What is Transforming the Smart Grid

Smart grid is the paradigm for a class of technology being designed to join forces and modernise our entire energy industry. This story gives a glimpse of how it is being done and what it means for you

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Imagine a country with no load shedding, power cuts or black-outs. A new era of reliable and efficient electricity supply is what the smart grid concept promises.

Integrating modern digital electronics technology into the electrical power grid enables the utility to detect, monitor and respond digitally to any changes, thus making it a smarter version of the grid and earning it the name 'smart grid' in the process.

The current power grid is based on decades-old technology that makes it prone to a lot of outages. An imbalance in the stress on a power grid could cause electricity disruption. If this imbalance is not corrected in time, it could have a domino effect, affecting the functioning of other critical utilities.

By implementing the smart grid concept, the grid will be armed with a plethora of sensors, controllers, communication equipment and new technology that enables the grid to be truly automated—thus enabling it to promptly respond to any incidents in the grid. "This also means that the smart grid technology is a multidisciplinary area, requiring power engineers, IT, telecom and modelling forecasting to work together," says Sandra Diethelm, CEO, Exuta (India) Pvt Ltd.

How a smart grid responds to an outage

When a disturbance in the grid is initiated, the sensing and monitoring mechanism of the grid detects the cause of the outage and enables the grid to take measures to quarantine it so it does not affect the rest of the grid. In the quarantined grid, the technology begins working on recovering electricity distribution to the critical services first—providing power to hospitals, police institutions, communications, etc. It will also loop in consumer-controlled power-generation sources when the utility is unable to provide enough power, thus fostering energy trade within the community as well.

Elements of a smart grid

Evolution of smart grid technologies

Here we look at some recent advances in various aspects of smart grid technologies.

Even smarter meters. Smart meters are not only limited to measurement, but also play an integral part in deriving the quality of power. "An energy audit meter not only measures the power on a relative parameter, but also measures its quality," explains A.V. Srinivasan, area manager—south, M.B. Control and Systems Pvt Ltd. He further explains that smart audit meters analyse the power by decoding parameters such as harmonics, power factor and so on.

The newer meters not only monitor and provide data to services connected to it but also provide control over the network to designated control centres.

> "Smart grid is not always about smart meters. Australia's smart meter rollout made sense in Melbourne but not anywhere else. A national smart meter rollout does not appear to be on the agenda today, nor probably in the near future."
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> *—Sandra Diethelm, CEO, Exuta (India) Pvt Ltd*

With these meters, actions such as overshooting your maximum demand (MD) control or introducing harmonics into the grid will trigger a response from the control centre directly to your meter (which is now more of a controller).

In smart meter chips, metrology is an analogue function where we accurately detect energy across a wide current range. "Integrating multiple analogue functions into one chip is a tremendously difficult task because it involves merging functions that were originally optimised in different process geometries. Ultimately, the biggest challenge is in making the performance of analogue functions similar or better," says David Andeen, segment manager—smart grid, Maxim Integrated.

One indigenous example of this technology is in the MREV e2o electric vehicle manufactured by Mahindra Reva Electric Vehicles Pvt Ltd. Stated as Car2Home technology; it allows to power your home by using a car's power during times of need. An on-board computer smartly regulates the power supplied to your home, and a full battery can ensure that the house is powered up for several hours depending on the load. This technology is complemented by the Sun2Car technology, in which a 10 sq m solar panel is set up to provide sufficient energy to power your car.

However, Diethelm says, "The electricity network is not designed for two-way power flows. This means that the network can experience issues when people generate power on their own and supply it to the grid. A common issue is higher than normal voltage levels when connecting solar system, which then damages appliances of consumers who are connected to the same grid."

Evolving communication standards. One of the challenges in this area is the lack of a standard protocol for communication. "Various state utilities are experimenting in a different manner, for instance Maharashtra has looked at Zigbee for AMR-related data collection," explains Thakurdesai.

"The current focus is on powerline communication (PLC), where we have defined G3 and we are also implementing additional solutions. We have also partnered with RadioPulse for ZigBee solutions.," adds Andeen.

Syam Madanapalli, CEO and co-founder, iRam Technologies, explains why a smart grid network is best based on IPv6 (the successor to IPv4; the next generation protocols for the Internet) and IEEE 802.15.4 (the wireless standard from IEEE for the Wireless Personal Area Networks (WPANs)). According to him, "Various devices at a given location in the proposed architecture form a mesh using IPv6 and IEEE 802.15.4 and communicate to rest of the smart grid using a border router. These meshes would be replicated throughout the electrical grid and finally connected to utility using appropriate wide area network (WAN) technologies that are commercially available from the telecom operators or ISPs."

Advanced metering infrastructure (AMI) and distribution automation. AMI is being more deeply integrated into the grid, and its projects are increasingly implemented by utilities, particularly for use in distribution automation (DA) applications.

AMI networks require robust communications between individual meters and data concentrators. They use either RF mesh or RF star topology, or implement PLC.

For example, to implement AMI, an IPv6-based wireless communication module is attached/integrated into the home energy meter. Few hundreds of homes in a given locality can form a mesh and connect to the utility using one-gateway routers. An additional border router can be provided for load balancing and redundancy purpose.

Automated test equipment. The current slew of smart-grid test equipment is automated systems that can test all kinds of relays from manufacturers including ABB and Siemens, as well as different kinds of protection such as overcurrent, distance, differential and generator protection. When enquired about an instrument named smart Megger relay tester (SMRT), a senior engineer explained that conventional test equipment was fully manual and, as with any manual labour, there is a certain amount of human error that is introduced. Modern automated equipment takes away human error and also reduces the amount of work that he/she has to put in.

