market access to India

The project supports the cooperation between India and Europe in standardization related aspects, by identifying all potential opportunities for enhanced international cooperation and global harmonization of standards. Ultimately, the SESEI project aims at reducing the Technical Barriers to Trade (TBT) both between EU/EFTA and India and globally, thus supporting European and Indian industries by facilitating international trade.

SESEI project through its expert Mr. Dinesh Chand Sharma focuses mainly on the following priority topics, while also keeping a track and extending possible support to both EU/EFTA and India on the topics of WTO-TBT and Market Access, IPR, R&D and Innovation, National Manufacturing Policy: Make in India, EU-INDIA FTAs, Environment (Energy Efficiency) etc.

- Information and communication technology: /IoT, e-Accessibility, Security, 5G, NFV/SDN…
- Electrical Equipment including Consumer Electronics: Smart Grid, Smart Meter, LVDC, Micro Grids…
- Automotive: Connected Cars, e-Mobility, ITS…
- Smart Cities…

This Study Report on 'Smart Energy covering Smart Grid, Smart Meter, LVDC, Micro Grid" was commissioned to determine in brief the Sector Profile, future developments, Challenges & opportunities in India, i.e. the regulatory, policy, technical and technological challenges, limiting the market potential, related opportunities, latest Developments and current state of play covering Standards development & Policy Initiatives in India to support the sectorial growth. With this study report and through further deliberation on it at the "3rd Indo-European Conference on Standards & Emerging Technology scheduled for 26th April 2018 at Hotel The Lailt, New Delhi", Project SESEI aims to determine list of actions as a way forward which shall help further Project SESEI in achieving its objective and strengthen the cooperation and collaboration between EU/EFTA and India.

EXECUTIVE SUMMARY

The Power Sector in India is undergoing transformation with ambitious goals being set by the Government of India to provide affordable power to every resident by the year 2019 through its "Power for All" scheme. An environment is being created through policies, regulations and agencies to facilitate working towards this goal. With development of new technologies, the electric power grid across the world is undergoing a massive transformation, bringing to fore immense potential and opportunities for a region like India, in the areas of power electronics, sensing, communication, data management and data analytics. Additionally, there is thrust towards Electric Vehicles (EV) and Intelligent Transport Systems (ITS) to form the bulk of transportation by 2030. Technologies like the Internet of Things (IoT) and Artificial Intelligence (AI) are considered chief enablers of this change.

This paper is set against a backdrop where India is at an important juncture in the energy landscape – a present riddled with many challenges and an imminent future of multiple opportunities led by technology implementations. The paper begins by providing an overall context to the Indian Power scenario and introduces the country's ambitious smart grids vision led by security, adaptability, sustainability, reliability and quality. In the next section, we delve deeper into the characteristics of the Indian Smart Energy ecosystem – exploring the market potential and opportunities as well as policies that are currently in place. The third segment is dedicated to standardization and an effort has been made to bring together all relevant standards (including IoT) as well as policies that enable their implementation. This segment also discusses cyber security and associated challenges, as these tenets are critical to the standards debate. The fourth segment explores opportunities and challenges that all these bring in the areas of renewable energy, transmission, distribution, micro-grids and security as well as their possible impact. In the final section, the paper puts forth some actionable recommendations for stakeholders in the energy ecosystem including calling for new policies around rooftop PVs, net metering, communications and IoT, data usage, distribution automation and management of distributed energy resources, schemes for incentivizing stakeholders as well as greater collaboration among ecosystem players. In doing so, it also highlights the benefits that collaborations such as those between India and EU could bring to accelerating both standards creation as well as implementation.

BACKGROUND

The interconnected electrical power grid is one of the most complex engineering systems. Traditionally, electricity gets generated at centralized power plants, transmitted over the long distance through high voltage transmission lines and reduced to lower voltages at the distribution lines with transformers. Electricity is then supplied to residential commercial and industrial users. The key aspect of an electrical power grid is that, at any moment of time, the generation and loads should be balanced. Also, it is important to note that electrical systems act very fast (< 1 sec) and hence maintaining the stability of the system is very critical.

With the development of new technologies, the electric power grid across the world is undergoing a massive transformation. Many types of renewable energy sources (especially Wind & Solar) have significantly penetrated the grid, and now with the advent of distributed generation & micro grids (including Low Voltage DC systems), energy storage and electric vehicles, the grid is becoming more and more complex. Handling the intermittent power from Wind and Solar, maintaining grid reliability and stability and accommodating bi-directional power flow from distributed power and electric vehicles are some of the key challenges.

On the other hand, significant technology developments have taken place over the last decade in the areas of power electronics, sensing, communication, data management and data analytics. The convergence of physical and digital innovations coupled with technology advances in energy systems has begun to drastically impact the ecosystem. The future of the power ecosystem will include more electrification, (Centralized & Distributed) and more digitization. New players coupled with new business models will emerge in order to address the challenges of balancing the fuel mix, integrating new technologies and maintaining physical and cybersecurity. This will present unprecedented opportunities to multiple stakeholders.

Smart Grid is a concept that leverages the development of information, communication and computing technologies to make the electricity grid more efficient, reliable and green. One of the key aspects of making smart grid development effective is to ensure interoperability across various systems. Across the world, several standards have been developed/being worked upon in the areas of Grid interconnection of Renewables, Transmission and Distribution of Electricity and Integration of Distributed Power/EVs into the grid. As India evolves the next generation grid, global standards can be leveraged effectively to potentially leapfrog very fast into a newer and more efficient electricity eco system.

This paper describes the current scenario in India, describes various technology opportunities/Challenges looking at Smart Grid as a system and presents the standards that will potentially enable faster transformation.

INDIA POWER SCENARIO – SETTING THE CONTEXT

The Energy Sector, more commonly known as the Power Sector, in India has had a long and chequered growth in the last seven decades. From a power surplus situation until the 1970s India moved into a zone of chronic shortage of electricity in the 90s, and has now yet again emerged as a power surplus country in terms of generation availability being greater than the demand.

The various power generation projects planned by the Government – both Central and States – combined with application of new technologies to improve power & energy efficiencies in the "Smart Grid" & Smart Energy" context indicate that India will be comfortable in the demand – supply equation at an aggregate level as forecast till 2050.

The sources of power generation today are both conventional and non-conventional. India's installed capacity is about 330 GW and electrical energy consumption in 2017 is about 1400 TWh (real time information on these matters can also be accessed on smart phones via the "Vidyut Pravah" app of the Ministry of Power, Government of India). India is thus already the 3rd largest producer of electricity in the world.

More than 80% of it these are met through conventional sources like coal, oil and gas besides large hydro and nuclear sources. The rest is met through wind, solar, biomass and small hydro. From a study of the various reports from governmental and other sources, the general outlook is that the Government plans to add 100 GW by 2022 taking up the generation capacity to ~430 GW. The target is also to have 175 GW of this in the form of renewables, primarily wind (60 GW) and solar (100 GW). This means about 40% of the generation will be from non-conventional sources as opposed to less than 20% now.

The following are the context within which these plans need to be understood:
The installed capacity and the planned capacity additions are to be surplus to demand albeit marginally.
The transmission and distribution grids are geared towards a centralized generation, mostly thermal
Between 230 and 300 million people have yet to have access to electricity – primarily in the rural areas (last mile connectivity).

Policy support like 100% FDI (Foreign Direct Investment) in this sector
Aggregate Technical & Commercial (ATC) losses are much higher than acceptable levels across most of the electricity distribution sector. Utilities and other stakeholders are working in tandem to bring these down to single digits in percentage, in line with internationally accepted norms, over the next few years
The Government's aim is 24/7 "Power for all" by 2019.

Besides the Central and State govts., major domestic and foreign investors – like the Tatas, GE, top global investment companies – have shown keen interest in participating towards this initiative by committing finances to the tune of USD 300 billion in various areas. (lists in latter sections of this report)

The policy environment is now conducive and the administration amenable to and encouraging innovative, latest and efficient modes of demand satisfaction

This naturally brings up the following:

a major shift from largely centralized to a combination of centralized and distributed (some would say fragmented) power generation

Solar and wind are highly variable/intermittent energy sources dependent on cycles of sunlight and wind speeds respectively.

Connecting such generation to existing grids for distribution adds to the complexity of the already complex grid – Power Quality, Handling the intermittent power from Wind and Solar, maintaining grid reliability and stability and accommodating bi-directional power flow from distributed power – smart grids and micro grids

On the other hand, significant technology developments have taken place over the last decade in the areas of power electronics, sensing, communication, data management and data analytics.

