India Smart Grid Forum

ISGF White Paper

Role of Smart Grids in Distribution

Abstract

The electric grid is at the threshold of a paradigm shift. The grid that was designed for unidirectional flow of electrons, revenue and information will now accommodate bidirectional flow of these entities. Decentralized generation is the key enabler behind this shift. Open, scalable and standards-based Machine-to-Machine (M2M) communications will help in monitoring and controlling the power flow along the low voltage lines as well. In such a grid, cyber security and data analytics will be equally important. This transition to smart grids will achieve the overarching objectives of the Ministry of Power of reducing the AT&C losses and providing 24x7 power to all households.

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About India Smart Grid Forum

India Smart Grid Forum (ISGF) is a public private non-partisan initiative of the Ministry of Power (MoP), Government of India for accelerated development of smart grid technologies in the Indian power sector. ISGF was set up in 2010 to provide a mechanism through which academia, industry; utilities and other stakeholders could participate in the development of Indian smart grid systems and provide relevant inputs to the government's decision making.

1. Introduction

Traditional electricity networks have been designed for "unidirectional" flow of electricity, revenue and information. Electricity is generated centrally at a power plant and is transmitted over high voltage transmission lines before being distributed over medium voltage and low voltage distribution lines. Communications is used only to monitor and control the power flow up to the medium voltage and low voltage substations using Supervisory Control and Data Acquisition (SCADA)/Energy Management Systems (EMS).

In a smart grid, two-way Machine to Machine (M2M) communications[1] would be used to monitor and control the power flow in the low voltage grid till the end consumers. This would be done by deploying SCADA/DMS (Distribution Management Systems). Also, there would be millions of points of electricity generation wherein electricity would be generated in a distributed manner much closer to the end consumer. Consumers would be able to generate electricity and become 'prosumers'. By doing so, they would be able to feed electricity back into the grid and generate revenue. Hence the traditional boundaries between generation, transmission and distribution are fast disappearing. M2M communications would help in monitoring and controlling these intermittent, unpredictable and dispersed sources of generation. This bidirectional flow of electricity, revenue and information in a smart grid is a major transformation from the traditional grid.

