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Challenges of Smart Grid

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Abstract: Smart Grid has been evolved as the innovative idea globally as a solution for the power demand problems. Countries worldwide are looking for an efficient implementation of the same. A lot of research is now going on the various issues and challenges on the implementation and real time operation of the various components of Smart Grid. This paper presents a review on different challenges of electric power system in smart grid aspects. This also gives an insight into the current status of the research and developments in the field of smart grid. Authors strongly believe that this survey article will be very much useful to the researchers for finding out the relevant references in the field.

Keywords: Smart Grid Challenges, Intelligence, Communications, Integrating intermittent generation, Moving offshore, Energy storage, Plug-in hybrid vehicles

I. INTRODUCTION

An electrical grid is an interconnected network for delivering electricity from supplier to consumers. It consists of generating stations that produce electrical power, high-voltage transmission lines that carry power from distant sources to demand centres, and distribution lines that connect individual customers [1]. It is an indisputable reality that electric power is one of the major and most important technologies that led to the rapid industrialization and globalization in the twentieth century. Today's electrical grid suffers from a number of problems, including that it is: Old (the average age of power plants is 35 years), dirty (more than half of our electricity is generated from coal), Inefficient (the delivered efficiency of electricity is only 35%,and vulnerable (the worst blackout in the history which affected 620million people, 9% of the total population of the world occurred on 2012 July 30th and 31st across 22 states of Northern, Eastern and North-eastern India). About 32GW power was taken offline from the grid.

It is a well-known fact that Thomas Edison and Alexander Graham Bell were the key architects of the electric power and communication systems respectively. If both were somehow transported to the 21st century, Bell would hardly be able to recognize the components of today's communications systems. On the other hand, Thomas Edison will still be able to recognize almost all the major components in today's electrical grid system. This proves the fact that the existing electrical power system needs a lot of design improvements and vital upgrades to cope up with the 21st century needs[2].

II. SMART GRID

In accordance with IEEE [3], the Smart Grid has come to describe a next generation electrical power system. It is typified by the increased use of communications and information technology in the generation, delivery and consumption of electrical energy. Another definition of Smart Grid can also be considered. According to Wikipedia it delivers electricity from suppliers to consumers using digital technology to control appliances at consumer's premises to save energy, reduce cost and increase reliability and transparency. As said by Green Energy Act (Canada) it is a nickname for an ever widening palette of utility applications that enhance and automate the monitoring and control of electrical distribution. DOE: The Smart Grid transforms the current grid to one that functions more cooperatively, responsively and organically.

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[4]. The smart grid is intelligent as it is capable of sensing system overloads and rerouting power to prevent or minimize a potential outage;of working autonomously when conditions require resolution faster than humans can respond and cooperatively in aligning the goals of utilities, consumers and regulators .It is capable of meeting increased consumer demand without adding infrastructure which shows its efficiency. Accepting energy from virtually any fuel source including solar and wind as easily and transparently as coal and natural gas; capable of integrating any and all better ideas and technologies energy storage technologies. This grid enables real-time communication between the consumer and utility so consumers can tailor their energy consumption based on individual preferences, like price and/or environmental concerns. This creates new opportunities and markets by means of its ability to capitalize on plug-and-play innovation wherever and whenever appropriate. Smart grid should be quality-

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focused – capable of delivering the power quality necessary – free of sags, spikes, disturbances and interruptions – to power our increasingly digital economy and the data centres, computers and electronics necessary to make it run. It is increasingly resistant to attack and natural disasters as it becomes more decentralized and reinforced with Smart Grid security protocols. It shows the advance of global climate change and offering a genuine path toward significant environmental improvement.

As illustrated in Figure 1, the smart grid can be defined as a system that employs digital information and control technologies to facilitate the deployment and integration of distributed and renewable resources, smart consumer devices, automated systems, electricity storage and peak-saving technologies.

