Smart Grids, Deployment Efforts and Challenges

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Abstract:- **With changing times and ever advancing technologies, it is very pertinent that the current electric power system evolves. The improvement in the existing system is whetted by exigent necessity to decarbonize electricity supply, to replace ageing assets and to make potent use of booming information and communication technology (ICTs). The aforementioned requirements are met by Smart Grids, the concept of which revolves around the idea of providing greater visibility to lower voltage networks and enabling the consumers in the operation of power system, through Smart Meters and Smart Homes. Thus, Smart Grids tend to make use of the advanced ICT to control new energy system consistently, reliably and efficiently. There are thousands of power plants that generate electricity using wind energy, nuclear energy, coal, hydro, natural gas, and a variety of other resources. These electric generating stations produce electricity at a certain electrical voltage, which is stepped up or down as per the requirement at each level of distribution of electricity. A network of electrical components deployed to supply, transfer, and use electric power make up a power system. The basic idea behind Smart Grids is to add monitoring, analysis, control, and communication capabilities to the electrical delivery system to maximize the energy throughout of the system while reducing the loses. Consumers, thus, with the advent of Smart Grid will have the flexibility and choice to manage their electrical use helping them in slashing the electrical bill.**

I. INTRODUCTION

Existing electric power system has developed over the past seventy years. Electrical power from generators through generating transforms is fed to high voltage interconnected network. Such web of transmission lines, substations, transformers and more, forming a nexus of synchronized power providers and consumers, conveying electricity from the generating station to homes and businesses is an electric grid. In India, to allow the transmission of excess electricity between States in each region, in 1960s individual State grids were interconnected to form 5 regional grids- Northern, North Eastern, Eastern, Western and Southern. In October 1991, the interconnection of North Eastern and Eastern grids took place which was followed by linking of the Western Grid with the aforementioned grids, in March 2003. Subsequently with the interconnection of the Northern grid, in August 2006, a Central Grid operating at one frequency was formed. The Southern Grid, the only remaining regional grid, too was synchronously linked to the Central Grid, with the commissioning of the 765 kV Raichur-Solapur transmission line, on 31 December 2013. Thus, the National Grid was established making Indian power system as the largest operating synchronous grid in the World.

The large generating units and transmission grids together form the part of the power system which supplies energy. This part, for the sake of integrated operation of the generators and transmission circuits, has great communication links, which ensures effective operation, enables market transactions and helps in maintaining security of the system. However, the part of the power system that feeds the loads, i.e. the distribution system, has very little communication. In distribution system, except for extremely large loads, there is no real time monitoring of either the voltage being offered or the current being drawn by load, making this extensive system almost entirely passive. In fact according to the Ministry of Power, with an average of 26 per cent of total electricity produced, India's transmission and distribution losses are amongst the highest in the world. These losses do not include non-technical losses like theft etc. The effective management of loads, reduction of losses and wastage of energy needs accurate information. With the advent of internet and other revolutionary communication technologies, there is actually a strong possibility to monitor and control the power system more thoroughly so as to make the entire operation more effective, flexible and economical.

There is also a demand for the development of low-carbon energy technologies in order to address the global challenges of energy security, climate change and sustainable economic growth. India is, thus, steadily venturing into generation of electricity with the help of renewable energy resources like wind and solar. It is necessary to have a grid that is highly adaptive as the use of large amounts of renewable generation marks feeding of the grid with uncertain and unpredictable energy sources. Hence there is a requirement for the integration of the load in the operation of power system in order to help balance supply and demand.

As good electricity supply is one of the key infrastructure requirements to support overall development, the need of the hour is to modernize existing power system and Smart Grid is a nebulous term spanning various functionalities geared towards modernizing the electricity grid. It represents a grid that can automate and manage the increasing complexity and needs. With the help of digital technology, a two-way communication between the utility and its customers is possible, by using sensors, along the transmission lines. The opportunity to use new information

and communication technologies (ICTs) to restructure the existing electric power system is the Smart Grid. It is a dynamic interactive, real-time infrastructure that responds to the challenges of designing and building the power system of the future, rather than being simply a marketing term. The smart grid represents the longer-term promise of a grid remarkable in its intelligence and impressive in its scope. At its core, a smart grid utilizes digital communications and control systems to monitor and control power flows, with the aim to make the power grid more resilient, efficient and cost effective. Since 2005, a great deal has been accomplished to develop and communicate the concepts that define what we call the smart grid today. A number of studies have concluded that, when viewed at a high level, the benefits of a smart grid far outweigh its costs—that is, when all costs and all benefits applicable to all stakeholders are included.