The majority of devices we use in homes, offices, healthcare facilities, greenhouses or data centres can use electricity from localized renewables as direct current (DC), without conversion to alternating current (AC). This includes for example battery operated equipment, consumer electronics & appliances, water pumps, LED lighting, electric vehicles and more. With the national goal of moving towards 100% LED lighting and only EV sales from 2030 onwards, LVDC becomes a significant technology to reckon with.

From the grid perspective, the Central Electricity Authority of India (CEA) advises the government on matters related to the National Electricity Policy and formulates short term and perspective plans for the development of electricity systems. Central Electricity Regulatory Commission (CERC) and State Electricity Regulatory Commissions (SERCs) regulate tariff, formulate policies regarding and promote efficient and environmental benign policies a central and state levels, respectively. Central Electricity Authority and the central transmission utility, Power Grid Corporation of India Ltd (POWERGRID) are responsible for national and regional power transmission planning.

The Vision of India on Smart Grids is 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”.

SMART ENERGY ECO-SYSTEM, MARKET DYNAMICS & POTENTIAL

Smart Grid including Renewables Integration

India's total power generation is ~335,000 MW out of which the power from Wind is ~32,000 MW and Solar is around ~16,000 MW. There is a big push by the government to increase renewable penetration to ~175,000 MW in the next 5 years. This has resulted in several developers setting up wind and solar farms. These developers have to minimize any spillage from renewable power thereby enhancing the reliability/ performance of the plant. On the other hand, since wind and solar power are intermittent in nature, the conventional power plants would need to exercise flexibility in order to maintain grid integrity – through faster controls, Energy Storage or Demand Response.

Transmission

Maintaining Transmission grid Reliability is the key driver. India has the largest synchronous grid in the world connecting 5 regions. India has had a major blackout in 2012 due to faults in the transmission grid. Since the impacts of these blackouts are severe, there is a need to develop the ability to handle these faults and prevent cascading trips. With the advent of digital technologies, one can envision a scenario where the operator can be given an indication of how far the grid can be stretched and the margins of failure.

Distribution

Maintaining Reliability, Efficiency and Power Quality are the key drivers for distribution. Despite the fact that the generation capacity is more than the total demand, consumers in India face outages very frequently due to the lack of reliable distribution grid.

A variety of factors including the aggregate technical & commercial losses being very high have eroded the financial health of many such electricity distribution utilities, thereby imposing constraints on critical investments needed for adopting new technologies and upgrading their systems.

Taking cognizance of this the Government of India has come out with the UDAY scheme for electricity distribution utilities across India that is designed to correct this situation with active support and participation by all the state governments.

This initiative is a key driver and is thus expected to revive investments in upgrading distribution networks across India and leverage smart grid technologies to improve the efficiency, reliability, power quality and resiliency of the network in the emerging environment.

Renewable Integration

The emerging changes is the expectations and attitudes of the Indian consumers who are now increasingly unwilling to accept sub-standard quality of civic and utility services. This is well recognized by the various Governments and there is a heightened sense of awareness about providing better services in the administration as well.

Another key driver shall for the overall transformation of legacy grids to Smart Grids will now be the adoption of “Grid Edge Technologies” (see paper published by the World Economic Forum in March 2017 on the Future of Electricity http://www3.weforum.org/docs/WEF_Future_of_Electricity_2017.pdf)

Within these and the rapidly increasing presence of Electric Vehicles, integrating Renewables will also be important driver in Smart Electrification; PV & Storage, and Micro grids shall be a driver for decentralization. Rapid advancements in Sensors, Communications, Analytics and Control will accelerate Digitalization.

LVDC and Micro Grids

Out of the ~700 M rural population, over 230 M people do not have access to electricity. Now, with the reduction of costs in solar and energy storage, Hybrid distributed power and micro grids are emerging rapidly.

India’s rural electrification program, called Deen Dayal Upadhyaya Gram Jyoti Yojna, includes a target of delivering power to 18,452 villages by 2018. Of these, 14,204 can be served by grid extensions, and the remaining 3,449 need off-grid power. While work on grid extensions is proceeding ahead of schedule, with 51 percent of villages already connected, only 20 percent of the off-grid target has been achieved so far, according to government figures. Thus Mini grid (> 10 kWp) and Micro grids (< 10kWp) deserve public policy support, they make sense to extend the reach of electricity to the people without access to grid power. (Ref: https://powermin.nic.in/ , http://www.ddugjy.gov.in/mis/portal/index.jsp)

A new policy framework has been drafted by the Ministry of New and Renewable Energy to support mini grids and micro grids for rural electrification in India. The policy provides some much-needed certainty to the sector and includes measures such as single-window clearance, grid connectivity and pricing visibility for evolution of bankable business models. The policy aims to create up to 500 Megawatts of capacity over the next five years. The targets for the policy are fairly small in terms of Megawatts to be added.

The pressing need to improve the overall performance of the electricity distribution utilities shall be a key driver for intelligent investments directed towards transforming legacy grids to smart grids, thereby improving services to the consumers.

Smart Meters

The costs of the electrical, communication, software components and cloud based services declining rapidly is leading to faster adoption of these technologies for all the smart grid segments.

Consumers of electricity can leverage the grid edge technologies and are expected to become prosumers selling excess electricity back to the grid. One can expect all the devices to be connected and operated seamlessly helping consumers optimize the use of electricity, utilities able to operate the grid more efficiently and reliably with the help of smart meters, AMI and demand response and electric vehicles being able to charge seamlessly and smartly across the grid and potentially send electricity back to the grid.

The WEF report [Ref] states that new value of US $2.4 Trillion shall be created over the next 10 years in transformation of electricity. The adoption of these grid edge technologies is expected to take off just like the communications and Internet revolution 2 decades ago.

India is best positioned to take a leapfrog jump into the Future electricity ecosystem with the help of the grid edge technologies. Several of the key plaguing problems such as power pilferage; limited/no access to electricity in several parts of the country coupled with limited oil/gas resource challenges can be well addressed with the grid edge technologies.

It is imperative that all the stakeholders in the future electricity eco system work together to accelerate the proliferation of these grid edge technologies thus making the smart grid more efficient, reliable and efficient. This is also a perfect opportunity to develop standards across all segments and keeping the future system in mind and preparing for the rapid changes facing the electricity industry.

POLICY INITIATIVES AND STANDARDIZATION

National Programmes in Smart Grids and Renewable Energy

Fourteen (14) smart grid demonstration/pilot projects were sanctioned by Ministry of Power with 50% Government of India grant amounting to US$ 29.56 million and 100% funding for Smart Grid Knowledge Centre for managing research and innovation activities in 2012. Subsequently, four full Smart Grid projects were also sanctioned in 2016 with 30% funding from Ministry of Power under NSGM. The details are in http://www.nsgm.gov.in/en/sg-projects . In addition, the country strives to install 35 million smart meters by 2019.

Time-based pricing (Time-of-Use Tariff) signals the consumer to be more dynamic. The Indian Electric Vehicle (EV) rollout requires a functional charging infrastructure – and its management. Distribution Companies (DISCOMs) provide the anchor infrastructure for smart grids and cities creating a need for value added services and new business models. However, there is critical need to establish business cases for self-finance of these investments.

Furthermore, a similar need for value added services is recognized with the large electricity consumers. In addition, smart grid utilities require a variety of digital technologies such as analytics, mobility solutions and customer touch points. The distributed generation based on hybrid sources could provide a sustainable and cost effective power supply to the un-electrified pockets. Option of negotiating smart grid projects with the campus owners (educational, special economic zones, industrial parks, etc.) is a viable market entry option for smaller companies and company consortiums. Moreover, several large Public-Private Partnership smart grid projects present a true mega opportunity for the companies that already operate in the Indian market.

Tata Power Delhi Distribution Limited/North Delhi Power Ltd. (TPDDL/NDPL), previously is a joint venture between Tata Power and Delhi Government. NDPL is among the earliest adopter of Smart Grid approach. They have collaborated with General Electric (GE) for using various Smart Grid approaches for efficient distribution of electricity. NDPL serves the National Capital Region (NCR). HCL Technologies Limited (HCL) has partnered with Echelon (A Smart Grid Product Development Company) for providing smart metering and network infrastructure services. Telvent recently announced that it is going to partner with L&T for Smart Grid Projects in Maharashtra State. KEMA has served as knowledge partner to Bangalore Electricity supply company Ltd. (BESCOM) for its Smart Grid project.