The voltage levels faced whilst testing circuit breakers are very dangerous. "Modern equipment allows you to do dual-ground testing, which enhances safety levels considerably. Conventionally, with both sides grounded, you are unable to even make a measurement, but our new solution is so unique in that this can be carried out," explains Ajay Goyal, managing director, Megger (India).

A switchgear will have electrical disconnect switches, fuses or circuit breakers used to control, protect and isolate electrical equipment. V. Narayanan, senior application engineer, Megger (India), says, "To check one switchgear, they needed the help of two to three people in order to test it properly. A new tool targeting this problem is the protection condition analyser. This tool allows to test simultaneously all of the key elements of substation protection systems—including protection relay,

Factors that led to initiation of the July 2012 grid disturbance in India

1. Weak inter-regional corridors due to multiple outages
2. High loading on 400kV Bina-Gwalior-Agra link
3. Loss of 400kV Bina-Gwalior link

Ensuring grid security. To ensure grid security, islanding scheme for Delhi has been finalised and is under finalisation for UP, Punjab and Haryana. DISCOMs were asked to ensure compliance within ±150MW or 12 per cent of their schedules irrespective of frequency. Feeder transmission lines have been identified for disconnection in case of violation of overpower withdrawal limits.

— Report of Enquiry Committee on Grid Disturbance in Northern Region on July 30, 2012

Advantages of using IPv6 for the smart grid network

Scalability. It provides uniform addressing and seamless connectivity to a larger number of devices.

WAN connectivity. This architecture provides aggregation of many household energy meters/sensors/controllers (typically few hundreds, say 500).

Energy consumption. Each sensor or end node needs to communicate to another device, which is typically located at few meters to few hundred meters; thus the amount of energy consumed will be much lower.

Seamless web services. Applications can be developed independent of the transport network as the applications are not tied to the equipment and can be obtained from the open market.

Open standards. All IP networks are based on true open standards; utilities can mix and match the equipment from multiple vendors across the world.

Simple network architecture. Every device talks IP—no protocol translators, no address translators, no information translators—yielding a simple all-IP network—easy to operate and maintain with low cost of ownership.

End-to-end security. Internet Engineering Task Force (IETF) has developed extensive security protocols for use with IP that provide end-to-end security across multiple heterogeneous interconnected administrative domains.

—Syam Madanapalli, CEO and co-founder, iRam Technologies

Smart meters and harmonics analysis

Harmonics are electrical voltages and currents that appear as a result of non-linear electric loads. "It shows up as an intermediate frequency riding on a fundamental current, which is an interruption to the main current. It is a loss not only for energy but also for motors, transformers and similar equipment," adds Srinivasan.

Harmonics generate a lot of heat as they travel on the surface of the conductor, which affects insulation and drastically reduces equipment life span. A smart grid meter addresses this problem by monitoring the power quality and taking actions in accordance with its observations.

Electromagnetic compatibility and the smart grid

Electromagnetic compatibility (EMC) must be considered to ensure continuous reliable real-time operation in many locations where the smart grid equipment will operate. Components and devices in the smart grid system are subjected to a wide range of conducted and radiated noise sources that are disruptive to all electronic systems (smart grid systems included). These sources can be categorised as follows:

1. Conducted noise from powerline harmonics, surge (from lightning and power system switching transients) and fast transients/bursts (interruption of inductive DC circuits)
2. Radiated noise or signals from known transmitters (AM, FM and TV broadcast transmitters, communications radios, wireless devices, etc).
3. High power events such as geomagnetic storms, intentional EM interference (IEMI) from portable transmitters and EM pulses associated with high-altitude nuclear detonation (HEMP).
4. Electrostatic discharge (ESD) events when a statically charged body (human or inert) comes in contact with a smart grid device.

—Excerpt from "Electromagnetic compatibility and smart grid interoperability issues" by SGIP Electromagnetic Interoperability Issues Working Group

circuit breaker, DC system and protection circuitry—even whilst the system is on-load. Once the test is completed, it outputs the results on the display.

Multiphysics simulation. The huge engineering project of migrating the electrical grid to a smart grid involves modernising several electrical components. For engineers at ABB Corporate Research Power Technologies in Sweden, multiphysics tools have proved an invaluable tool for modelling the coupled electromagnetic, thermal and fluid phenomena that take place within these systems.

Data modelling and forecasting

This is where all the data gathered by the sensors, smart meters and other equipment are put into use.

Avoid gold plating the electrical grid. Unlike how it sounds, 'gold plating' is where everything is over-designed to be safe, by going overboard with thresholds and limitations. Without smart technology to optimise the operation of the power network, gold-plating has been a common approach to ensure that the network is not going to melt during abnormal events.

One of the approaches to overcome gold-plating is the dynamic rating of equipment. This can be applied to overhead lines, underground cables, transformers, etc.

"A recently developed, groundbreaking technology is a 3D model of the electricity network which provides numerous applications including modelling and forecasting applications. An aeroplane loaded with sensors is flown over the network, where it gathers Lidar data point and other relevant data—such as temperature, wind speed, electromagnetic field, heatmaps, etc. An algorithm is run over the Lidar data to automatically extract the utility's assets, resulting into a 3D model and exact position of the utility's assets and nearby environment such as trees," explains Diethelm.

Is an automated power grid secure?

In addition to terrorist activities, natural disasters and ageing equipment can also bring down the electrical grid. Cumulative smart-grid cyber security investment from 2011 to 2018 will total $14 billion, forecasts Pike Research.

"This requires a better emergency management system with appropriate electronic access control and video surveillance to mitigate problems. The system should also be able to isolate problems and restore electrical services as quickly as possible when disaster happens," says Madanapalli. The existing SCADA systems are more prone to cyber attacks as the utilities start using more and more computer-based applications without an end-to-end design for the smart grid implementation. ●

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