Basic Definitions of Smart Grid Technologies and Applications

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BASIC DEFINITIONS OF SMART GRID TECHNOLOGIES AND APPLICATIONS

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ABSTRACT

Smart Grids came about as an answer to a need to modernize the electricity grid, make it greener and improve the delivery of power. Smart Grid provides consumers better choice of supply and information also permits consumers to play a part in optimizing operation of the system. It enables demand side management (DSM) and demand response (DR) through the incorporation of smart appliances, smart meters, microgeneration, electricity storage and consumer loads and by providing consumers the information regarding energy use and prices. Information and incentives will be provided to consumers for revising their consumption pattern to overcome few constraints in the power system and improving the efficiency. This paper provides an overview on the basic definitions of smart grid as well as an introduction about the applications of Smart Grid technologies for home and building automation, smart substation and feeder automation.

Keywords: Smart grid; Power quality; Energy Management System; Renewable energy.

1. Introduction

Electricity is the main driver of the world economy and it is a clear indication of community prosperity. The power system reliability, security, quality, and adequacy are the main challenge in all modern studies in this issue [1]. Due to the intermittent nature of the renewable energy sources, the increase in their penetration ratio may cause power quality problems in the power system [2]. The Smart Grid offers an answer to the shift to more sustainable technologies such as distributed generation and microgrids. A general public awareness and adequate attention from potential researchers and policy makers is crucial [3]. The Smart Grid [4] is a chance to utilize the new communication technologies and information to revolutionize the conventional electrical power system. Technically, smart grid is a concept for the conventional grids with some latest and automated features which make them more reliable and sustainable. mart metering and data management along with bidirectional communication provide a number of facilitates in the generation, transmission and distribution of energy. For instance, power outages can be avoided by applying the consumer threshold for energy usage in case of the lack of energy and it can be possible to prevent subscribers being without power by reducing downtime caused by overload. Apart from these, energy storage is another form of network balance by regulating energy supply and load demand in each hierarchical frequency control in micro-grid networks [5]. With the storage of renewable energy, DC power is considered as an energy supplement to make the network stable in AC power interruptions. The energy storage applications have also been conducted for different smart grid purposes by electric vehicles, renewable generation systems, electricity markets, energy policy and power system management. In addition, intelligent transformers can be operated in an effective manner in order to provide efficient energy protection and the algorithms can be improved for the detection of cyber-attacks that cause to the power outages in the smart grid environment [6]. Information encryption and decryption techniques should be implemented between manufacturers and consumers in smart grids [7]. Energy conservation and demand management programs included in Smart Grid helps in reducing energy consumption. Integrating climate change considerations into Smart Grid planning and deployment, electricity stakeholders can ensure that the implemented Smart Grid technology does not contribute to greenhouse gas emissions and does not result in a grid that is vulnerable to climate change related damage. Reduction in wasted energy, losses and effective management of loads needs accurate information. Combination of different generator modules increases the difficulty to manage the power system to run at constant output for commercial and technical reasons. It is hard to control and monitoring cost-effective and synchronized operation such a power system without the help a smarter grid. Hence, Smart Grid is essential for future power system [8]. Due to the fact that fossil fuel is a fading source, the world researchers are trying to utilize the renewable energy sources that can operate in multi-sources of Distributed Generations (DGs) units as a wind turbine, photovoltaic system, which consist of a microgrid system [9]. Microgrids generates electricity from small distributed sources such as wind parks and solar farms near consumer in order to prevent transmission and distribution losses [10]. Fig. 1 illustrates the sample of micro-grid design.

