International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 07 | July 2022 www.irjet.net p-ISSN: 2395-0072

Smart Grid Technology - The Future of Power Network: A Review

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Abstract - *The depletion of energy resources with the increases in demand of power pushes the world towards the smart power management system to balance it. This paper briefly discusses about the Auto Healing System popularly known as Smart Grid. This emerging technology leads to better utilization of energy with great efficiency. The system integration of Renewable Energy Resources (RER) with traditional plants brings better reliability and security to the system. The bidirectional flow of energy and information helps to provide the real time consumption detail to the consumers will make it more adaptable. Big Data collection through Advanced Metering Infrastructure and processed in a meaningful manner is a challenge to the system. Security management is also key concern in this area.*

***Key Words*: Smart Grid, Self healing, Advanced Metering infrastructure, Smart Meters, Phasor Measurement Unit, Big Data.**

1. INTRODUCTION

In present era, the deficit in power generation due to increase in demand of power to meet the need of electricity it is required to switch on a system which is more reliable, energy efficient, manage the power demand and having self healing property. All these features indicate towards "Smart Grid". Smart Grid(SG) is digital automated network which can store the data, analyze and make decision based on it. This helps to monitor, measure, and control the flow of power in real time that helps to minimize the losses along with it contribute to develop a system or actions that reduces the losses [1]. To maximize the reliability and stability of the system, SG make coordination between the requirement and capabilities of all the generators, grid users and end users. The infrastructure of existing fossil fuel based power system can be converted into smart Grid to optimize the assets[3].

1.1 Fossil power Grid Vs Smart Grid

By Comparing SG with traditional one, SG concept can be better understand. Conventional power system is a vertical unidirectional network having power flow from generation to end users through high voltage transmission line having centralized source of power supply. The difference in conventional and smart Grid are:

Traditional Power Grid	Smart Grid
1. Centralized source of power.	1. Centralized as well as distributed power plants.
2. Unidirectional flow of energy from generating end to user end.	2. Bidirectional flow of energy from generating end to user end.
3. Passive participation of customer.	3. Active participation of customer.
4. Real time monitoring is limited to generation & transmission only.	4. Real time monitoring is possible from generation to customer.
5. Difficult to integrate it with other alternative sources.	5. Possible to integrate with renewable energy sources.
6. At the time of failure and blackout, customer receive no energy.	6. It can be rerouted for the continuity of supply. In case of failure islanding mode is activated make the system more reliable.
7. Peak shaving is not possible as the flow of power is unidirectional.	7. Peak Shaving is possible i.e. electricity can send back when demand is high.

Table 1. Comparison of Fossil power plant and SG

Fig. 1: Power and information flow in Traditional power plant

The information flow from generating end to distribution end in traditional plants while in SG the information is shared from generating to consumer end.

Fig. 2: Power and information flow in Smart Grid

Here information flow is represented by blue color.

1.2. Features:

1. Flexibility: It is flexible to interconnect with the fossil as well as distributed power plants.

2. Efficient: Without adding extra infrastructure the fossil fuel power plant can be modernized into smart grid.

3. Power and data flow: Two-way communication of power and data between consumer and utility is possible that gives control to the consumers to reduce the wastage of power and precise & timely information of consumption of electricity.

4. Integration with advanced electrical storage devices.

5. Resilient: It is more resilient i.e. has ability to recover from adverse and abnormal condition and restore the normal one.

6. Reliability: Reliability is continuity of supply. It provides secure, consistent quality of supply to the consumers.

7. Cost Effectiveness**:** it provides cost effective power supply to the consumer by providing choice of both centralized and distributed power sources.

8. Environmental impact: It minimize the Environmental impact by reducing the emission of CO_2 in the atmosphere.

1.3. Characteristic of Smart Grid:

Fault and disturbances in power system are unavoidable. It's severeness depends on the fault type and the fault area. Here the unique attribute i.e. self healing (SH) property of SG make it popular. SH means at the time of fault, the SG system can repair itself [1-2]. It provides the detection and segregation of faulty network from heathier network. It is done through distributed generator (DG), smart switches and protection devices. During this action, no manpower is required. It is real time computational system to supervise, analyze and take corrective action quickly [2].