The Department of Science & Technology (DST), Government of India has funded around US $46.5 million towards R&D on Smart Grids. Indian academic institutions including Indian Institute of Technology (IITs), Indian Institute of Science (IISc) and private industries have been engaged in R&D on Smart Grids in India. Some of the projects undertaken by the academic institutions, which are funded by department of Science & Technology, Government of India, are at advance stage of completion. These funded projects include national as well as bilateral programs with countries like US, UK and Netherlands. Smart Grid Technologies involve deployment of ICT and IT infrastructure. Some of the functionalities/technological advancements adopted for smart grids in Indian scenario are:

Advanced Meter Infrastructure

Advanced Metering Infrastructure (AMI) facilitates monitoring and measurement of consumer information and control through Smart Meters installed at customer premises. It supports bidirectional flow of information between consumer and utility control centre through communication mode such GPRS/PLC/RF. Smart meters will also enable Time of Use (ToU) and Critical Peak Pricing (CPP)/Real Time Pricing (RTP) rate metering for demand response. Large scale deployment of Meters is ongoing across the country. Even for Renewable Power integration/Roof top Solar Power Net Metering is being deployed in most of the states which uses bidirectional meters thus can record the export of power to grid.

Peak Load Management

The peak load management refers to controlling the demand and matching it to the available supply at the instant of peak. The peak load management function shall take inputs from SCADA/EMS/DMS regarding power availability and volume of shortage. Based on the shortage, the peak management function shall run algorithms considering various constraints and priorities predefined on the basis of customer profile. The approach shall be to avoid tripping of feeders for load shedding and manage peak load either by load curtailment through AMI or by price incentives/disincentives in the form of ToU pricing.

Power Quality Management

Power Quality Management addresses events like voltage flickering (Sags/Swells), unbalanced phases voltages and harmonic distorted supply, etc. This will facilitate efficient and reliable operation of the power system, reduce losses, improve customer satisfaction and minimize equipment (utility/consumer) failures. Power Quality managements hall include Voltage/VAR control, load balancing, harmonics control etc. This is most critical when we are integrating large scale Renewables.

Outage Management

Outage Management System (OMS) manages unscheduled distribution infrastructure like distribution Transformers (DTs), HT/LT feeders etc. It collects and coordinates information about outages including customer calls and report the operator for taking corrective actions through crew management and remote control enabling customer satisfaction, improves system availability and reliability.

Standards

Smart Grid

One of the major aspects associated with implementation of smart grids is the interoperability of various devices. Hence standards (on the electrical and communication) are being developed to ensure that the various devices communicate with each other and enable seamless operation of the grid with various new elements such as renewables, distributed power, electrical vehicles etc.

The fig below as represented by NIST (National Institute of Standards and Technologies, USA) shows the various components including backbone power system network and interconnected Internet communication network. The interconnections indicated in red represent the power system while the ones indicated in blue represent the Internet connectivity. While the standards for Electrical components like switchgears and Smart Meters, etc. have been developed, many others are in the formative stages and these standards may be adopted in India.

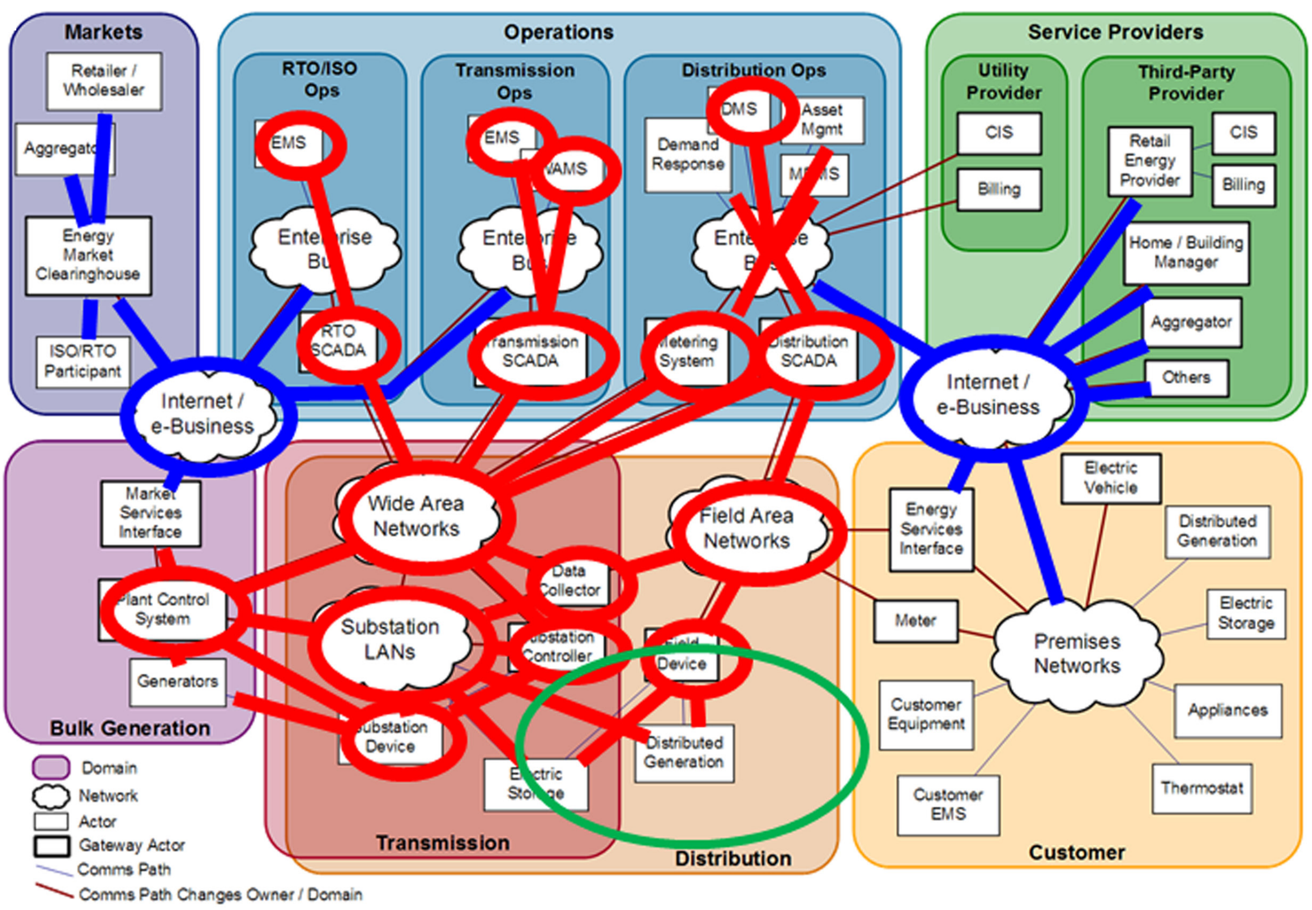


Figure 1: NIST Smart Grid Twiki

Communications and IoT

As discussed in the earlier sections, Energy and Utility companies are faced with the need to transform due to increase in demand, improving the efficiency of their operations, reducing outages, improving reliability and predictability and with the advent of distributed power generation and renewable energy sources.

Currently, the use of M2M/IoT in energy and utilities is primarily happening for:
Advanced metering infrastructure - AMI
Smart grid applications for supervisory control and data acquisition and distribution automation - SCADA/DA

Some key Energy and Utility IoT use cases are:
Asset health monitoring and predictive maintenance
Demand forecasting and energy analytics
Remote monitoring and Outage management
Performance optimization
Energy optimization / reduced energy consumption
Renewable energy
Safety and Security
Enhanced customer experience and control plus availability of smart meter data for energy analytics

Energy and Utility assets (meters, pipes, grids/wiring, transformers etc.) are deployed across cities, states and country making the M2M/IoT coverage requirement mostly across a wide area. The sensors/devices need not be mobile but are geographically spread over a wide area. Especially in the case of electricity, there is an option of using integrated communications with the power line.

The common network technologies used in Energy and Utilities IoT solutions are:
ZigBee
HomePlug (a form of PLC)
Power line communication (PLC) - narrowband or broadband
Narrowband / Broadband PTMP (point to multipoint network over RF, copper or fiber)
Wireless mesh networks (Wireless LAN or Wi-Fi)
Mobile network technology - GSM, CDMA, LTE
Ethernet over Fiber or SDH
Licensed PTP (point-to-point) like Microwave links
Low Power Wide Area Networks (LPWANs) and supporting technologies like LoRa, Sigfox, etc.