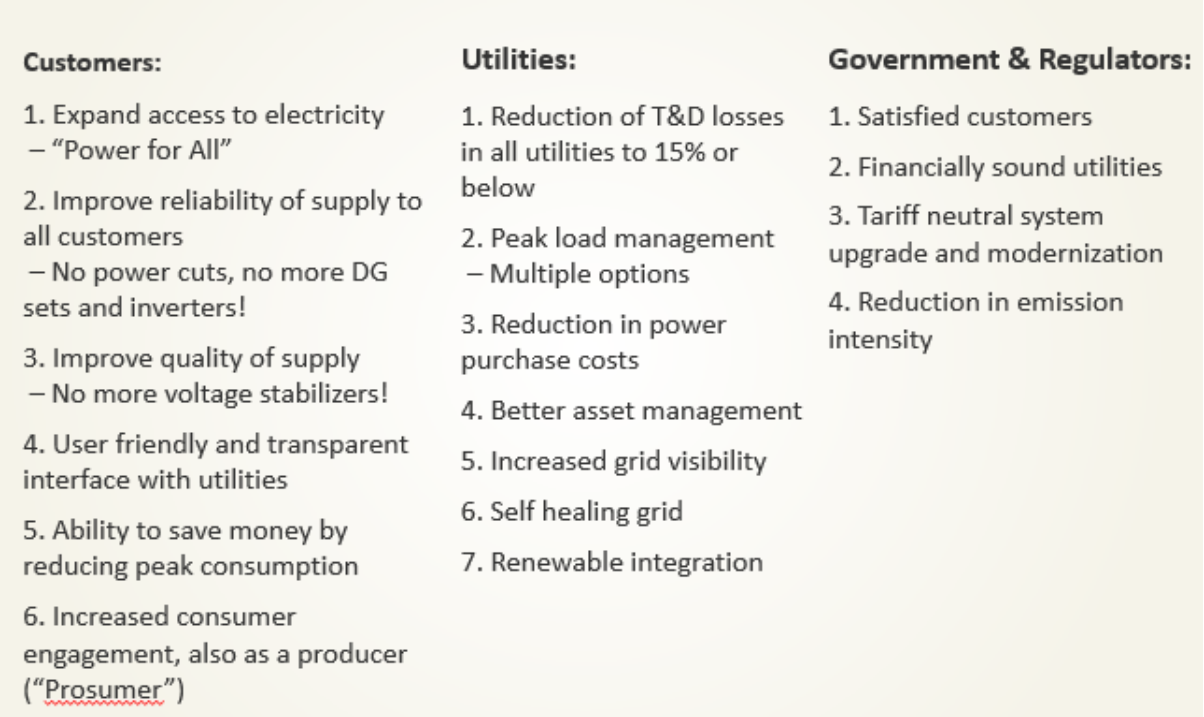


Figure 1: Drivers for Smart Grids in India

Source: '**Smart Grid Vision and Roadmap for India**' released by Ministry of Power, Government of India in September 2013.

[1] India Smart Grid Forum (ISGF) White Paper on '**M2M Communications in the Indian Power Sector**' published on December 18, 2014.

There is already a debate whether to invest in transmission or in megawatt scale energy storage technologies. This is because generating electricity in a distributed manner and storing it for local distribution seems to be an efficient, faster, less complex and a cost-effective alternative over centralized generation and transmission over long high voltage transmission lines.

Smart metering would benefit both, consumers and utilities by enabling remote reading, remote connection disconnection, remote load control via time of day or time of use prices, detecting outages early etc. Wide Area Monitoring System (WAMS) would offer a high degree of visibility in the electricity grid which would synchronously measure the phase of the current and voltage vectors.

With satisfied consumers and financially sound utilities, the Indian Government would have fulfilled the expectations of its nation. In order to reduce the carbon emission, both Government and Regulators are setting bold targets for electricity generation via renewable sources of energy.

The first attempt to implement M2M communications in the power sector was Automated Meter Reading (AMR) being implemented by distribution companies (DISCOMs) and SCADA/EMS by transmission companies (TRANSCOs). Now, many DISCOMs are also in the process of commissioning SCADA/DMS and many have already done so.

It is believed that the grid is emerging as the "Grid of Things" just like the Internet has evolved as the "Internet of Things".

2. Key challenges in the distribution sector

2.1 Accessibility

Over 300 million people have no access to electricity. Also, large parts of the country experiences power cuts for several hours every day. In order to combat this, customers keep storage invertors/standby generation facilities. Moreover, with the quality of power being poor, consumers require voltage stabilizers, UPS, inverters and so on.

2.2 AT&C losses

The transmission and distribution losses are quite high, about 7 per cent and 26 per cent respectively. Power theft is a major contributor of the distribution losses. AT&C losses translate to a loss of over 200 billion units of electricity every year which accounts for a loss of over USD 17 billion (Rs 100,000 crores) per year[2]. Transition to smart grids will achieve the overarching objectives of the Ministry of Power of reducing AT&C losses and providing 24x7 power for all households.

2.3 Ageing infrastructure

Ageing infrastructure is also consistently a concern for grid operators as they face a wave of asset replacements across their service areas. Asset monitoring, edge-of-grid sensing, improved communication networks and a better understanding of power flows on the network can all contribute to preventative asset maintenance and offer further improvements in reliability. Developing countries such as India need to improve the stability of off-grid or microgrid systems and help detect technical and non-technical losses (theft).

Moreover, there are about 500 million Aluminium-wire joints in the distribution network in India and 99% of these are improper joints. On average, 10W power is lost in each joint which means 5 million kWh lost every hour in these joints! Very long low voltage lines add to the distribution losses and in many states people steal electricity making the entire business in the sector unviable.

[2] Taking Rs 5/unit as the tariff

2.4 Grid Reliability

Grid reliability is a key concern for grid operators globally as they look to reduce the frequency and duration of outage events and ensure high quality of service. A wide range of smart grid technologies and applications are being deployed to tackle these problems, including Fault Location, Isolation and Service Restoration (FLISR), distribution automation, asset monitoring and integration of Advanced Metering Infrastructure (AMI) data into outage management systems. Much of this is being implemented at the low and medium voltage level – an area in which utilities have historically had little visibility into – but new technologies such as synchrophasors are also improving visibility at the transmission level. These tools have been demonstrated to provide cost effective ways of improving grid reliability, as measured typically by system average interruption duration and frequency indices, SAIDI and SAIFI respectively.