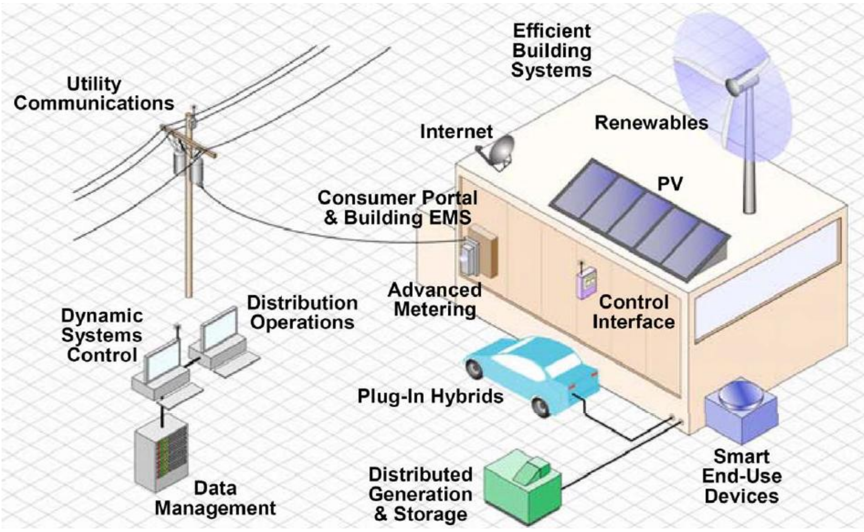

Figure 1. Smart Grid concept

A Smart Grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies toward:

1. Better facilitate the connection and operation of generators of all sizes and technologies
2. Allow consumers to play a part in optimizing the operation of the system
3. Provide consumers with greater information and choice of supply
4. Significantly reduce the environmental impact of the whole electricity supply system
5. Deliver enhanced levels of reliability and security of supply

Smart Grids deployment must include not only technology, market and commercial considerations, environmental impact, regulatory framework, standardization usage, ICT (Information & Communication Technology) and migration strategy but also societal requirements and governmental edicts.

Table 1 shows a comparison between the traditional or current electric grid and the smart grid.

TRADITIONAL GRID	SMART GRID
Centralized Generation	Distributed Generation
Electromechanical	Digital
Failures and Blackouts	Adaptive and Islanding
Lack of real time monitoring	Extensive real time monitoring
Slow Reaction time	Extremely quick reaction time
Manual Restoration	Self-healing
One way Communication	Two way communication
No energy Storage	Energy Storage
Total control by Utility	Increased customer participation

Table1. Comparison of Traditional Grid and Smart Grid

III **SMART GRID CHALLANGES**

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The Key Challenges for Smart Grids are: Strengthening the grid, Enhanced intelligence, Communications, Integrating intermittent generation, Moving offshore, Capturing the benefits of DG and storage and Preparing of plug-in hybrid vehicles. Let us peep in to each one separately

A. Strengthening the grid

It should be ensured that there is sufficient transmission capacity to interconnect energy resources, especially renewable resources. The electric power grid is over a century-old and is considered to be the largest and most complex interconnected physical system on earth. Due to its vastness, complexity and being inextricably linked to human development and involvement, it is termed to be an ecosystem in itself.

B. Enhanced intelligence

FREEDM SYSTEM is proposed with the purpose of developing technology to revolutionize the nation's power grid, henceforth speeding renewable electric-energy technologies into every home and business. Since it contains many novel devices, the Future Renewable Electric Energy Delivery and Management system has features that are different from the traditional distribution system. The system diagram is shown in Figure 2 where it contains distributed energy storage device and distributed renewable energy resource has a loop configuration, which may allow a more flexible operation and improve the supply reliability; however, it becomes more challenging to protect the FREEDM system. In the FREEDM system, power electronics devices have been widely applied to gain intelligent energy management, improved power quality, and other advantages [6].

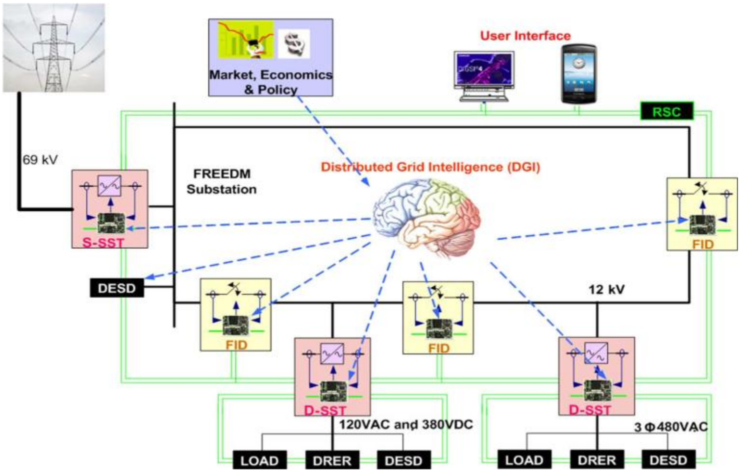

Figure2 : Electric grid diagrams conceptualizing the FREEDM system and its interfaces