The Energy and Utility communication network is mostly categorized into three parts:
Home area network and Smart meter network (HAN/AMI system) - this connects the customer residences/ smart meters to the AMI Collector / access point. ZigBee, HomePlug (a form of PLC) or LPWANs and supporting technologies like LoRa, etc. are typically used for this.

Field area network (FAN) - this is the wide area network, spread over a geographically vast area which connects the collectors / access points to the core network (data centers, substations). Field area networks mostly use PLC or wireless networking technologies like narrowband / broadband PTMP, mobile network technology or wireless mesh networks (based on Wireless LAN or Wi-Fi) and now upcoming LPWAN supporting technologies like LoRa

Core IP network - this connects the core part of the energy and utility communication network like data centers, sub stations etc. This part mostly uses high-voltage PLC or fiber or SDH or licensed PTP links like microwave links.

Relevance of IoT Standards

All of the market projections for the growth of Machine-to-Machine (M2M) communications and the Internet of Things (IoT) are unrealistic without the emergence of a global standardized platform. In other words, this industry will not take off without significant consolidation and the economies of scale that standardization can bring, which also means Standardization is needed to deliver the scale and flexibility the market requires to maximize the full potential of IoT and M2M. A few of the global standards organizations are:

ETSI

ETSI, which is an officially recognized European Standards Organization, and is producing globally-applicable standards for Information and Communications Technologies (ICT) had established a TC on M2M way back in 2008 and first set of M2M platform standards and specification were published to market in 2011.

oneM2M

Considering the market fragmentation, a need was realized to consolidate the standardization efforts under one umbrella. Hence in July 2012, oneM2M Partnership Project was established, which has now become a leading global standardization body for M2M and IoT. This partnership project in line with 3GPP was established through an alliance of standards organizations from around the world to develop a single horizontal platform for the exchange and sharing of data among all applications. The largest part of ETSI M2M work was transferred to oneM2M project in July 2012 which became the basis for further oneM2M work for the world. One M2M unveiled its Release 1 standards in early 2015 to ensure optimized M2M interworking and created a foundation platform for IoT devices and applications. Several open source foundations and projects have been actively using oneM2M standards in various applications and services since its first release in January 2015. oneM2M'sRelease 2, which also addressed the interworking capabilities was published during mid-2016. Alongside open source implementation by players such as CISCO, KETI, FRAUNHOFER etc. commercial implementations of oneM2M standards have also grown since the first implementation as announced in December 2014 by Korea.

Market Dynamics and Potential

According to a 2011 Deloitte report,[22] "the adoption and potential for EVs in India is undeniable given anxieties around energy independence, high cost of imported fuel and the ability to increase the availability of power through the grid by multiple sources like coal, renewable sources, gas and nuclear power." The report also states that in India, "the rapid rise of fuel prices and the desire to be on par with the rest of the world in terms of emission would facilitate the growth of the EV market."

For the Original Equipment Manufacturers (OEMs), EVs offer a great opportunity but also pose a threat, as the technology could change the contours of the industry and render large parts of the value chain that has been created over the last decades worthless. This is particularly true for a country like India, where most of the ICE value chain was created after the mid-1990s. [22]

Several Indian ministries are important stakeholders for the EV industry including the Ministry of Heavy Industries (MHI), the Ministry of Urban Development (MoUD), the Ministry of Environment and Forest (MoEF) and the Ministry of Road Transport and Highways (MoRTH). The Society of Manufacturers of Electric Vehicle (SMEV) is an association of Indian manufacturers of electric vehicles (EV) and electric vehicle components. It works with Indian governments bodies to assist formulation of policies and processes supporting the EV ecosystem. Lastly, all the major automobile players including Tata Motors, Ashok Leyland, Maruti Suzuki, Mahindra & Mahindra, Bosch, Volkswagen, Volvo, etc. have been involved in the production and research of new and/or existing models electric variants

Standards Setting in India

Organizations

The establishment of Telecommunications Standards Development Society, India (TSDSI, www.tsdsi.org/) and its recognition as Indian Telecommunications Standards Development Organization (SDO, http://www.dot.gov.in/telecommunications-standards-development-society-india-tsdsi) by Department of Telecom, Ministry of Communication & IT, had been a welcome step. It is encouraging that TSDSI is successfully federating the industry (manufacturers, service provider and R&D units), academia and Government of India within its membership. Collaboration with global Standards Development Organization is now happening at the level of the Global Standards Collaboration (GSC, https://www.itu.int/en/ITU-T/gsc/Pages/default.aspx) initiative, where TSDSI is a full member and at the level of 3GPP where, TSDSI is the 7th 3GPP Operational Partner (from January 1, 2015), and has also joined oneM2M as a Partner Organization. The industry is also happy to note that TSDSI have taken up important areas of technical work such as M2M, Smart Energy, Security, 5G to name a few. TSDSI is fully operational with a leadership in place, an active Technical Organization having its own IPR policy.

Standards Implementation in India-Current Status & the Future

Amongst the organisations which have adopted these oneM2M standards importantly include our Indian research organisation CDOT under Department of Telecom, Ministry of Communications along with many other multinationals such as NEC Corporation, LG subsidiary LG CNS, SK TELECOM, SIERRA WIRELESS, HUAWEI, HP, Inter Digital, Sensinov etc. 3GPP is also focusing work on NB-IOT, EC-GSM, EMTC. oneM2M Standard in its release 3 has addressed various important functionalities such as interworking with 3GPP C-IOT, Smart City use cases and best practices for use of oneM2M in smart cities, Automotive as an important vertical and advanced semantics which will act as an enabler to big data and analytics. This Release 3 draft was issued at the end of 2017.

With this all done at the global platform we all know that a lot has also been done in India on this subject such as: DoT had released M2M roadmap long back which laid down set of recommendation covering M2M Numbering Plan, M2M Quality of Service, M2M specific Roaming, M2M Service Provider (MSP) registration process, KYC, SIM Transfer, International roaming, M2M frequency bands, M2M Pilot Project and many more.
TEC (Telecommunications Engineering Centre - the Specifications making arm of the Department of Telecom) WG on M2M published various technical reports covering M2M Gateway & Architecture, M2M Enablement in Power Sector, in Automotive (Intelligent Transport System) Sector, Remote Health Management, Safety & Surveillance Systems, M2M Number resource requirement & options, V2V / V2I Radio communication and Embedded SIM, Spectrum requirements for PLC and Low power RF communications etc. and work continues for ICT deployment and strategies for India's Smart Cities, Communication Technologies in M2M/IOT, Smart Home etc.

TSDSI (India's official Standards Development Organisation in the area of Telecommunications & Applications) WG on M2M/IOT also released report covering Indian Use cases for utilities, Environment, Smart cities, Smart Governance, Smart Villages, Transportation, Health, Smart Homes etc.

DoT also released draft M2M Service Providers Registration Guidelines, which is pending finalisation post issue of TRAI's Final Recommendations on a) Regulatory & Licensing framework, b) what should be the quantum & type of spectrum required to meet the M2M communications requirement in the future, c) International Roaming requirements, d) SIM/eUICCe) Security etc. It is expected that with the release of the National Telecom Policy 2018 on the anvil, the guidelines for M2M /IoT Communications would be finalised and issued
Ministry of Electronics & IT (MeITy) has also released its IoT policy and have established Center of Excellence (CoE) in CDAC Bangalore and other CDAC centres are also working on the IOT subject and its role in the smart city with ULBs.

IET – The institution of Engineering and Technology INDIA has established it's IoT Panel which is focussing on the areas: Retail, Energy, Healthcare, Agriculture, Connected Homes, Telecom, IoT Labs, Standards & Legal, Education and Social Impact. CDOT under DoT has built a M2M/IOT platform based on oneM2M specifications.

Cybersecurity

Security in Smart Grids is an essential requirement in order to ensure that the whole system functions smoothly and safe from any sorts of attack and intrusion. This covers a wide range of solutions targeting threats such as denial-of-service, eavesdropping on transmission, routing attacks, flooding for generation plant security, data centre security, WAN security, identity management, access control, and so forth. Conventional centralized IT network security models are not directly applicable to the highly distributed and low-cost devices in M2M communications networks due to the need for dispersed and decentralized methods.

