Smart Grid Technology an Overview

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Abstract--Established electric power systems, which have developed over the past 70 years, feed electrical power from large central generators up through generator transformers to a high voltage inter connected network, known as the transmission grid. The distribution system, feeding load, is very extensive but is almost entirely passive with little communication and only limited local controls. The present revolution in communication systems, particularly stimulated by the internet, offers the possibility of much greater monitoring and control throughout the power system and hence more effective, flexible and lower cost operation. The Smart Grid is an opportunity to use new ICTs to revolutionize the electrical power system. The purpose of this paper is to explain the concept of Smart Grid and through light on importance of Smart Grid development, its domains and challenges ahead.

Index Terms--Distribution Management System, Information and Communication Technology, Smart Grid, Wide Area Management System.

I. INTRODUCTION.

The electric power system delivery has often been cited as the greatest and most complex machine ever build. It consists of wires, cables, towers, transformers and circuit breakers. All are bolted together in some fashion. [1]

Established electric power systems, which have developed over the past 70 years, feed electrical power from large central generators up through generator transformers to a high voltage interconnected network, known as the transmission grid. Each individual generator unit, whether powered by hydropower, nuclear power or fossil fuelled, is large with a rating of up to 1000 MW. The transmission grid is used to transport the electrical power, sometimes over considerable distances, and this power is then extracted and passed through a series of distribution transformers to final circuits for delivery to the end customers.

The part of the power system supplying energy (the large generating units and the transmission grid) has good communication links to ensure its effective operation, to enable market transactions, to maintain the security of the system, and to facilitate the integrated operation of the generators and the transmission circuits. This part of the power system has some automatic control systems though these may be limited to local, discrete functions to ensure predictable behavior by the generators and the transmission network during major disturbances.

The distribution system, feeding load, is very extensive but is almost entirely passive with little communication and only limited local controls. Other than for the very largest loads, there is no real-time monitoring of either the voltage being offered to a load or the current being drawn by it. There is very little interaction between the loads and the power system other than the supply of load energy whenever it is demanded.

The present revolution in communication systems, particularly stimulated by the internet, offers the possibility of much greater monitoring and control throughout the power system and hence more effective, flexible and lower cost operation. The Smart Grid is an opportunity to use new ICTs to revolutionize the electrical power system. In brief, smart grid is the use of sensors, computational ability and control in some form to enhance the overall functionality of the electric power delivery system. [2]

II. THE SMART GRID

The Smart Grid concept combines a number of technologies, end-user solutions and addresses a number of policy and regulatory drivers. It does not have a single clear definition.

The European Technology Platform [3] define the Smart Grid as: "A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies."

In Smarter Grids: The Opportunity [4], the Smart Grid is defined as: "A smart grid uses sensing, embedded processing and digital communications to enable the electricity grid to be observable (able to be measured and visualized), controllable (able to manipulated and optimized), automated (able to adapt and self-heal), fully integrated (fully interoperable with existing systems and with the capacity to incorporate a diverse set of energy sources)."

According to the US Department of Energy [7]: "A smart grid uses digital technology to improve reliability, security, and efficiency (both economic and energy) of the electric system from large generation, through the delivery systems to electricity consumers and a growing number of distributed-generation and storage resources."

The literature [7–10] suggests the following attributes of the Smart Grid:

1) It enables demand response and demand side management through the integration of smart meters, smart appliances and consumer loads, micro-generation, and electricity storage and by providing customers with information related to energy use and prices.
2) It accommodates and facilitates all renewable energy sources, distributed generation, residential micro-generation, and storage options, thus reducing the environmental impact of the whole electricity sector.
3) It optimizes and efficiently operates assets by intelligent operation of the delivery system and pursuing efficient asset management.
4) It assures and improves reliability and the security of supply by being resilient to disturbances, attacks and natural disasters, anticipating and responding to system disturbances (predictive maintenance and self-healing), and strengthening the security of supply through enhanced transfer capabilities.
5) It maintains the power quality of the electricity supply to cater for sensitive equipment that increases with the digital economy.
6) It opens access to the markets through increased transmission paths, aggregated supply and demand response initiatives and ancillary service provisions.

III. NEED OF SMART GRID TECHNOLOGY

Since about 2005, there has been increasing interest in the Smart Grid. The recognition that ICT offers significant opportunities to modernize the operation of the electrical networks has coincided with an understanding that the power sector can only be de-carbonized at a realistic cost if it is monitored and controlled effectively. In addition, a number of more detailed reasons have now coincided to stimulate interest in the Smart Grid.