2.6 Distributed Generation and Grid Integration

With distributed generating capacity being connected directly to the medium and low voltage grid, issues such as voltage rise, reverse power flows and network capacity constraints are becoming more common. This is forcing DISCOMs to manage their networks more actively, something previously only done at the transmission level, and it is creating new demand for smart grid applications like Volt/VAR optimisation as well as more data and communications integration. It also blurs the lines between DISCOMs and TRANSCOs. Traditional network reinforcement solves some of these problems but can eventually become cost-prohibitive. In the longer term, new regulatory models are needed to reflect changing grid management roles and to incentivise investment in innovative grid technologies.

2.7 Communications

Although many options are present for providing last mile connectivity, simultaneously satisfying requirements such as reliability, latency and total cost of ownership still remains a challenge. In addition, with the initiatives such as the Internet of Things (IoT), M2M and Smart Cities that India has already embarked upon, they may be a need to allocate additional spectrum in the sub-GHz range. As on today, there are 2 un-licensed bands, namely, 433-434 MHz and 865-867 MHz. However, the 433-434 MHz band would not be suitable for many smart grid, smart city, M2M and IoT applications as it is regulated to operate inside the consumer's premises only.

Furthermore, the communication technologies are evolving at a much faster rate than the equipment in which it is residing. Hence the communication technology must have a long technology lifecycle for it to be used for a longer duration without being obsolete. Having pluggable communication modules will definitely solve this issue.

2.8 Interoperability

In a smart grid, interoperability is required at the device level, network level, data transport level and software (database) level. This has been a global challenge and the world is still working hard to find a solution. However, achieving interoperability at the head-end level alleviates the need to satisfy interoperability at the above mentioned levels. If we have such a scenario in smart metering, there would be different head-end systems for different meter manufacturers (and their communication technologies) and one common Meter Data Management System (MDMS).

2.9 Cyber Security

Industrial Control Systems (ICS) are critical assets of any nation. The operation and well being of the nation is directly proportional to the security of ICS. Attacks such as Stuxnet, Shamoon and Aurora (experiment) show us that resiliency and robustness need to be built by design in the ICS. There is an enormous shortage of skilled man power in India. India Smart Grid Forum (ISGF) designed a two

semester course on Cyber Security for Power Systems but it could commence as there are no teachers that can teach this.

Many utilities are still struggling to implement IT systems for baseline data gathering. Securing ICS is a far-fetched thought. This has led to the utilities being completely dependent on vendors or system integrators for maintaining their IT systems. Hence the utilities are not only unaware about any cyber security incident, but also missing out on an opportunity to obtain hands-on experience on securing the cyber space of their organisation. Moreover, cyber security for power systems has never been considered for budgetary allocations explicitly. It has always been the responsibility of the IT department to allocate funds for cyber security.

3. Role of Smart Grids in Different Domains

Smart Grid is a superposition of 2 networks: the electrical network and communications network. The electrical network includes power generation, transmission and distribution. The communications network includes the Core/Backbone network, Backhaul/Wide Area Network (WAN), Last Mile/Access/Neighborhood Area Network (NAN)/Field Area Network (FAN) and Home Area Network (HAN).

3.1 Geographical Information System (GIS)

GIS can effectively manage information on the distribution side till the end customers. This typically includes information such as asset mapping (of the electricity wires, poles, distribution transformers, substations etc.) and the attributes of each customer such as location and electricity use. DISCOMs constantly engage in updating their consumer data and the corresponding electrical network attributes. Using GIS, the entire electrical network can be overlaid on a satellite image or a vector base map. Part A of the R-APDRP program which was launched by Ministry of Power included: Preparation of base-line data for the project area covering consumer indexing, GIS mapping, metering of distribution transformers and feeders, and automatic data logging for all distribution transformers and feeders and SCADA/DMS (only in the project area having more than 4 lacs population and annual input energy of the order of 350 MU). This would include asset mapping of the entire distribution network at and below the 11Kv transformers and include the distribution transformers and feeders, low tension lines, poles and other distribution network equipment.