A smart grid is a large-scale system that extends from a power generation facility to each and every power consuming device such as home appliance, computer, and phone. This large-scale nature has increased the possibilities of remote operation of power management and distribution system. With energy being a premium resource, ensuring security against theft, abuse, and malicious activities in a smart grid is of prime concern.

Global Scenario

For an overview of the global scenario covering work at Europe on Smart Grid Architecture Model (SGAM) and report on set of standards (covering work on standards around the world such as IEC, IEEE, IETF along with ENs) as available here for Smart Grid https://www.cencenelec.eu/standards/Sectors/SustainableEnergy/SmartGrids/Pages/default.aspx and Smart Meter https://www.cencenelec.eu/standards/Sectors/SustainableEnergy/SmartMeters/Pages/default.aspx

In India, considerable work by BIS ETD (Smart Meter) and LITD (Smart Grid) are being done through its various technical committee such as ETD13: Smart Meter, ETD 46: Grid Integration (considering renewable and e-Mobility aspect), ETD 50 – LVDC Power Distribution System, LITD 10: Power system Control and associated Communications (EMD.DMS, SCADA, SMART GRID etc.). More information is available through the links http://tec.gov.in/pdf/M2M/M2M Enablement in Power Sector.pdf

The table below gives the details of standards applicable (source ISGF)

Standard	Description
Open Geospatial Consortium Geography Markup Language (GML)	A standard for exchange of location-based information addressing geographic data requirements for many Smart Grid applications.
IEC 62351 Parts 1-8	This family of standards defines information security for power system control operations.
IEC 61851	Applies to equipment for charging electric road vehicles at standard alternating current (ac) supply voltages (as per IEC 60038) up to 690 V and at direct current (dc) voltages up to 1000 V, and for providing electrical power for any additional services on the vehicle if required when connected to the supply network
IEEE 1686-2007	The IEEE 1686-2007 is a standard that defines the functions and features to be provided in substation intelligent electronic devices (IEDs) to accommodate critical infrastructure protection programs. The standard covers IED security capabilities including the access, operation, configuration, firmware revision, and data retrieval.
SAE J2836/1	This document establishes use cases for communication between plug-in electric vehicles and the electric power grid, for energy transfer and other applications.
IEEE 1815 (DNP3)	This standard is used for substation and feeder device automation, as well as for communications between control centers and substations.
IEC 60870-6 / Telecontrol Application Service Element 2 (TASE.2)	This standard defines the messages sent between control centers of different utilities.
IEC 61850 Suite	This standard defines communications within transmission and distribution substations for automation and protection. It is being extended to cover communications beyond the substation to integration of distributed resources and between substations.
GREEN BUTTON Standards	Green Button standards represent the contributions made by the OpenADE, NAESB ESPI, and NIST SGIP- PAP20, PAP10.
IEEE C37.118-2005	This standard defines phasor measurement unit (PMU) performance specifications and communications for synchrophasor data.
IEEE 1547 Suite	This family of standards defines physical and electrical interconnections between utilities and distributed generation (DG) and storage.

IEEE 1588	Standard for time management and clock synchronization across the Smart Grid for equipment needing consistent time management.
IEEE C37.238	Profile of IEEE 1588 for electric power systems.
Internet Protocol Suite, Request for Comments (RFC) 6272,Internet Protocols for the Smart Grid.	IPv4/IPv6 are the foundation protocol for delivery of packets in the Internet network. Internet Protocol version 6 (IPv6) is a new version of the Internet Protocol that provides enhancements to Internet Protocol version 4 (IPv4) and allows a larger address space.
Inter-System Protocol (ISP)-based Broadband-Power Line Carrier (PLC) coexistence mechanism: (Portion of) IEEE 1901-2010 (ISP) and International Telecommunications Union Telecommunication Standardization Sector (ITU-T) G.9972 (06/2010)	Both IEEE 1901-2010, "IEEE Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications," and ITU-T G.9972 (06/2010), "Coexistence mechanism for wireline home networking transceivers," specify Inter-System Protocol (ISP) based Broadband (> 1.8 MHz) PLC (BB-PLC) coexistence mechanisms to enable the coexistence of different BB-PLC protocols for home networking.
MultiSpeak	A specification for application software integration within the utility operations domain; a candidate for use in an Enterprise Service Bus.
NEMA Smart Grid Standards Publication SG-AMI 1-2009 – Requirements for Smart Meter Upgradeability	This standard will be used by smart meter suppliers, utility customers, and key constituents, such as regulators, to guide both development and decision making as related to smart meter upgradeability.
NAESB WEQ19, REQ18, Energy Usage Information	The standards specify two-way flows of energy usage information based on a standardized information model.The standards specify two-way flows of energy usage information based on a standardized information model.
NISTIR 7761, NIST Guidelines for Assessing Wireless Standards for Smart Grid Applications	This report is a draft of key tools and methods to assist smart grid system designers in making informed decisions about existing and emerging wireless technologies. An initial set of quantified requirements have been brought together for advanced metering infrastructure (AMI) and initial Distribution Automation (DA) communications. These two areas present technological challenges due to their scope and scale. These systems will span widely diverse geographic areas and operating environments and population densities ranging from urban to rural.
Organization for the Advancement of Structured Information Standard (OASIS) EMIX (Energy Market Information eXchange)	EMIX provides an information model to enable the exchange of energy price, characteristics, time, and related information for wholesale energy markets, including market makers, market participants, quote streams, premises automation, and devices.
Open Automated Demand Response (OpenADR)	The specification defines messages exchanged between the Demand Response (DR) Service Providers (e.g., utilities, independent system operators (ISOs) and customers for price-responsive and reliability-based DR
OPC-UA Industrial	A platform-independent specification for a secure, reliable, high-speed data exchange based on a publish/subscribe mechanism. Modern service-oriented architecture (SOA) designed to expose complex data and metadata defined by other information model specifications (e.g. IEC 61850, BACnet, OpenADR). Works with existing binary and eXtensible Markup Language (XML) schema defined data

OPPORTUNITIES, GAPS AND CHALLENGES

Smart Grid including Renewables

Considering the Variable generation from Renewable Sources as one of the main source of energy of future, an expert Committee at GOI level on Large Scale Integration of RE was constituted by GOI in April, 2015 for various issues relating to large scale integration of renewable generation. It recommended several actions such as bringing flexibility in the conventional generation, frequency control, maintaining generation reserves, introduction of ancillary services, forecasting, scheduling, deviation settlement mechanism, balancing mechanism and robust data telemetry and communication systems. In order to facilitate the seamless integration of large scale deployment of Renewables and allowing power flow and power exchange through regional grids, a green transmission corridor is being developed by POWERGRID in the country. Separate renewable desks have been set up at Regional Load Dispatch Centers and such Renewable Energy Management Centres (REMCs) are to be co-located with the state, regional and national load Centres as per the recommendation of a Technical Committee formed by MoP in April 2016.

Technologies such as real time forecasting and controls and can help enhance the performance of the system thereby resulting in increased reliability, availability and throughput of the plants. Hybrid technologies that includes a combination of Wind/Solar/Storage/conventional plants can help optimize the performance of the system. Any excess Wind or Solar can be stored in batteries and be used when the grid needs it. The electrical balance of plant can be leveraged for the multiple sources thereby optimizing the system. However the operation and control of such plants become complex and one needs to be able to model the entire system, analyze the impact of these systems when connected to the grid and develop controls to seamless integrate with the grid and maximize throughput.

Transmission

The grid management in India is being carried out on a regional basis. The country is electrically demarcated into five regions namely, Northern, Western, Southern, Eastern and North Eastern Region. Indian grid is operational as a single synchronous grid operating at single frequency. All these five regions have Regional Load Dispatch Centre (RLDC), which is the apex body to ensure integrated operation of the power system in the concerned region. At national level, National Load Dispatch Centre (NLDC) has been established for optimum scheduling and Dispatch of electricity among the regions. The RLDCs, in conjunction with State Load Dispatch Centres (SLDCs), are responsible for carrying out the real time operation of the grid and dispatch of electricity within the region through secure and economic operation of the regional grid.