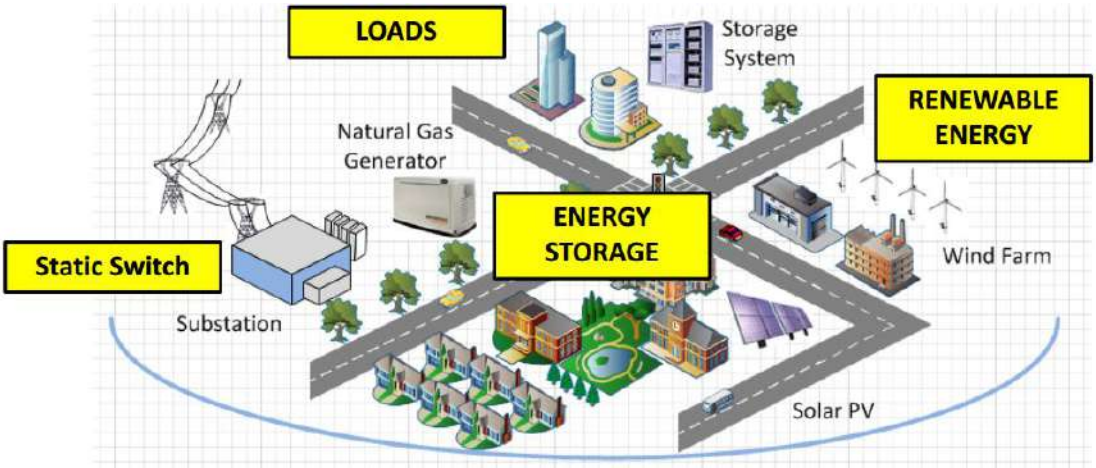

Figure 1. A sample of Micro-Grid design.

2. Benefits of the Smart Grid

Providing security of supply in the network raises the issue of energy efficiency. The customer also has great responsibility alongside energy efficiency starting from subscriptions until delivery to the subscriber in an optimized way. Subscriber will contribute to this process by the selection of equipment and using it at convenient times. Keeping in mind the balance of the entire system constructed by the network structure will reveal itself. Consumers would support more longevity of the network and the effective protection minimizing technical losses by changing habits and drawing energy from the network over time.

2.1 Reliability

Smart Grid has a potential to detect any fault and allow the self-healing of the system. Success of the grid system depends upon the customer need which is measured as reliability. This mean as flaw less and error less system with continuous supply of electric power [11-12]. Smart Grid has a potential to detect any fault and allow the self-healing of the system. Smart Grids have capability to monitor and store all the data and estimate its service reliability. It may also possible to monitor remotely for hybrid generation and management of the grid which enhance its reliability. Conventional grids have issues regarding interaction of renewable resources, micro grid and demand response but these points are very well addressed by Smart Grid. Smart Grids can have better reliability with the advancement in communication system.

2.2 Security

With the increase of automation, remote monitoring and controlling of the grid make the grid more unsafe by cyber assault [12-13]. So, security is considered one of the biggest barriers for implementation of Smart Grid technology.

2.3 Demand side management system

Smart grid provides the demand side or user to interact with the grid by using two ways communication ability. Smart grid provides a chance for the consumer to use the electric power in an economical way. Smart grid will not only help for increasing efficiency at demand side but also at distribution end. Smart grid helps grid to reduce demand and stress during peak period by reducing or shifting power requirement to alternatives [12]. Demand side management (DSM) allows customers to make informed decisions regarding their energy consumption, helps the energy providers to reduce the peak load demand and reshape the load profile [14]. DSM is carried through demand task scheduling, usage of stored electric energy and real-time pricing [15]. DSM techniques increase the operational complexity of the power system, redistribute the load but do not reduce the total energy consumed by the appliances [95,96]. In case of loading the system with its maximum capacity, the value of DSM is high. Otherwise, it is low in systems with spare capacity. For this reason, the generation capacity of electricity grid represents the main challenges for DSM [16,17]. On the one hand, the lack of knowledge about demand response (DR) programs, the response fatigue caused by keeping track of frequently varying prices and the extensive payback time for recovering the installation costs of smart meters are considered as consumer-based barriers [18,19]. On the other hand, the existence of substantial confusion about whose responsibility the promotion of DR programs is, the loss of revenue for firm due to the lowering peak usage in case the electricity is more expensive and the lack of formal measures for the recovery of initial investment in DR infrastructure are regarded as producer-based barriers [18,20]. In some countries, it is difficult to establish a unified standard policy system due to the imbalance regional development of DSM [21]. In addition, a rebound of energy use after high price signal can lead to bigger peaks in DSM [22].