3.2 SCADA/DMS

SCADA (Supervisory Control And Data Acquisition) is a system for acquiring and controlling the numerous devices placed on the electrical grid. SCADA/DMS is used to measure the voltage, current, active power, reactive power, power factor etc., acquiring the status of switches, protection relays and faults of Feeder Terminal Unit (FTU), and controlling switches and relays from the control centre.

Typically, a Remote Terminal Unit (RTU) acts as an intermediate device between the control centre and Intelligent Electronic Devices (IEDs) on the grid. The communication requirements for SCADA are very stringent. These include (but are not limited to) extremely high availability, reliability and information security, along with very low latency.

3.3 Advanced Metering Infrastructure (AMI)

From electromechanical meters to electronic meters to AMR (Automated Meter Reading) and prepaid meters to smart meters, the metering industry has embraced evolving information and communication technology for bringing along a revolution in utility operations. With the advent of an

Advanced Metering Infrastructure (AMI), both consumers and the utilities would benefit. The consumers would be able to[3]:

a. View their consumption of electricity accurately on a regular basis
b. Manage loads in different manners based on the design, ranging from remotely turn ON/OFF their appliances to managing total demand to allow curtailed supply instead of load-shedding
c. Save money from Time of Use (ToU) tariffs by shifting non-priority loads
d. Face reduced outages and downtimes, and even lower or zero load-shedding

Utilities would benefit in the following ways (which would pass on to the consumer):

a. Financial gains by
    i. Managing the load curve by introducing ToU/ToD tariff, demand response etc.
    ii. Reducing equipment failure rates and maintenance costs
    iii. Enabling faster restoration of electricity service after fault/events
    iv. Detecting energy theft/pilferage on near real-time basis
    v. Streamlining the billing process
    vi. Remote meter reading which reduces human resources, human errors and time consumption for meter reads
b. Respond to power outages and detect meter failures (with no on-site meter reading)
c. Enhanced monitoring of the system resources that would significantly improve the reliability indices like CAIDI/CAIFI, SAIDI/SAIFI etc.
d. Improvement in other key performance indicators

In November 2014, the Government of India released IPDS[4] (Integrated Power Development Scheme) and DDUGJY [5](Deen Dayal Upadhyaya Gram Jyoti Yojana). As part of these schemes, the optical fiber being installed to provide broadband connectivity to 250000 gram panchayats [as part of the National Optic Fiber Network (NOFN)] will be extended for connecting all 33KV and above substations to create a backbone network for the Indian power sector.

3.4 Distribution Automation and Substation Automation

A typical distribution network consists of grid substations with HT incomers, distribution transformers, Ring Main Units (RMU), reclosers and voltage regulators. By employing automation elements at all/some of these locations, the overall reliability of the network and the efficiency in maintaining the network can be improved. The general scope of this system covers the following functions –

- Centralized monitoring and control of distribution networks
- Energy monitoring
- Load profiling & demand side management

Similar to SCADA/DMS, the communications requirements for distribution automation are more stringent as compared to AMI.

[3] India Smart Grid Forum (ISGF) White Paper on '**Smart Metering Scenario in India**' published on March 31, 2014.

[4] Ministry of Power Website - http://powermin.nic.in/upload/pdf/Integrated_Power_Development_Scheme.pdf

[5] Ministry of Power Website - http://powermin.nic.in/upload/pdf/Deendayal_Upadhyaya_Gram_Jyoti_Yojana.pdf

3.5 Outage Management System (OMS)

An outage management system (OMS) is a utility network management software application that models network topology for safe, efficient field operations related to outage restoration. OMSs tightly integrate with call centres to provide timely, accurate, customer-specific outage information, as well as SCADA systems for real-time-confirmed switching and breaker operations. These systems track, group and display outages to safely and efficiently manage service restoration activities. In other words, fault identification, isolation and restoration are key elements of OMS.

3.6 Distributed Generation

Distributed generation refers to the generation of electricity by using small scale technologies close to the end user. Examples of distributed generation using renewables include solar, small hydro, wind, biogas and hydrogen energy. Non-renewable fuels such as diesel, natural gas and kerosene are also used for generating electricity in a distributed manner.