The self-healing(SH) primarily objective is to tackle the fault in better way and secure the whole system. To understand this characteristic deeply, the self-healing property is studied under generation, transmission, and distribution system. At Generation side, DG & reconfiguration of smart switches present for SH [4]. In transmission system, for SH the parameters studies are related to transmission line, transformer, circuit breaker and smart sensor. Smart sensors observe the temperature of transmission line, current carrying capacity of conductors, thermal ability, fault location, sag, ice loading and isolator failure [5-6]. In distribution system, fault diagnosis is very important and crucial factor to improve the power quality, reliability. The challenge in this section is the increase in magnitude of fault current which make it difficult to maintain the stability and synchronism. To limit the fault current magnitude, fault current limiter (FCL) is used in between main grid and microgrid[8].

The FCL can be used as energy storing device connected to power grid to maintain the stability of the system. In distribution network even after the clearance of fault, the power quality, reliability, efficiency affected. Voltage supply and frequency should be in prescribed limit for better power quality. Reliability means continuity of supply so Quick and high-quality research needed in distribution system to restore the system after clearance of fault.

One of the SH method in distribution system is based on speed of travelling wave. At the time of fault the speed of travelling wave increases that indicate the occurrence of fault [8-9]. Other methods are Markov analytical method and adaptive over current method[9]. When load varies relay automatically restore the setting but in case of any disturbance the islanding mode is activated in adaptive overcurrent method. When there is decrease in frequency load shedding Algorithm is used [9].

The architecture of SH control divided in direct and conditional control system [10]. Direct control is based on the closed loop analysis for fault recovery and prevention, maintaining the optimal control while the conditional control depends on logical control on several parameters from bus and take action immediately on faulty section [5]. It acts as protective control between customer and utility.

Normal and faulty condition are the two condition in SH. During normal condition SH enhances the stability margin and performance while during the faulty condition it control the load variation automatically [1].

2. Components of Smart Grid:

According to Electric Power Research Institute the "Smart Grid" is one that incorporates information and communication technology into every aspect of electricity generation, delivery, and consumption in order to minimize environmental impact, enhance market, improve reliability and services and reduce cost and improve efficiency[12].

NIST (National Institute of Standard and Technology) gives a conceptual model of Smart Grid where power and information flows in bidirectional mode[12]. Flow of power

is represented by red line where as blue color represent the flow of information.

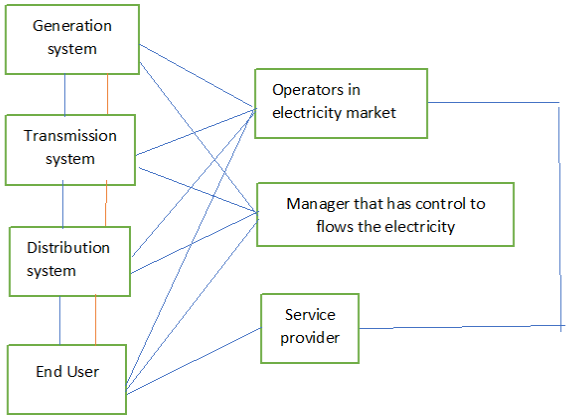

Fig. 3: The conceptual model of SG

The Smart grid consists of digitally automated systems to sense, communicate, analyze, and control the functions of grid. To understand completely Smart Grid (SG) divides in three system[12]:

1. Infrastructure system

2. Communication system

3. Protection system

1. Infrastructure System: the system is further subdivided into energy system, data, or information collection system. The energy system generates, transmit and distribute energy.