2.4 Metering

Metering provides a channel to enable two-way communication in Smart Grid concept between consumer and distributer. They not only help distributor for more accurate billing system but also help consumer to control their use of electrical energy. These meters are equipped with sensors for automation, power quality monitoring and power outage notifications. There are different drivers like price increase after electricity market deregulation, consumer dissatisfaction and monthly metering directives which encourages smart meters [12]-[23]. In traditional grid systems, SCADA was only used for communication purposes which provide a central control unit to monitor and control with second scan rate. But it's not much cost effective at different levels of electrical power distribution especially at utility end [24]. Advanced Metering Infrastructure (AMI) provides a real time solution that collects consumer data and provides a communication networks from grid to utility end. AMI provides opportunity to step forward for the modernization of the huge grids by combining consumer with the distribution system. It provides an opportunity for outage management, integration of electrical vehicles and smart devices, transformer and feeder monitoring and fault isolation [12][25].

2.5 Micro-grids and integration of renewable resources

Micro-grid is a small-scale power supply network that is designed to provide power for a small community. It enables local power generation for local loads, and contains of various small power generating sources that makes it highly flexible and efficient. Smart grid is connected to both the local generating units and the utility grid thus preventing power outages. Excess power can be sold to the utility grid or can store in storage system. Size of the microgrid may range from housing estate (few kW) to municipal regions (few MW). there are many solutions to maintain the voltage and to reduce the power losses in the power system. Flexible AC Transmission System (FACTS) devices are considered a famous way for reactive power compensation [26]. By using the renewable Distributed Generation (DGs) near the loads can contribute to save the system stability, decrease the power losses and decrease the operation running cost [27]. Furthermore, renewable energy is friendlier with the environmental at compares with the traditional power plants [28]. The optimal DGs planning can play an important for enhancing the performance of the distribution power network to meet the expected and the profitability system as the voltage stability, power loss reduction and the system reliability [29]. In the future, renewable energy will be the main driven generation system to save fossil fuel and to avoid the influence of the conventional generation into environmental aspects. The renewable energy sources can be wind, photovoltaic cell, biomass, nuclear power and small hydropower plant [30]. Due to the availability of the sun or the wind in nature, the solar and the wind generation are considered as the famous renewable generation. A microgrid, in this context, refers to a controlled system of a cluster of loads and distributed micro energy sources that can provide electrical power to its neighboring areas. It can effectively coordinate different types of distributed energy resources through local power managements. A conceptual illustration of a microgrid within the context of a smart grid is shown in Fig. 2 [31].

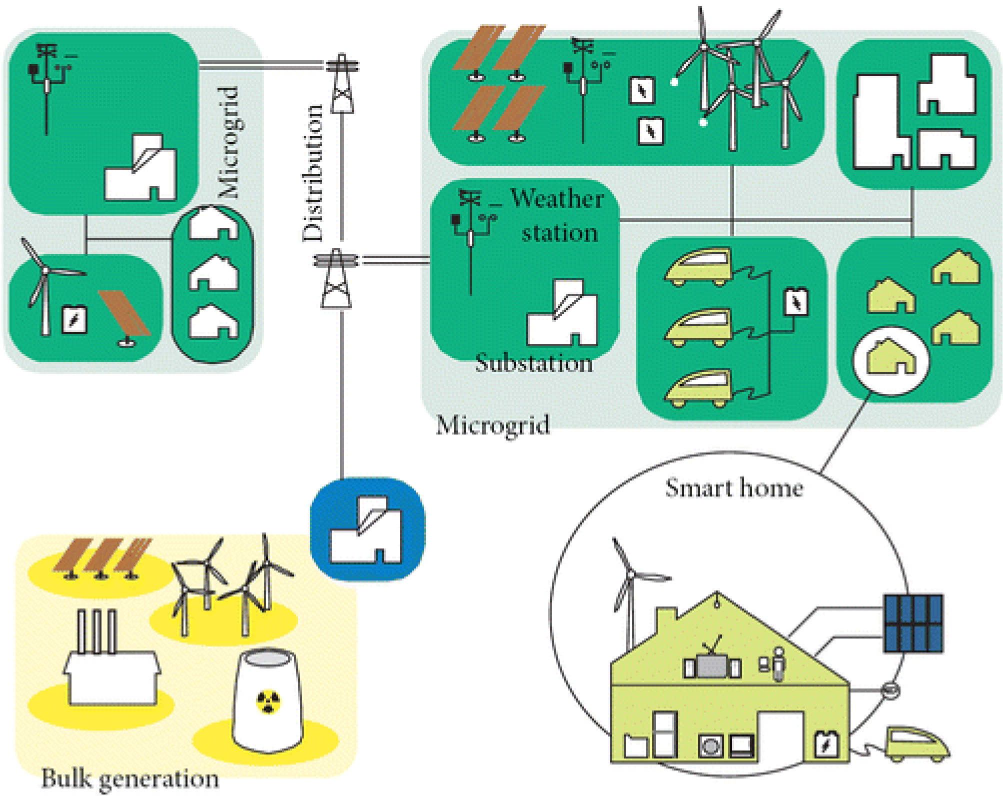

Figure. 2 A conceptual illustration of a microgrid.