However, those that connect to the grid directly or through a transformer, can only allow about 2 pu current to flow during a fault; thus, the traditional fault detection methods, such as over current detection, is hindered because the current is not high enough. In addition, the load and supply of the FREEDM system may be significantly asymmetrical, resulting from the presence of distributed energy storage device and distributed renewable energy resource. The basic symmetrical components analysis therefore cannot be applied without modifications because the system is already asymmetrical under normal conditions. The conventional differential protection is not appropriate for a distribution such as the FREEDM system as well because the protection range of the system is the section, including not only the distribution lines, but the loads.

C .Communications

Smart Grid will integrate all the components of power system to enhance the performance of the grid. Much of the integration of components relates to communication systems, IT systems, and business processes. Efficient communication is needed for proper co-ordination of protective devices to adopt the new operating conditions. Distribution networks are designed to deliver power to customers within certain voltage tolerances without overloading equipment. For Smart grid, real time data and active grid management, requires fast and two-way digital communication with third party entities. Electric utilities use a wide variety of telecommunications including wired and wireless telephone, Voice and data dispatch radio, Fibre optics, Power line carrier communication, Satellite and internet. A group-based protocol for improving the energy distribution in smart grids which is able to self organizes connections between smart nodes from different groups based on their available network connections and load [7]**.**

Advanced metering infrastructure (AMI) includes the both the physical smart meter (a digital electricity meter located at the end consumer that enables two-way communication) as well as the communications infrastructure to transport the data that is generated. The latter involves the development of an intelligent field area network, that will

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facilitate the communications link back to the utility's operations and control center, but also to the network inside the home or building[8]. One of the key outstanding questions in the AMI space is how smart meters will communicate with one another and with other devices on the grid. Here there are three main competing technologies: broadband over powerlines, radio frequency mesh networks, and cellular networks. Smart Meters provide knowledge, increase awareness and change customers' behaviour and attitudes in using renewable energy. In the future, renewable energy is the means to reduce carbon emissions and gas emissions during power generation. Although it may not be cheap in terms of the generation cost at the moment, customers can at least reduce the impact on climate change. Hence, if every household can use electricity and gas efficiently, there is a resulting need to minimize power generation as well [9].

D. Integrating intermittent generation

Economic dispatch deals with the minimum cost of power production in electrical power system analysis [10], [11]. More specifically, in solving this problem, one seeks to find the optimal allocation of the electrical power output from various available generators. Prior to the widespread use of alternate sources of energy, the problem involved only conventional thermal energy power generators, which use depletable resources such as fossil fuels. It has become apparent that there is a need for alternatives to thermal energy power generation.

Finding the best ways of integrating intermittent generation including residential micro generation is a tough task.The main challenges of operating a power grid with a high proportion of generation based on renewable resources include that these resources: are less predictable than traditional fuel based power plants, may be far from load centres so power may have to flow through congested transmission paths, do not generally match the daily cycle of load variation, suffer from unusual operating constraints, such as, rapid variation or complicated weather dependence, and need to be tightly coupled to storage. It is widely accepted that renewable energy sources are the key to a sustainable energy supply infrastructure since they are both inexhaustible and non-polluting. A number of renewable energy technologies are now commercially available, the most notable being wind power, photovoltaic, solar thermal systems, biomass, and various forms of hydraulic power. A method has to be proposed for optimally allocating different types of renewable distributed generation units in the distribution system so as to minimize annual energy loss [12].