Power System operation Corporation Limited (PoSoCo), as an independent government company, operates the NLDC and RLDCs since January, 2017. It ensures independent system operation and provides level playing field to all stakeholders. POSOCO is also implementing various projects on Wide Area Monitoring, Control and Protection System. A pilot project is already operational at national Load Dispatch Center with more than 60 Phasor Measurement Units (PMUs) already installed starting 2010 in the Regional Grid. Under Unified Real Time dynamic State Measurement (URTDSM) Project, the POWER GRID is installing about 1700 PMUs covering all 400 kV and above voltage level substations and major 220 KV Generating Station for enhanced dynamic security monitoring and visualization of the transmission system, thereby improving transmission capacity and reliability. Some of the analytics are being developed by IIT Bombay.

Digital Substation and Substation Automation are already deployed thereby resulting in improved reliability, reduced of O&M Cost and faster restoration. Approximately 110 substations have been equipped with Substation Automation with gateway for remote operation and monitoring from centralized location leading to virtual manning of substations.

Whether conventional power plants or renewable power farms like wind or solar, power evacuation systems, for example substations play an important role in delivering power to the grid. Starting with numerical digital protection and control, automation devices and systems, evolution has happened with emergence of standards like IEC 61850 and Digital Substations. Ethernet based communication and IEDs (Intelligent Electronic Devices) have made Digital Substations smarter, cost effective and faster to install and commission. This also enables effective asset monitoring and management while providing effective protection and control of equipment, system and operation on integrated digital platform. There is a huge opportunity in the technology development of Substation automation.

With the advent of digital technologies, one can envision a scenario where the operator can be given an indication of how far the grid can be stretched and the margins of failure.

The grid should be able to absorb all the renewable power to the extent possible, handle the intermittency, distributed power, grid connected microgrids and electric vehicles in a seamless manner – via intelligent energy management, including Demand Response, decentralized decision-making and ensure highest levels of reliability/efficiency.

Technologies such as Phasor Measurement Units, Wide Area Measurement systems, Digital Substations, Advanced Energy Management systems, Distribution Management Systems, Grid Automation, Intelligent assets (Smart Transformers, Smart Inverters etc.), Demand Response, Load management (Optimal charging of EVs) would play a significant role to help digitize the grid operations and help evolve an efficient and self-healing system. The interoperability of various systems and cybersecurity are extremely critical in ensuring the reliability and safety of the networks.

Reducing energy cost, especially wind and solar together with battery storage has been challenging conventional power plants and systems to produce and manage more power with less investments (capex and opex). Ageing assets in the system need to be utilized better and made more efficient with extended life. Digitalization plays a key role in monitoring the condition and health of these assets to achieve higher level of utilization, energy efficiency, operation and uptime. For example, Smart Sensor is fitted non-intrusively on the surface of motor to monitor its vibration, temperature and electrical parameters. The data is captured using a mobile device or gateway to push data to the cloud enabling predictive and fleet analytics. Similar approach is used for transformer, not only for operational data, but also for design, environmental, test and maintenance data to predict its health index. Digitization of complete value chain in asset management starting from real-time monitoring-analytics to work order and maintenance workforce management helps in preventing failures and lowering down time of the equipment and system.

Several technology concepts like robotics and drones for asset inspection, non-invasive evaluation of assets, optimal management, life optimizing controls, real-time controls, self-healing algorithms, are used in the digital platform for next level of asset management.

Distribution

The distribution systems are a critical link in the electricity value chain and need the implementation of various measures to transform transformation of legacy distribution grids to Smart Grid systems.
The three key challenges faced in the past were:
Financial constraints of the distribution utilities
High capital costs for new equipment and solutions needed
Insufficient knowledge & skill levels at the “operations level” to manage the adoption & maintenance of new sophisticated technologies

Of the above three challenges , the magnitude of the first two has significantly reduced due to the determined steps taken by the various governments on easing the financial burden on electricity distribution utilities and that costs of electronic hardware & software needed have come down significantly over the last few years.
In addition the recent evolution of a widespread and reliable communications network in India combined with its rapidly dropping data carrying costs will contribute significantly to far better operational viability of smart grid investments. The successful operation of the Smart Grid requires seamless connectivity of technology thus make the distribution system completely visible at an aggregate level. The available communication technology in India is at par with many developed nations in the world. However, there are issues in terms of interoperability of devices and systems with reference to smart grid deployment in utility environment. Even if the technological developments are aligned, there is an issue of integration of the entire hardware system to manage high volumes of data. It requires complex data models to manage the various data formats that flow into the system. As the distribution grid evolves, it should have the ability to handle the proliferation of rooftop PVs, Electric Vehicles and Energy Storage systems GoI set up two bodies namely India Smart Grid

Task Force (ISGTF) and India Smart Grid Forum (ISGF) in 2010 with the objective of developing roadmap for Smart Grid implementation and assisting utilities in deployment of smart grid technologies in a cost effective, efficient and scalable manner. The Ministry of Power (MoP), GoI in consultation with India Smart Grid Forum and India Smart Grid Task Force has formulated a Smart Grid Vision and Roadmap for India in Sep 2013 aligned to MoP's overarching objectives of "Access, Availability and Affordability of Power for All" and has envisaged transformation of the entire power system to smarter grids by 2027. In 2015, Ministry of Power, Government of India, established National Smart Grid Mission (NSGM) to plan and monitor the implementation of policies and programs related to the smart grid activities in India. The role of ISGTF was merged into NSGM, NSGM is also coordinating for development of smart grids in the smart cities under Smart Cities Mission. NSGM promotes deployment of Smart Grid technologies like Advanced Metering Infrastructure (AMI), substation renovation and modernization with deployment of Gas Insulated Substations (GIS) wherever economically feasible and distributed Generation in the form of Rooftop Solar PVs, real-time monitoring and control of distribution Transformers, creation of Electrical Vehicle (EV) charging Infrastructure for supporting proliferation of EVs, development of medium sized Micro-grids and provision of power quality improvement measures. Government of India is promoting deployment of Smart Grid projects under the NSGM through funding support of 30% on capital expenditure some of the pilot projects in some states are in the advance stage of implementation. The whole idea of Ministry was to show case them with the results to other utilities, so that they can adopt the same for better management of their distribution system.

Considering that India's power demand is continuously growing, there is a tremendous opportunity for the distribution grid to be on par with the world's best.

LVDC and Micro grids

On the technical side, since many of these systems will be remote, the challenges are in the areas of operation, maintenance, remote monitoring and controls. However, with the evolution of Industrial internet, cloud technologies etc., it would be possible to remotely access the technical and nontechnical data from the various micro grids, perform analytics and remotely fix any problems, to the extent possible remotely. What technology architecture would be appropriate? Would Low Voltage DC grids take off? How can this be robust, cyber secure? Can you prevent physical damages? Is predictive maintenance possible? How can you make it easy for customers to pay? These are the questions that can potentially be answered with accelerated technology and standards development and policy enforcement. Besides, in the digital world, evolution of new market mechanisms, energy trading across the network with Utility serving as a platform, digital twins of all assets and systems, Blockchain technologies etc. are some of the future concepts. The amount of data that needs to be collected, stored, communicated and analyzed will become exceedingly complex and innovations are expected to emerge significantly in these areas.

Communication and Security

To enable accelerated adoption of these concepts, the regulations have to be re-established in the new scenario that can strengthen the engagement of consumers, improve the economic viability of implementation, establish infrastructure (e.g. Power and Communications for charging of EVs) to handle EVs and micro grids on the network and create new business/service models to emerge to enable smoother and faster supply of electricity (both technical and commercial).

The challenges of ensuring Cybersecurity in a smart grid are diverse in nature due to the diversity of the components and the contexts where smart grids are deployed. Deploying a smart grid without strong and diligent security measures can allow advanced cyberattacks to remain undetected, which can eventually compromise the entire system. Inadequate security measures can also compromise the stability of the grid by exposing it to, for example, utility fraud, loss of confidential user information and energy-consumption data

The cyber security objectives can be classified into the following three categories

- (i) Integrity. Protecting against the unauthorized modification or destruction of information. Unauthorized information access opens the door for mishandling of information, leading to mismanagement or misuse of power.
- (ii) Confidentiality. Protecting privacy and proprietary information by authorized restrictions on information access and disclosure.
- (iii) Availability. Ensuring timely and reliable access to information and services. Availability can be compromised by disruption of access to information which undermines the power delivery.

Availability and integrity are the most important security objectives in the smart grid from the perspective of system reliability. However, due to the systems interactions with customers, the importance of confidentiality is also growing in this two-way data communication system that interconnects the whole system including meters, collectors, communications network, and utility data centers.