A. Ageing assets and lack of circuit capacity

In many parts of the world the power system expanded rapidly from the 1950s and the transmission and distribution equipment that was installed then is now beyond its design life and in need of replacement. In many countries the overhead line circuits, needed to meet load growth or to connect renewable generation, have been delayed for up to 10 years due to difficulties in obtaining rights-of-way and environmental permits. Therefore some of the existing power transmission and distribution lines are operating near their capacity and some renewable generation cannot be connected.

B. Thermal constraints

Thermal constraints in existing transmission and distribution lines and equipment are the ultimate limit of their power transfer capability. When power equipment carries current in excess of its thermal rating, it becomes over-heated and its insulation deteriorates rapidly. This leads to a reduction in the life of the equipment and an increasing incidence of faults.

C. Operational constraints

Any power system operates within prescribed voltage and frequency limits. If the voltage exceeds its upper limit, the insulation of components of the power system and consumer equipment may be damaged, leading to short-circuit faults. Too low a voltage may cause malfunctions of customer equipment and lead to excess current and tripping of some lines and generators.

D. Security of supply

Modern society requires an increasingly reliable electricity supply as more and more critical loads are connected. The traditional approach to improving reliability was to install additional redundant circuits, at considerable capital cost and environmental impact. A Smart Grid approach is to use intelligent post-fault reconfiguration so that after the faults in the power system, the supplies to customers are maintained but to avoid the expense of multiple circuits that may be only partly loaded for much of their lives.

IV. SMART GRID DOMAINS

A. Generation

Co-existence of various types of renewable and non-renewable generating technologies, such as coal, hydro, nuclear, solar, biomass, geothermal, etc. system operator has to coordinate the operation of the generation plants, and ensure the stable and secure operation of the system. Wide area measurement system (WAMS) enabled by communication technologies need to be used to control the operation of the generating stations. WAMS based power system stabilizer is one such example. Communication infrastructure needs to be in place between the generating facilities and the system operator, electricity market, and the transmission system.

B. Transmission

Energy-efficient transmission network will carry the power from the bulk generation facilities to the power distribution systems. Communication interface exists between the transmission network and the bulk-generating stations, system operator, power market, and the distribution system. The transmission network needs to be monitored in real-time, protected against any potential disturbance. The power flow and voltage on the lines need to be controlled in order to maintain stable and secure operation of the system. An important task of the system operator is to ensure optimal utilization of the transmission network, by minimizing the loss and voltage deviations, and maximizing the reliability of the supply.

C. Distribution

Substation automation and distribution automation will be the key enablers for the smart distribution systems. Increasing use of distributed energy resources (DERs) will be an important feature of future distribution systems. Distribution system operator typically controls the distribution system remotely. Communication infrastructure to exchange information between the substations and a central distribution management system (DMS) therefore should be in place. An important job of the distribution system operator is to control the DERs in a coordinated way to ensure stability and power quality of the distribution system. Information exchange between the distribution system operator and the customers for better operation of the distribution system is a new feature of the smart distribution systems.

D. Customer

Customers can be classified into three main categories: residential, commercial, and industrial. In smart grids, customers are going to play a very important role through demand response. By peak-load shaving, valley-filling, and emergency response, customers are going to play an active role in better operation of the distribution system Building or home automation system will monitor and control the power consumption at the consumer premises in an intelligent way. Proper communication infrastructure will be required for the consumers to interact with the operators, distribution systems, and the market.

E. Operation

Smart grid operations require communication interface with the bulk generating facilities, transmission system, substation automation, distribution automation, DMS, consumers, and the market. Metering, recording, and controlling operations come under the purview of the smart grid operations. Real-time information exchange with the power market needs to be established in order to implement power trading and scheduling. The operators need to interact with various service providers for ensuring proper functioning of the smart grid. Information exchange with the consumers or prosumers is the key for the operators to implement the so called demand management system.

F. Markets

Smart grid power market needs to develop, keeping in mind all the objectives of the smart grid. The communication infrastructure integrating the bulk generation, transmission, distribution, consumers, markets, and service providers is the key to the success of the power market in a smart grid. Appropriate regulatory policies need to formulate for seamless integration of the various domains, including the storage and DER aggregators into the smart grid market. The pricing information has to be made available online for shorter intervals (hours or even minutes).

G. Service Providers

Various service providers will emerge, as the smart grid business model matures. Communication interface with the operator, market, and consumers will be needed for the service providers. Examples of services are forecasting for renewable generation, Billing and customer complain management, Building and home management, Installation and commissioning services, Account management etc.

V. TECHNOLOGIES FOR SMART GRID

To fulfill the different requirements of the Smart Grid, the following enabling technologies must be developed and implemented [2]

A. Information and communications technologies.

These include:

1) Two way communication technologies to provide connectivity between components in the power system and loads.
2) Open architectures for plug-and-play of home appliances; electric vehicles and micro generation
3) Communications, and the necessary software and hardware to provide customers with greater information, enable customers to trade in energy markets and enable customers to provide demand side response.
4) Software to ensure and maintain the security of information and standards to provide scalability and interoperability of information and communication systems.