3. Issues and Challenges in Smart Grids

The smart grid is expected to revolutionize existing electrical grid by allowing two-way communications to improve efficiency, reliability, economics, and sustainability of the generation, transmission, and distribution of electrical power. However, issues associated with communication and management must be addressed before full benefits of the smart grid can be achieved. Furthermore, how to maximize the use of network resources and available power, how to ensure reliability and security, and how to provide self-healing capability need to be considered in the design of smart grids.

- battery wearing, low penetration of the Extra Voltages, new battery technologies.
- costs, consumer engagement.
- distributed generation in distribution system and distribution system automation.
- physical security, cyber security, vulnerabilities in metering data.

4. Smart Grid Component

There is no specific start of Smart Grid. This concept was start evolving with the start of distribution system of electrical networks. By the time different requirements were needed like control, monitor, prices and services of transmission and distribution of electrical power. Normally, Smart Grid implementation is associated with the installation of smart meter. In 1970s and 80s they were used to send the information of consumer back to the grid [12]. But the most important and fundamental need which is still under consideration even with latest advancement is reliability and efficiency of energy transmission and distribution via electric power grid. But in the latest advancement research is undergo that grids and network systems should not limit to transmission and distribution but also play a vital role in generating clean and sustainable energy in order to reduce greenhouse gases and carbon foot print [12]. It provides its stakeholder an opportunity to maximize the efficiency, reliability, economic performance and security of their electrical network. An overview of its architecture is shown in Fig. 3.

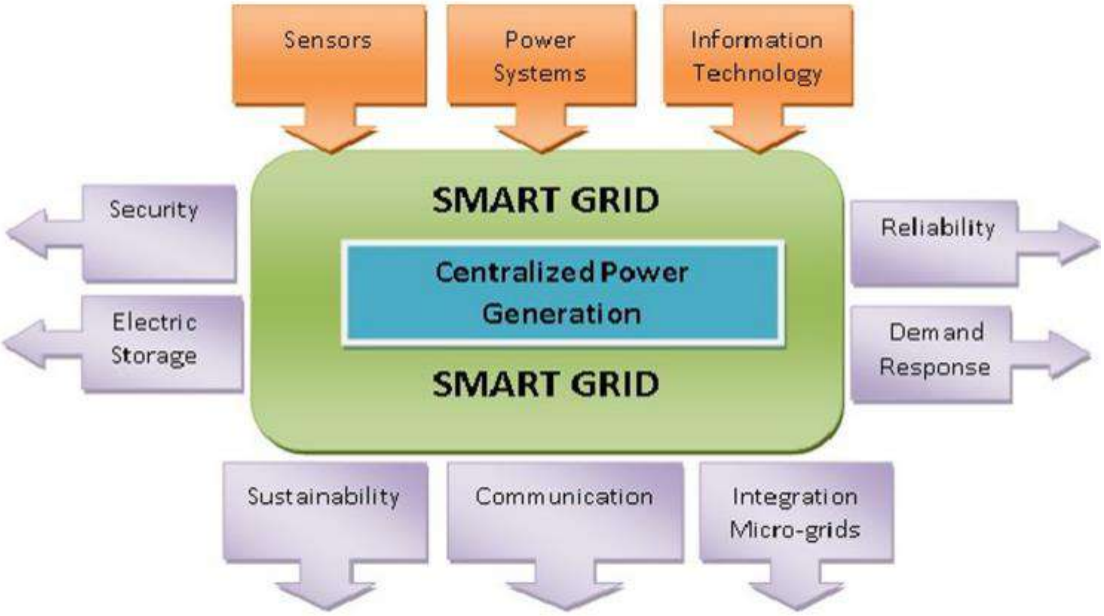

Fig. 3. Overview of Smart Grid design.