One associated term is MPPT - Maximum Power Point Tracking. Electricity in a PV system is generated by individual PV cells operating at low voltage and low current, dozens of individual cells are arranged in series-parallel configurations within a PV module, and tens to hundreds of modules are then arranged in series-parallel arrays to create high voltage and the desired power. But connecting cells in series forces the same current to flow in each cell, and connecting them in parallel enforces the same voltage .This is acceptable if each cell is perfectly identical and operates at the same temperature and insolation level. In practice, however, because the voltage-current characteristics of the PV cell are nonlinear, even small differences can result in substantial lost generation. Binning, the process of sorting cells based on tested performance by the module manufacturer adds cost to the system and can't compensate for differences that occur to statistical divergence as the cells age. Techniques for maximum power point tracking have therefore become standard practice [13].

E .Moving offshore

Developing the most efficient connections for offshore wind farms and for other marine technologies is a key issue. Potential benefits of the smart grid technology are that it's central control will now be able to control and operate many remote power plant, optimize the overall asset utilization and operational efficiently. In [14] propose an innovative approach for the smart grid to handle uncertainties arising from condition monitoring and maintenance of power plant.Unlike traditional maintenance optimization methodologies that only consider the equipment lifetime distribution, an adaptive condition-based maintenance scheme is proposed in this paper. The key difference is that other operation-related variations are also considered. This feature is particularly useful for offshore power systems because they are remotely located and difficult to access for data acquisition, inspection, and maintenance.

F. Capturing the benefits of DG and storage

Even if connected to the utility grid, renewable energy storages are usually coupled with other energy sources to improve robustness against intermittent outages. Hybrid energy systems are absolutely essential for remote off-grid installations. The popular approaches include the use of fossil fuel-driven generators (diesel), batteries, flywheels, super capacitors and compressed air systems. Their environmental impact is important, since the use of RESs is strictly related to providing a more sustainable energy processing. An adhoc hydrogen network in parallel to the electric grid may offer an effective storage system, leading to the use of renewable energy storages directly producing hydrogen and fuel cells as a transportable storage. This may eventually lead to the hydrogen era foreseen by some scientists[15].

For new wind farms, the types of interconnection studies that are required at the distribution level can be summarized in terms of power quality and voltage impacts (short term and long term). For bulk systems, the typical concerns are more related to the impact on stability, voltage support, and ability to balance the intermittency using complementary generation, typically by allocating sufficient spinning reserves. Various studies have been completed in these areas. However, more work is still required in order to provide a generalized methodology, as existing methods are either not yet sufficient, or have not been made public [16].The main challenges with wind farm integration and energy storage can be listed as Intermittency, Ramp rates, Limiting wind farm power output [17].

G.*Preparing of plug-in hybrid vehicles*

Smart Grids must accommodate the needs of all consumers, electric vehicles are particularly emphasized due to their mobile and highly dispersed character and possible massive deployment in the next years, what would yield a major challenge for the future electricity networks. The emerging of plug-in hybrid vehicles results not only in the increase of electric vehicles as means of transportation, but also in the utilization of vehicle batteries for grid support, which is referred to as vehicle-to-grid (V2G). However, V2G is still at a conceptual stage, and the lack of practical and realistic frameworks to help moving from concept to implementation causes serious challenges to its adoption. In this context,[18] proposes a practical model for the assessment of the contribution of V2G systems as a support to energy management within realistic configurations of small electric energy systems including renewable sources, such as Microgrids

H. *Advanced power system monitoring, protection, and control*

Synchronized phasor measurements are becoming an important element of wide area measurement systems used in advanced power system monitoring, protection, and control applications. They are power system devices that provide synchronized measurements of real-time phasors of voltages and currents. Synchronization is achieved by same-time sampling of voltage and current waveforms using timing signals from the Global Positioning System Satellite (GPS). Synchronized phasor measurements elevate the standards of power system monitoring, control, and protection to a new level.

IV**. CONCLUSION**

The transition towards a smart grid from the current electric grid is one of the most important decisions to meet for electric reliability, economy, efficiency and sustainability goals. Only through a well structured grid, efficient, reliable and secure communication technologies and integrated intelligent decision making capabilities associated with the structure, a Smart Grid can evolve. An integrated environment with distributed generation sources, a good transmission management system, Outage management system etc. are also inevitable in this environment. All these have to be brought into the existing power grid in a very cost effective manner. For the same a lot of research works still remain with respect to the different components of Smart Grid.

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