A proper implementation means strengthening the grid, including extending it offshore, developing decentralized architectures for system control, enabling an active demand side and thus, delivering communications infrastructure, integrating intermittent generation, capturing the benefits of Distributed Generators (DG), preparing and propagating electrical vehicles. Obviously, this indicates towards an overall intelligence of generation, demand and the grid. It is to be kept in mind, with that amount of, physical and institutional complexity of electricity systems makes it unlikely that the market alone will implement smart grids on the scale that is needed. So, Government, the private sector, consumer and environmental advocacy groups must work together to define needs of electricity system and determine smart grid solutions.

II. STIMULI FOR SMART GRIDS

Although, most stakeholders will enjoy some benefits of a Smart Grid, the biggest winner will be society as a whole. The piqued interest in Smart grids, since 2005, is because a number of reasons and advantages have coincided. The smart grid is expected to provide benefits to society in the following areas:

- *Ageing Assets:*

The current power system expanded rapidly from the 1950s and the transmission and distribution equipments set up and installed then, at most of the places, are now out dated far beyond their design life. Also with the ever increasing demand, population boom and heightened technical developments many of the power transmission and distribution lines are operating near their very capacities. Along with that, in some places, renewable generation cannot be connected to the main system. An opportunity to innovate with new and novel designs and operating practices is, thus, presented with the need to refurbish the transmission and distribution circuits. It is about time for the literati to come up with methods to increase the power transfer capacity of circuits dynamically and rerouting the power flows through less loaded circuits.

- *Thermal Constraints:*

The ultimate limit of the power transfer capability in existing transmission and distribution lines and equipments is the thermal constraint. Due to overheating an increase in the number of incidents of fault are seen as overheating deteriorates the insulation, reducing the life of equipment. Public safety, also, comes under scanner as any time the current passing through overhead line is too much, the length of conductor increases, which in turn increases the sag of the catenaries, hence the clearance to the ground is reduced. The use of dynamic rating might be a viable solution for increasing system capacities as the thermal constraints depend on environmental conditions which are continuously changing

- *Supply Security:*

Reliable electrical supply is a must in today's day and age as more and more critical loads are connected and dependence on electricity is increased. An intelligent post fault reconfiguration that can actually help supply power to consumers after, almost inevitable, faults is by making sure that the circuits are only partly loading for most of their lifetimes. This reduces the number of redundant circuits, resulting in a better utilization of assets, reduced capital costs and lesser environmental impact. Although, electrical losses should be increasing due to partial loading.

- *Energy costs:*

Smart Grids monitors and adjust energy use through smart meters and home energy management systems. Smart grid improvements convert system events into instantly-retrievable digital information, thus facilitating the real time trouble shooting. With such improved efficiency come reduced producer costs. Smart grid allows direct communication with end-user equipment to reduce consumption during the peak periods, lowering the need for costly standby power plants.

- *Operational Constraints:*

Each power system has specific voltage and frequency limits under which it can properly operate. On exceeding the upper limit, the insulation gets damaged reducing the span of life of the components of power system. This might even cause short circuit faults. Lesser voltage than the lower limit causes malfunctioning of equipments at consumer’s end. A large current may start flowing and can cause tripping of some lines and generators. Renewable power cannot be predicted well in advance and generated power generally has variable output. Nuclear power plants can operate at a constant output only, due to technical reasons and traditional fossil fuelled plants may take around six hours to start up from cold. Due to all these reasons, achieving a proper balance between supply and demand, while keeping supply frequency constant is difficult. While spinning reserves might seem like the answer, for only part load generation the financial investment are high.

Smart Grids make renewable power feasible, by ensuring that this energy can be stored safely and distributed where and when it's needed. In coming times, a more flexible system is hoped to be in place and Smart grid might take our nation's position at the forefront of the world's transition toward a clean energy future and might even secure its power independence.

III. THE PRINCIPAL CHARACTERISTICS OF THE SMART GRID

1. Active consumer side

2. Various Generation and storage options

3. New products, services, and markets

4. Provides power quality for the digital economy

5. Optimizes asset utilization and operates efficiently

6. Anticipates and responds to system disturbances (self-heals)

7. Operates resiliently against attack and natural disaster

Technological Solutions Required for a Smart Grid Implementation:

Smart grids are complex systems. The following technology solutions are generally considered when a smart grid implementation plan is developed:

- *Information and Communication Technologies:*

One of the most prominent features of Smart Grids is a two way communication between different components in power system and loads. ICT thus, presses towards unified communications and the integration of telecommunications, computers as well as necessary enterprise software, middleware, storage, and audio-visual systems, which enable users to access, store, transmit, and manipulate information. ICTs include open architecture for plug and play of home appliances, electric vehicles and micro-generation. ICTs also provide the necessary software and hardware which enables customer's trade in energy market and provide demand-side response. It enables, with proper software, to exchange and make use of information, maintain and ensure security of that data and standards to provide scalability.