4.1 Smart devices interface component

Electronic devices usually connected to other devices or networks via different wireless protocols and, which can operate interactively and autonomously are termed as smart devices. Smart devices for monitoring and control forms a part of the generation components real time information processes.

4.2 Storage component

Due to the inconsistency of RES and mismatch between peak consumption and peak availability, it is significant to find methods to store the energy for future use. Storage component improves reliability and resiliency for the utility grid and electricity consumers. Energy storage technologies include flow batteries, ultra-capacitors, pumped-hydro, super-conducting magnetic energy storage and compressed air.

4.3 Monitoring and control technology component

Monitoring and control technology component consist of devices for self-monitoring, self- healing, predictability and adaptability of generation, smart intelligent network and devices enough to handle reliability issues, instability and congestion.

4.4 Demand side management component

DSM and energy efficiency options are developed for modifying the consumer demand to cut down operating cost by reducing the use of expensive generators and postpone capacity addition. DSM options contribute to reliability of generation and reduce emissions. These options have an overall impact on the utility load curve. A standard protocol for consumer delivery with two-way information highway technologies is essential.

5. Characteristics of Smart Grid

Smart Grid employs innovative products and services along with intelligent control, communication, monitoring and self-healing technologies. The literature suggests the following attributes of the Smart Grid [8].

(1) Smart Grid provides consumers better choice of supply and information also permits consumers to play a part in optimizing operation of the system. It enables demand side management (DSM) and demand response (DR) through the incorporation of smart appliances, smart meters, microgeneration, electricity storage and consumer loads and by providing consumers the information regarding energy use and prices. Information and incentives will be provided to consumers for revising their consumption pattern to overcome few constraints in the power system and improving the efficiency.

(2) As one of the biggest environmental issue is pollution due to vehicles. Use of electrical vehicles has the solution of this problem. There are several challenges for EVs to interact with the grid which include infrastructure, communication and control. Mostly it is seen that EVs are charged at home and even sometime charging take place at public or commercial Charging station [32]. Therefore, it is possible that it directly stresses the electric distribution network. But contrary it is possible that this EV charging can improve the quality of power and performance of grid if integration of EVs with the grid is well planned and follow the standards set for it. As Smart Grids have advance technologies in the form of communication, smart meters and control [33]. So, it has a potential to offer electric vehicles not only as a load but can be used as a flexible energy source [34-35]. Smart meters play a vital role to address the

challenges faced by the grid due to EV. As these meters have bidirectional communication ability and to monitor real time data so these smart meters can help in implementing a smart scheduling to optimize the available power in the grid [34-35].

(3) It allows the connection and operation of generators of all technologies and sizes and accommodates storage devices and intermittent generation. It accommodates and assists all types of residential micro-generation, renewable DERs, DGs and storage options, thereby considerably reduces the environmental impact of the whole electricity supply system. It allows ‘plug-and-play’ operation of microgenerators, thereby improves the flexibility.

(4) It optimizes and operates assets efficiently by pursuing efficient asset management and operating delivery system (working autonomously, re-routing power) according to the need. This includes the utilizing of assets depending on when it is needed and what is needed.

(5) It operates durably during cyber or physical attacks, disasters and delivers energy to consumers with enhanced levels of security and reliability. It improves and promises security and reliability of supply by predicting and reacting in a self-healing manner.

(6) It provides quality in power supply to house sensitive equipment that enhances with the digital economy.

(7) It opens access to the markets through increased aggregated supply, transmission paths, auxiliary service provisions and DR initiatives.

6. Conclusions

Regarding the traditional grid became limited and needed more features. So due to technology grew, the devices and systems are able to support the formation of a more intelligent grid. The Smart Grid concept has evolved from a vision into a goal that is slowly being realized. As technology grew, devices and systems are able to support the formation of a more intelligent grid. Concrete energy policies facilitate Smart Grid initiatives across the nations. Smart Grid practices in different regions barely indicate competition but rather an unbordered community of similar aspirations and shared lessons. Evolution of Smart Grid concept has potential to meet all the future needs of utilization of energy in best possible manner by reducing carbon emission and integrate with more renewable energy mix. It can bring a considerable change in the conventional grid and consumer behavior towards utilization of energy by improving reliability, efficiency and quality of power delivery. Governmental policies are needed to facilitate smart grid implementation.

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