

Smart Grid and Commutation Technologies

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Abstract: Smart grid is a distributed automated network which uses two way communication and energy flow to consumers at minimum disturbance. The grid, refers to the electric grid, a network of substations, transmission lines, transformers and meters that deliver electricity from the power plant to our business and home. Power generation and distribution are the key aspects in the progress and development of our societies. The communication network and infrastructure are the main part of the smart grid. The smart grid reliability is one of the important features which depend on the data received from distribution side of the network. Different challenges are faced in the conversion of conventional grid to smart grid and still research is going on the different issues of smart grid such as secured communication, network enhancement and reliability. Home energy management depends on the utilization of the electricity on consumer side. The smart grids follow the renewable energy generation, latest sensing and communication technology, smart metering and power management. Wireless sensor networks and wireless communication technologies also play very important role in smart grid communication. WSN has been proved promising solution for energy efficient, reliable, seamless and low cost control and monitoring in smart grid. The research is study based on the study of smart grid, smart grid system and different communication technologies.

Key words: Smart grid communication, wireless, sensor, networks, renewable, energy

INTRODUCTION

The electricity is the main part of our society. The power generation and its distribution is one of the main aspects of electrical plant in a city. The power system performance and efficiency depends on its distribution and utilization and electricity can be saved in different aspects. The research on the power plant and its efficiency enhancement is going on since long time. The existing power grids (Bari *et al.*, 2014; Bharothu *et al.*, 2014) are based on traditional approach and accommodate energy business at lower level. The use of renewable resources for energy production has created distressed system and the power system network requirements are incumbent today, very difficult to maintain the changes in power systems. In order to understand these requirements and issues the concept of smart grid was introduced which is based on two way communication and delivers the electricity based on different demands between suppliers and consumers. It can control the consumption of electricity in distribution and utilization end. The

existing systems are mechanical system having consist of different wires, transformers, cables interconnected links, etc., provides us uninterrupted power supply. It is the current requirement of the existing grid that the distribution should be smart and controlled electronically and association should be with some intelligent sensors and electronic communication infrastructure. Although, all the electronic system need power to energize, so, it becomes very essential to ensure that the power system should be more efficient and reliable.

The demand of power is greater than its supply and it is also fluctuating. Sometimes we can rely on renewable resources like wind and solar panels to meet the current need but they are also giving fluctuating supply. The smart grid (Vikram *et al.*, 2015; Beidou *et al.*, 2010) increases the performance of power system. The main reason is that the grid is based on electronic intelligent devices, communication, smart metering, sensors, communication technologies (Farhangi, 2010; Chhaya *et al.*, 2017) and control techniques to make the system smart. The main objective of the smart grid is

to ensure power supply in reliable mode, optimize the existing hardware and provide cost effective solutions to customers. The biggest advantage of the smart grid its cost effectiveness. The grid communication is based on the internet. It uses TCP/IP, ethernet communication and other operating systems because internet communications can provide the cyber-attacks (Chhaya *et al.*, 2017). It is needed to enhance the grid security. The system is affected by the attackers, can disrupt the load and meters of the system.

The smart grid includes several energy measures and operations measures include smart appliances, smart meters, energy efficient resources and renewable energy resources. The electronically control (Chhaya *et al.*, 2017; Iyer, 2011) and power condition for production and distribution are the main aspect of the smart grid. European provided the technology platform to smart grid and defined policies are followed. It also implies that the smart grid is the re-engineering in electricity to enable services in industries and provides limited infrastructure. The first ac power grid was centered in Great Barrington Massachusetts in 1986. It was unidirectional system based on demand driven control for electrical power transmission and distribution.

MATERIALS AND METHODS

Smart grid architecture: The electrical network consists of two subsystems one is transmission and another is distribution system. The electricity is moving in bulk form in transmission system from 345-800 kV over AC-DC lines. The power is flowing in one direction and distributed by the network to consumers at 132 kV. The smart grid is providing bidirectional communication and metering unlike to current grid. The grid is having a smart meter and monitoring system which is keeping the information of electricity consumption. The grid is following the transmission lines and help in the reduction of resistive losses. The lines are also compatible with other sources of energy such as solar and wind (Fig. 1 and 2).

In the general way, the smart grid network can be divided into three segments: Wide Area Networks (WAN), Neighborhood Area Networks (NANs) and Home Area Networks (HAN).

Wide Area Networks (WAN) is the path between the data concentrators and data center of service provider. It is two way communication networks with high bandwidth and handles the data transmission and reception over long distance for smart grid control and monitoring. The communication architecture provides the best outreach and coverage at very low cost such as fiber cables, LTE, power line communication networks cellular network (3G, 4G) are major adopted networks by smart grid.