- *Sensing, Measurement, Control and Automation Technologies*

To fulfill the different requirements of the Smart Grid advanced protective relaying, measurements and fault records for the power system requires Intelligent Electronic Devices (IED). Phase or Measurements Units (PMU) and Wide Area Monitoring, protection and Control (WAMPAC) are also needed to ensure the security of the power system. The much needed technologies also include integrated sensors, measurement, control and automation system and information 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. To maximize safety, comfort, convenience and energy savings of home smart appliances, communication, controls and monitors are required. Advanced metering infrastructure (AMI) is architecture for automated, two-way communication. AMI provides utility companies with real-time data about power consumption and allows customers to make informed choices about energy usage based on the price at the time of use. Customer technologies, such as in-home displays and programmable communicating thermostats, combined with AMI enables utilities to offer time-based rate programs and incentives that encourage customers to reduce peak demand and manage energy consumption and costs. A Distribution Management System (DMS) is a collection of applications designed to monitor and control the entire distribution network efficiently and reliably by acting as a decision support system to assist the control room and field operating personnel with the monitoring and control of the electric distribution system. Transmission Enhancement Applications exploit the time periods in which the offered load of a particular type is less than its minimum allocated bandwidth by allowing the difference to be available to other generic load. Asset/System Optimization (AO) is a set of activity created to make sure that the operational performance is maximized relative to the cost. The major aim of optimization is to achieve the best possible performance from the grid.

- *Power Electronics and Energy Storage:*

Energy storage will, obviously, lead to increased flexibility and reliability as a whole of the system. Power electronic interfaces and integrated communications and control are bound to support system operations by controlling renewable energy resources, energy storage and consumer loads. Power Electronics and Energy Storage technologies also include high Voltage DC (HVDC) transmission and Flexible AC Transmission System (FACTS) to enable long distance transport and integration of renewable energy sources. HVDC, FACTS along with active fiters and integrated communication control increase flexibility, reliability and power quality mainfolds. There are, also, various other power electronic interfaces and supporting devices to provide efficient connection of renewable energy sources and energy storage devices. Series capacitors, Unified Power Flow Controllers (UPFC) and FACTs devices provide great control over the power flows in AC line.

IV. SMART GRID DEMONSTRATION AND DEPLOYMENT EFFORTS

Most current smart grid pilot projects focus on network enhancement efforts such as local balancing, demand-side management (through smart meters) and distributed generation. Demonstration projects have so far been undertaken on a restricted scale and have been hindered by limited customer participation and a lack of a credible aggregator business model. Data (and security) challenges are

likely to increase as existing pilots expand to larger-scale projects. Non- network solutions such as ICTs are being used in a growing number of smart grid projects, bringing a greater dependence on IT and data management systems to enable network operation. Although significant effort and financial resources are already being invested in smart grids, the scale of demonstration and deployment co-ordination needs to be increased. Several organizations have created, are creating or are calling for the creation of an inventory or database of detailed case studies to gather the lessons learned from such projects, particularly in the areas of policy, standards and regulation, finance and business models, technology development, consumer engagement and workforce training (Momoh, 2009). Some national smart grid demonstration and deployment efforts:

China: China's State Grid Corporation (SGCC) outlined plans in 2010 for a pilot smart grid programme that maps out deployment to 2030, releasing a medium-long term plan for development of Smart Grids and related technologies. Smart grids investments will reach at least USD 96 billion by 2020. By 2020, Chinese government also intends to decrease carbon emission per unit of GDP to 40-45 % of that in 2008.

United States: USD 4.5 billion was allocated to grid modernization under the American Recovery Reinvestment Act of 2009, including: USD 3.48 billion for the quick integration of proven technologies into existing electric grids and USD 435 million for regional smart grid demonstrations. According to Public Law 110-140- DEC 19, 2007 the States "is supporting modernization of electric transmission and distribution networks to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve increased use of digital information and controls of technology."

Australia: The Australian government announced the AUD 100 million "Smart Grid, Smart City" initiative in 2009 to deliver a commercial-scale smart grid demonstration project.

Japan: A smart grid that incorporates solar power generation is being tried to be developed by the Federation of Electric Power Companies of Japan to mainstream the solar power generations by 2020 with government investment of over USD 100 million. The Japanese government has announced a national smart metering initiative and large utilities have announced smart grid programmes. Along with that, 26 electrical utilities, manufacturing and research laboratories in Japan have conducted a national project called "The Field Test Project on Optimal Control Technologies for Next Generation Transmission Distribution System" to develop the required technologies. Smart Grids have also garnered much attention for the reconstruction of damaged districts from Tohoku Earthquake on March 11, 2010

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