Solar PV has already achieved grid parity in many parts of the globe including in Delhi where the highest slab for domestic consumers is Rs 8.9/kWh whereas PV rates have come out to Rs 6.00/kWh which will unleash a rooftop PV revolution in India. PV technology[6] is not the only factor changing demand patterns. Smart thermostats and heating control systems are becoming increasingly popular in North America and Europe and provide homeowners with more control over energy consumption. Residential Demand Response (DR) programmes aiming to tap into this demand side flexibility are also increasing. Uptake of smart appliances such as washers and dryers able to respond to TOU pricing of DR events has been limited so far, but could provide further flexibility.

M2M communications would be used for communicating the amount of electricity generated in near real-time to a control centre, remote asset monitoring and controlling the amount of energy generation as per the needs of the utility.

3.7 Electric Vehicles

Ministry of Heavy Industry in 2012 launched the National Electric Mobility Mission Plan (NEMMP), which envisage target of 6 million electric vehicles (2 million four wheelers & 4 million two wheelers) on the road by 2020. Department of Heavy Industries (DHI) in order to support NEMMP, has formulated a scheme called FAME - India [Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India]. Main focus areas envisaged in this scheme are: technology development, demand creation, pilot projects and charging infrastructure.

Electric vehicles carry sufficient energy in their battery packs that can be utilized for other purposes other than powering the propulsion system when the vehicle is not in use. Vehicle to Grid (V2G) technology is the technology that is used to provide power to the grid. V2G is gathering increasing acceptance through pilot projects around the world and has shown positive results. With a vision of such a large number of vehicles on the road, India has a huge potential to use these electric vehicles as virtual power plants.

In order to relay the information regarding charging of the electric vehicle to the utility, M2M communications will be vital for the functioning of the electric vehicle charging infrastructure. Thus, a reliable and secure communications technology would be required for the EV charging infrastructure.

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[6]India Smart Grid Forum (ISGF)-Bloomberg New Energy Finance (BNEF) Knowledge Paper on '**Smart Grids in India**' published on March 03, 2015.

3.8 Energy Storage

With India aiming at 175 GW of grid connected renewable generation resources, there is a need for storage applications to address the issues of variability, intermittency, unpredictability and location dependency of renewable energy sources.

Large-scale storage facilities can arbitrage base load generation by storing electricity during non-peak hours and providing power in long-duration discharges and also provide low-cost ancillary services such as load following and spinning reserves. Large scale energy storage helps on both the supply and demand side of the wholesale generation market. Although they do help offset the need for additional peaking capacity, large-scale storage facilities are focused more as system optimizers rather than generation replacement.

M2M communications, both at the supply side and the demand side, would be needed to provide the necessary visibility in the grid for monitoring and controlling the amount of electricity storage in near real-time.

3.9 Microgrids

A microgrid is a local grid with integrated energy system that intelligently manages interconnected loads and distributed energy resources and is capable of operating in parallel with, or independently, from the existing utility's grid. The generation and distribution of power can be operated in island mode or grid connected mode.

Microgrids can customize local energy demand curve for a particular area by integrating conventional power supply with locally installed distributed Generation viz. solar, wind, biomass, waste to energy etc. As a result, they reduce load on main grid, encourage distributed power generation, allow for islanding from main grid which in turn lead to grid independence and offer a reliable and un-interrupted source of energy to the users connected to the microgrid.

The driving factors of microgrids include (but are not limited to) efficiency, reliability, energy security, economic savings, revenue generation and sustainability.

The main components of a microgrid are a master controller (that matches the load with generation by optimising the integration, dispatching and control of distributed energy resources and loads), AMI, distributed energy resources and energy storage.

3.10 Application Integration

Over time, data have been exchanged, duplicated and changed from applications to applications without formal governance and management; resulting in data quality, integrity, security, accuracyand consistency issues in many area. Size and variety of data have grown exponentially and will only increase in the future; yet data and information remain locked within silos of business and technologies.