a. Energy System:

i. Generation of Power: Power is generated through Generator in the power plants. In traditionally power plants, the energy is generated centrally. These plants are large in size and located at center of load. Use of Distributed generators (DG) in SG gives an advantage to it. These DG can be connected to Distributed energy Resources (DER) power plant as well as fossil fuel power plant but connection of DG to existing system is a big challenge. The wide Fluctuation in power generated by DER, there is always a wide gap between generation and demand. Also, the operating cost for generation of one unit of electricity by DG is comparatively high to the generator connected centrally producing electricity at large scale in tradition power plant[12]. Although we have limitations but in future SG will adopt DG at a large scale to generate power.

ii. Transmission System: It include the existing transmission network with addition of new technology power electronics devices and a smart substation. Here the self-healing property of substation making the system more reliable[13].

iii. Distribution System: One of the challenge among this is how to distribute the energy effectively so that the losses are minimum[14]. Many research work has been proposed to connect many DG with Smart Distribution Grid to increase the system flexibility with the generation system.

b. Data or information collection system**:** To collect information from end user, meters and measurement equipment is required. Smart meters, smart sensors, Phasor Measurement unit(PMU) is connected for this. AMI(Automatically Metering infrastructure) make the two way communication with consumer while AMR (Automatic meter Reading) collect the reading i.e. consumption of electricity of consumer and send it to centrally data base system to generate tariff. Smart Sensors are microprocessor based device used for monitoring and measuring. PMU measures voltage and frequency at any point of time and provide time stamped data to system operator to compare the shapes of AC wave generated by no. of PMU's connected to respond quickly and making the system more secure and reliable[17].

2. Communication System**:** the system is responsible for the flow of information among various devices and systems.it can be wired or wireless. For this SCADA with other outage system which collectively known as operational technology (OT) is used[15]. The functions of OT are:

i. Monitoring and controlling of all the devices connected to grid.

ii. monitoring and controlling of grid devices i.e. circuit breaker, field switches and power electronics devices.

In parallel with OT, IT system manage the billing, revenue collection and depreciation cost.

3. Protection system**:** it comprises of fault prediction and prevention, diagnosis, fault clearance along with end user errors, device failure[16].

3. Role of big data in Smart Grid:

The advanced metering infrastructure (AMI) and Measurement Technologies that make up the power grid contains Smart meters, PMU's. Through these measuring devices the real time data with high resolution is collected that make the smart grid two way communicator with end user. The real time stored information is utilized to enhance the observability of power grid, reliability and economic operation of grid & consumer's behavior[big data]. Smart meter collect the energy consumption in every 15 min. whereas PMU's record it with high resolution in every 30-60 sec. The data generated by smart meters and PMU's is 3TB/yr and 40TB/yr respectively[18]. This big data can be utilized for the advancement of smart grids. Application of big data in smart grid are[18]:

1. Help to improve reliability and flexibility to connect to renewable energy resources

2. Improvement in performance by analyzing the previous data

3. Analysis improvise the decision making

4. Optimum utilization of resources.

The data volume, data uncertainty and data security are the key challenges. As the utilities increasing in exponential rate so the data volume is very high. To convert the big raw data into actionable information, quality data is required that must have accuracy, completeness, and consistency but in real world due to aging of sensors, noise etc. error occurred. We all know the data security is an important issue nowadays. Data security means privacy and data integrity. Cyber security is another challenge [23]. Though we have these challenges but the possibilities of emergence of new technologies to clear these issues are also there. Lot of research work been proposed regarding the data security [17].

The vision of SG leads to environmentally friendly solution with better reliability of supply. However, the challenges included integration with consumers, service providers, new technologies developers are still to overcome and provide safe, secure, self healed and resilient operation of SG.

4. CONCLUSION

In this paper, the review of auto healing characteristics of Smart Grid has been discussed. As Smart Grid is emerging technology so lot of research work is still going on to develop the new technologies to enhance the better utilization of electricity. A pilot project has been initiated by POWERGRID with open collaboration of Electricity Department, Govt. of Puducherry to develop Smart Grid at Puducherry [20]. Thus, Smart Grid provides efficiency, reliability, safety, security, and stability to the power sector. Also, it brings an advantage to the consumer by making their participation active.

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