Smart grid has introduced new concepts in energy sector such as real-time pricing, load shedding, demand management, and integration of distributed, renewable power sources. It is based on numerous control systems, which can be targeted by the attacker. Furthermore, smart grid has created many more access points and with commands emanating from interfaces in homes and businesses in HAN any of these access points can be manipulated by the attackers to penetrate a network, gain access to control software, and alter load conditions to destabilize the grid in unpredictable ways. It is important to note that attack at any point can affect the entire smart grid as it is mostly based on mesh network, and any malignant attack can propagate to the entire grid, as all components in a smart grid can communicate with each other. One particular point of concern in this regard is from a customer meter to the data collector, which can use wireless communication. This can provide an opportunity to the attacker, if security mechanism is not adequate.

Smart grid security mechanism should be enforced at several layers including physical and logical layers.

Physically, smart grid systems and component must be secured from harm, tempering, theft, vandalism, and sabotage. Examples of physical layer security include installation of fence, video surveillance, and alert system Security in the logical layer deals with protecting the digital data. Logical layer security mechanisms include the following:

1. Encryption. Data encryption in smart grid, from meter to utility center, is a useful tool to prevent snooping, hence preserving the confidentiality of data. Strong but efficient algorithms can be used; however, all smart grid devices, for example, meters, collectors, processors, and routers, must be enabled with encryption processing capabilities.
2. Authentication. It is the process of determining that a user or entity is, indeed, the same as been claimed. Smart grid applications must have strong authentication capabilities, to detect and reject unauthorized connections between its components, for example, meter and the utility interfaces
3. Application Security Controls. Smart meter applications should be designed and coded appropriately so that cybercriminals cannot access a meter to mount buffer overflow attacks or to embed a malware. Data validation is an example of techniques that can be used
4. Security Patches. It can protect an application from known threats; therefore, codes should be kept up to date with latest security patches
5. Malware Removal. Use of antivirus and antispyware software throughout the smart grid applications can help to detect and to remove malwares from the system

Ensuring cyber security in smart grid needs continuous monitoring so that any possible attack can be detected in time and appropriate actions can be taken quickly. Also, monitoring various smart grid parameters can help identifying any suspicious or abnormal activity. Furthermore, having a rapid restoration plan is also important

Few approaches proposed to handle security issues in the smart grid are outlined below:
Public Key Infrastructure based solution. PKI is a mechanism that binds public keys with unique user identities by a certificate authority (CA). Users have to obtain certificate public keys of their counterparts from the CA before initiating secure and trustworthy communication with each other. The scope of a PKI also encompasses policies and procedures, specific to the security requirements of a domain, on a combination of hardware and software platform. Under this scheme various participants in a smart grid require communicating through a PKI system.

Anonymization. The usage (of energy) data needs to be sampled at a high frequency for real-time load balancing in a smart gird. This kind of data also exposes the most amount of sensitive information. An approach to protect this confidential information is by anonymization. The idea is that attributing the usage data is not required unless it is for billing purpose. Sampling for billing can be performed at a lower frequency without negatively affecting the performance of automatic load balancing mechanism. Sampling for demand sensing and load balancing can be carried out in an anonymous manner at a higher frequency.

Privacy Preserving Smart Metering. The information network in a smart grid frequently transports confidential information relating to customers, for example, identity, location, possession of electronic appliances and devices, and power usage profile. Due to the increasingly important role of privacy and proprietary information in a modern socioeconomic landscape, protecting the privacy of a user is of significant importance. Several solution approaches have been proposed in this regard, one of them is a privacy preserving smart metering scheme. The steps of this scheme are as follows.

The meter transmits certified readings of measurements to the user through a secured channel.
The user calculates the final bill by combining meter readings with a certified tariff policy.
The bill is transmitted to the provider alongside a zero-knowledge proof that validates the calculation.
No other data is transmitted from user to the service provider. By limiting the data exchange to only the billing information the user's privacy is preserved. The proposed approach has the flexibility to incorporate different tariff schemes as well as certification techniques.

Distributed Data Aggregation for Billing. A distributed incremental data aggregation approach for billing is proposed here. A special entity, called the aggregator, acts as the root of the aggregation tree that covers all the meters in a given neighborhood. All smart meters in the given neighborhood follow the path dictated by the aggregation tree to forward their data towards the aggregator. The data en route is encrypted using homomorphic encryption. Homomorphic encryption represents a group of semantically secure encryption functions that allow certain algebraic operations on the plaintext to be performed directly on the ciphertext. Data is aggregated at each node of the tree before being forwarded to the upper level. The aggregator is responsible for maintaining communication with the service provider. Since the smart meters taking part in data aggregation and forwarding can see only a fragment of the final result, the user's privacy is protected. It has been claimed in that this approach is suitable for smart grids with repetitive routine data aggregation tasks.

Collaborative Usage of Resources. The dynamic demand against somewhat constant energy supply in a smart grid can be met by collaborative usage of resources. This allows a decentralized, somewhat autonomous, local distribution. However, since several entities in a grid share the pool of energy, it is also possible for one or more malicious entities on the grid to selfishly demand more energy while depriving other users sharing the same pool. To counter this kind of malicious or selfish behavior, the concept of collaborative customer and a collaborative resource usage scheme called the "voucher scheme" is introduced by grouping two or more entities together to share energy, a level of decentralization can be achieved. It is proposed that the central authority supplies energy to the group, and the group distributes the energy among the members depending on their demands. This reduces the need to send sensitive information to the central point of control. Within the group, a power user in need of extra power issues a voucher, a certificate which is immune to various security attacks, to another power user who is willing to transfer the right to use power to the former user. Thus both parties gain monetary benefit.

To summarize, the smart grid has opened up many opportunities, also many security risks. Protecting the energy generators must be given highest priority, in addition to protecting the privacy of the consumers. Power houses can be attractive terrorist targets, as much as defense installations. Therefore, in order to achieve the benefits of a smart grid, it is imperative to develop a network solution that is highly reliable and secure.

CONCLUSIONS AND RECOMMENDATIONS

Our recommendations are in line with the paper recently published by The World Economic Forum on the Future of Electricity (Ref). The three trends - Electrification, Decentralization and Digitization are expected to transform the future of electricity.

Standards have to be developed/leveraged especially as rooftop PVs proliferate

Policies across net metering needs to be developed/evaluated

Investment in R&D across the sector needs to be increased

More incentives for local manufacturing should be explored.

The implementation of PMUs should be accelerated, Standards for communication and IoT for the data arising from PMUs should be developed/leveraged and technology development in coming up with ultra-fast remedial action schemes should be proposed.

Standards needs to be developed/leveraged for distribution automation, DER management, EV integration etc. DUs should be incentivized for maintaining grid reliability and keeping losses under control. They should be encouraged to invest in new technologies.

Policies for managing Distributed Energy Resources need to evolve fast.

The real impact will be on private-sector driven Micro grid-based electrification. Several startups have enjoyed limited success...but a scalable, profitable model seems to be elusive. It is expected that the policy would address current challenges by, for example, regulating prices for Mini grid projects, streamlining regulatory approvals and clarifying where grid extensions are not planned. Other helpful measures include creating local committees at village level for payment collection and dispute resolution, supporting grid connections to sell power to local utilities, and specifying quality and performance and safety standards. R&D investments to ensure reliable and efficient operation of the micro grids should be increased and Standards for such future systems should be developed/leveraged.

India should also leverage the Electrical, Communication and IoT standards developed/implemented globally in each of the Smart Grid segments (Renewables integration, Transmission, Distribution, Micro grids) and tune them for local application, thereby accelerating the transformation of the Indian electricity ecosystem.

Department of Telecom and Telecommunication Engineering Centre (DoT/TEC) should continue its support and sanctification in making TSDSI a well-established and recognized Standards Development Organization from India and continue its momentum and work through tabling local requirements at global platform, promote relevant locally developed standards and contribute to its global harmonization. TSDSI may like to develop country specific standards where suitable international standards are lacking, including country specific applications and futuristic technologies however table these locally developed standards in global forums and get them acknowledged for its harmonization and implementation. Implement available international standards for telecom system products to avail smooth inter – connectivity, interoperability and economies of scale, wherever so applicable.