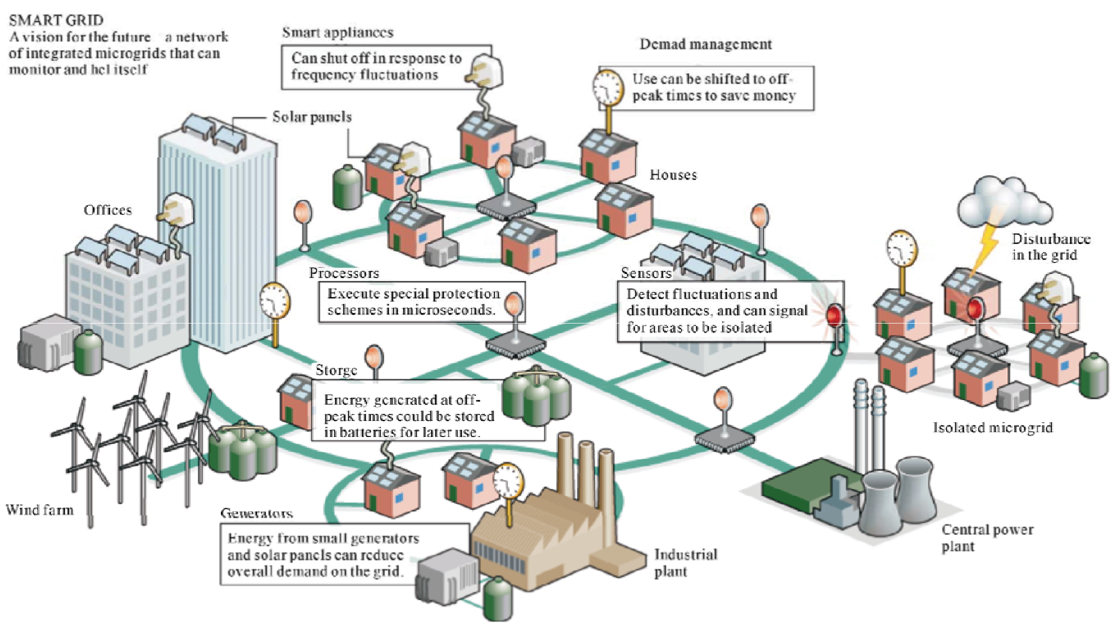

Fig. 1. Conceptual Smart Grid

B. Sensing, measurement, control and automation technologies.

These include:

1) Intelligent Electronic Devices (IED) to provide advanced protective relaying, measurements, fault records and event records for the power system;

2) Phasor Measurement Units (PMU) and Wide Area Monitoring Protection and Control (WAMPAC) to ensure the security of the power system;
3) Integrated sensors, measurements, control and automation systems and information and communication technologies to provide rapid diagnosis and timely response to any event in different parts of the power system. These will support enhanced asset management and efficient operation of power system components, to help relieve congestion in transmission and distribution circuits and to prevent or minimize potential outages and enable working autonomously when conditions require quick resolution.
4) smart appliances, communication, controls and monitors to maximize safety, comfort, convenience, and energy savings of homes;
5) Smart meters, communication, displays and associated software to allow customers to have greater choice and control over electricity and gas use. They will provide consumers with accurate bills, along with faster and easier supplier switching, to give consumers accurate real-time information on their electricity and gas use and other related information and to enable demand management and demand side participation.

C. Power electronics and energy storage.

These include:

1) High Voltage DC (HVDC) transmission and back-to-back schemes and Flexible AC Transmission Systems (FACTS) to enable long distance transport and integration of renewable energy sources.
2) Different power electronic interfaces and power electronic supporting devices to provide efficient connection of renewable energy sources and energy storage devices;
3) Series capacitors, Unifide Power Flow Controllers (UPFC) and other FACTS devices to provide greater control over power flows in the AC grid;
4) HVDC, FACTS and active filters together with integrated communication and control to ensure greater system flexibility, supply reliability and power quality;
5) Power electronic interfaces and integrated communication and control to support system operations by controlling renewable energy sources, energy storage and consumer loads;
6) Energy storage to facilitate greater flexibility and reliability of the power system.

VI. CONCLUSION

We can conclude that “Smart grid” that we call it *Thinking Network*, is the term commonly used to refer to an electrical grid whose operation has been transformed from a twentieth century analog technology base to the pervasive use of *Digital Technology* for communications, monitoring (e.g., sensing), computation, and control. Managing the large amount of information and ensuring its security will be a big challenge. Cyber-security and cloud computing applications are bound to get increased importance. Experts from various domains need to be involved.

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