Major programs such as AMI, DAS, Asset/Work Management, GIS, OMS etc. will introduce many times more data with more vendor applications and their new proprietary data formats, resulting in potentially more silos. To help the utility enterprise to commit to managing data and information as assets, a strategy and roadmap needs to be developed to facilitate strategic thinking amongst the key stakeholders and set paths for future pragmatic plans. Hence integration of all the applications that will be used in a smart grid will be critical to its seamless operation.

3.11 Home Energy Management/Building Energy Management

Smart homes would offer monitoring and control of the electricity usage within the consumer premises. Aggregators or energy management systems would be the core of home automation. In addition to a smart meter that would remotely connect and disconnect the supply, smart appliances would provide the energy consumption data to the consumer and the utility. These smart appliances would lead to a reduction in the energy consumption via efficient use of electricity. The consumer could view the consumption data via an In-Home Display (IHD) device or via SMS, e-mail or by logging on to a consumer portal. Furthermore, loads could be controlled via aggregators or energy management systems.

3.9 Cross Cutting Domains – Communications, Cyber Security and Data Analytics

In the above mentioned verticals, efficient operation of the cross cutting domains such as communications, cyber security and data analytics will be critical for the functioning of a smart grid.

3.9.1 Communications

While selecting communications technologies, there is no one cap size that fits all. The smart grid will consist of multiple communication technologies that would perform specific roles. However, the backhaul and backbone technologies may be same.

The selection of a technology will depend on the envisaged application. That is, for mission critical applications (such as SCADA/DMS, SCADA/EMS, Distribution Automation etc.), security, reliability and latency will be the key criteria for deciding the communication technology. Cost will be of least priority. For non-critical applications (such as AMI, connectivity for Distributed Generation, etc.), cost will be decisive.

3.9.2 Cyber Security

Protection of the critical infrastructure (encompassing energy, transportation, banking and finance, communication and IT, defence, space, law enforcement, sensitive government organisations, critical manufacturing and e-governance) is the primary objective of any nation and the power sector assumes top priority. With this convergence of the electrical technologies, information technologies and operational technologies in a smart grid, security of industrial control systems has become extremely important. The security of the information infrastructure directly decides the reliability of the power system infrastructure. The key objectives of security in a smart grid include ensuring confidentiality, integrity and accountability, and preventing denial of service.

As compared to enterprise IT systems that require a reliability of 95-99% and last for 3-5 years, ICS require a reliability in excess of 99.9 % and a lifespan of 15-20 years. In addition, for ICS, availability of data is of higher importance than integrity and confidentiality. In SCADA/DMS, one can trip electric feeders at will if one can gain access into the SCADA control centre. Also, replay attacks can overflow the buffers leading to a denial of service attack. In addition, if one gets to know the energy consumption pattern of a household, a potential robbery can occur.

Hence the enterprise IT systems and ICS should be physically or logically isolated. Zones and perimeters should be clearly defined and secured. Intrusion prevention and detection systems need to be put in place. Policies, Plans and Procedures such as Cyber security policy, Change Management Procedure, Configuration Management Procedure, Information and Document Management Procedure, Access Control Procedure, Identification and Authentication Procedure, Monitoring and Review Procedure, Personnel Security Procedure, Physical and Environmental Security Procedure, System and Communication Protection Procedure, Awareness and Training Procedure, Incident

Response Procedure, Media Protection Procedure, Risk Assessment Procedure, Business Continuity Plan etc. are a must. Furthermore, there needs to be separate budgetary allocation for cyber security.

3.9.3 Data Analytics

With the advent of multiple systems such as SAP, MDMS, AMI, DMS, GIS, CRM, DAS etc. being implemented by utilities, processing of data over different data formats and platforms is required to take business decisions. Analytics helps to sharpen the focus so that critical details can be seen to solve complex business problems and achieve key objectives.

4. Conclusion

Smart grids are a journey and not a product and hence it will evolve at different rates at different locations. A smart grid, being a system of systems, cannot afford to have a system requirement specification like R-APDRP.

Developed nations with reliable electric grids are investing in smart metering, data communications and advanced IT systems. In addition, they are also investing in analytics, tools for forecasting, scheduling and dispatching to further their smart grid journey. On the other hand, developing countries like India need to invest in both strengthening the electrical network as well as adding communications, IT and automation systems to build a strong and smart grid. Furthermore, it will be consumers and not information and communications technology that will transform the power sector.