Adoption of oneM2M standards by TSDSI and its implementation by DoT/MoUD (Ministry of Urban Development) through the Centre for Development of Telematics (CDOT) platform is a major step in this direction as World's First Standardization Platform for collaborative inter-working of sensors & devices. As part of the intended Smart City rollout, this will be an important milestone and it will also help having a common standard rollout across the cities, which will also bring economies of scale and make the implementation future proof.

Finally it is of utmost Importance that Indian standards development organization such as TSDSI and other Standards Organization from around the world are all working together as part of global standards organization such as oneM2M and 3GPP while highlighting their local requirements and developing these standards in coordination to bring economies of scale and make these global standards quickly available to our country. CDOT open standard platform based on oneM2M specification shall be supported for its implementation as part of 100 Smart City mission mode project.

The developments in Communications, IoT and Cybersecurity technologies can play a significant role in the accelerated development of smart grids. Each application of smart grid has to be looked into deeply and analyze the specific standards/technologies that can be suitable.

Given the rapid evolution & intertwining of technologies, India must deepen engagement of its standardization stakeholder community such as BIS, TSDSI, TEC etc. in global standards development activities to ensure Indian needs & requirements are well positioned in global platforms such as ETSI, 3GPP, oneM2M. IEC, ITU etc. and get such requirements accepted and harmonized within the overall development and implementation of such standards.

This Indian standardization stakeholder community should also intensify cooperation and collaboration with regional Standards Development Organizations (SDOs) directly or through their local chapters such as Project SESEI (www.sesei.eu), IEEE etc. to learn, contribute and partner towards creation of global standards. This cooperation and collaboration is potentially valuable for development of indigenous technologies that are suited for the heterogeneous conditions in India.The IET thanks the following experts who made this report possible.

Mr. Prakash Nayak

Prakash Nayak, CEng is Director, PEnA Power Engineering and Automation Pvt Ltd., He has over 35 years in the field of Power Engineering and Automation including having been a Director at ABB. He is keen on Research in the area of Renewable energy and sustainability and has been on several panels and committees of the Government of India, CIGRE etc.

Mr. Mustafa Wajid

Mr. Mustafa Wajid, is the Managing Director and Chief Executive Officer at the MEHER Group. Mr. Wajid has driven technology development & business creation in Power Capacitors, Harmonic Filters & Power Quality Solutions. In addition to his business responsibilities, he has also served on several committees of Government of India.

Dr. Kannan Tinnium

Dr. Kannan Tinnium, PhD in Electrical Engineering from Tulane University, USA in 1996, is an Independent Technology Professional in the area of Electrical Power. He has over 21 years of experience working with Entergy Services Inc, USA (1996 - 2001) – one of the largest electric utilities and GE Global Research (2001 – 2017) – India and USA.

At GE Global Research, he has led teams developing technologies in Power Systems, Power Electronics, Energy Storage, Controls and Smart Grids. At Entergy he was responsible for evaluating new technologies in Transmission and performing technical studies.

He also served as the chair of the IEEE – Power and Energy Society, Bangalore Chapter, 2014-15.

Mr. Debashish Bhattacharya

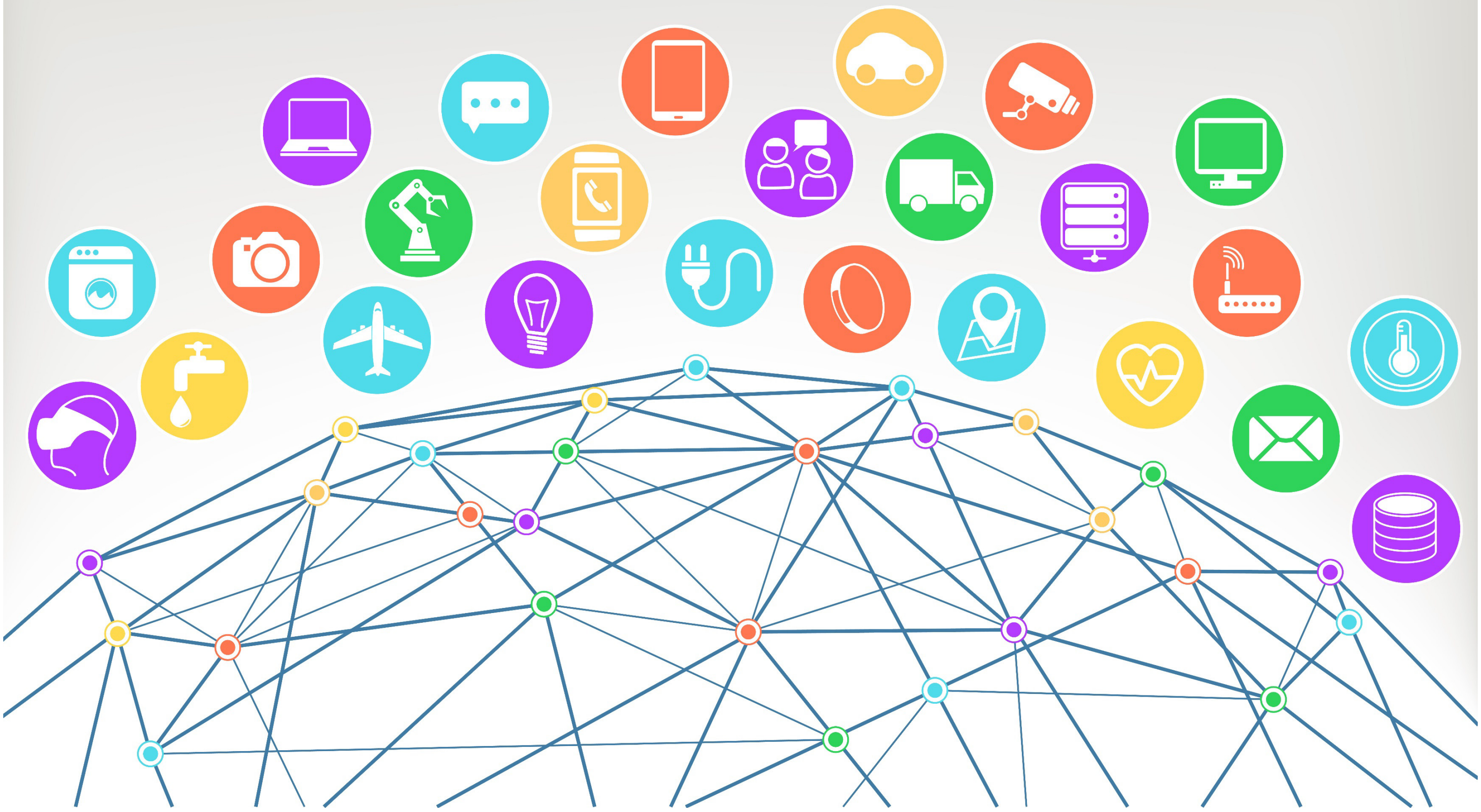
Debashish Bhattacharya is currently working as a Director-Technology & Policy at Advisory @ TVR which is a Policy & regulatory think tank solely dedicated to formulating, responding and providing suggestions, comments and inputs on various Govt Policies and regulatory interventions in the sector of Telecom, IT, Satellite, Broadcasting & Broadband. This group is headed by Mr. TV Ramachandran. Mr. Bhattacharya has capabilities in providing strategic insight in all the sectors with vast & ample experience and with special expertise of Telecom Services, Products and Solutions since last 30 Years.

Ms. Monika Gupta

Monika Gupta is the Chairperson - IET India IoT panel's Telecom working group. She is a Telecom Consultant with more than 20 years of work experience in Telecommunications / IT industry. She has vast international experience having worked on both telecom service provider and vendor side with organizations like Bharti Airtel, Ericsson, Nokia Siemens Networks, Hughes Software Systems. Her key areas of expertise are Telecom IT, OSS/BSS solutions and M2M/IoT.

Mr. M Srinivasan

Srinivasan is a staff member in the IET Office and heading Membership Operations for India. He coordinated with the other experts and SESEI in writing of this report.



CEN - European Committee for Standardization
CENELEC – European Committee for Electrotechnical Standardization
ETSI - European Telecommunications Standards Institute
EC - European Commission
EFTA – European Free Trade Association

SESEI
C/o EBTC, DLTA Complex, 1st Floor,
1, Africa Avenue, New Delhi 110029
Tel: +91 11 33521525, Fax: +91 11 33521501,
www.sesei.eu

IET India
Unit 405, 406
4th Floor, West Wing
Raheja Towers, M.G.Road, Bangalore – 560001
Tel: +91 80 4089 2222, www.theiet.in