Neighborhood Area Networks (NAN) is created between smart meters and data collectors in a neighborhood area. The collection and measurement of data is done with the help of short range communication techniques such as RF mesh communication technology, Wi-Fi, ZigBee, etc. and the data is transmitted to the data concentrator. The NAN is like Wireless Local Area Networks (WLAN) and offshoot of Wi-Fi hotspots and which permits users to connect to the internet very fast and at very less expense. It is the network that allows all the devices in small area to their neighborhood can communicate to each other. In the smart grid system, all the smart metes can communicate one to one in a neighborhood and with the router with forming the interconnections in mesh networks of smart devices.

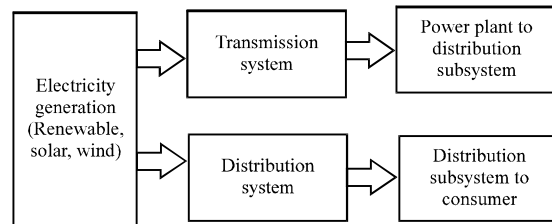


Fig. 1: General model of grid (Iyer, 2011)

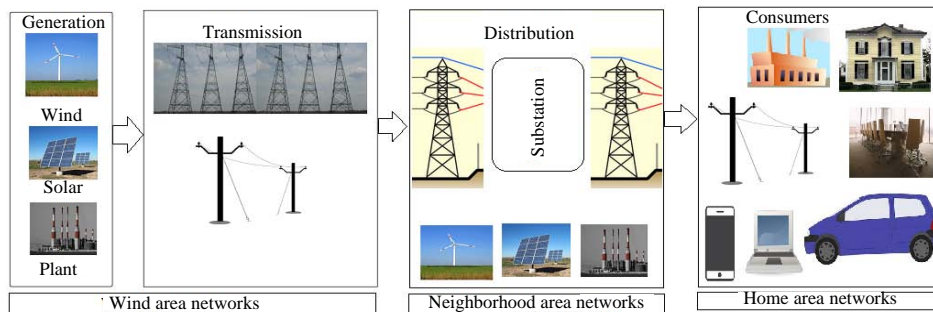


Fig. 2: Smart grid networks (ARRL, 2012)

The Home Area Network (HAN) provides connections and path establishment between smart meters, home devices and electrical vehicles or in consumer side. It enables the consumers to collect the information about their electricity usage and consumption in home display devices. The HAN applications require low bandwidth and communication technologies such as Wi-Fi, ZigBee and Bluetooth, etc. provides effective communication towards distribution to consumer end.

RESULTS AND DISCUSSION

Communication technologies: The existing telecommunications technologies (ARRL, 2012) are separated into four categories.

Landline communication: The communication is based on analogue subscriber lines, digital subscriber lines, fiber optic and coaxial cable. The analog communications networks are having switches through which the

connection is established between two or more users. In digital communication technology the routers are used to route the traffic and transmit the information to the end user.

Wireless communication: The communication which can be dynamic is wireless communication. It includes cell phone communications systems and other wireless communication techniques such as Wi-Fi, ZigBee and Bluetooth, etc.

Private radio: It includes trunk mobile dispatching channels and meshed meter networks. Sometimes it is called professional mobile radio. It was developed for the private use for business applications in which short distance communication is within a central base station/dispatcher. Professional mobile radio is also applicable in emergency services. It can have one or more number of base stations and many mobile terminals. The system is owned by organization and its users in a closed group (Table 1).

Table 1: Communication technologies (ARRL, 2012; ML, 2012; UKST, 2017) benefits and drawbacks

Category/Technology	Benefits	Drawbacks
Landline		
Optical Fiber	Larger bandwidth, low power loss, immune to electromagnetic interference secured, high speed	Transmission loss and may be broken More protection is required
Copper Unshielded Copper Premise (UTP)	It provides optimum performance because high frequency signals travels on copper skin. Widely available analog modem, offers Digital Subscriber Line (DSL) and T1 speed	Point to point and expensive Expenditure need to continue control is poor
Hybrid Fiber Coax (HFC)	Optical fiber and coaxial cable is used to carry the contents in the network such as broadband data (images, voice and video). It has some advantages of fiber cable that low noise, larger bandwidth and interference susceptibility) and no need to change the coaxial cable which are placed in the places of business and home. So, it the fiber to the group of homes or neighborhood	Lack of control
Fiber to Home (FTHH)	It is the use and installation of optical fiber directly from one central point to specific building such as business place, apartment buildings and residence to provide fast speed of the internet to access. It enhances the connection speed to the computers and users in comparison to other existing techniques. It has large bandwidth and extremely fast method. FTHH promises speed upto 100 Mbps It is faster 20-100 times than typical DSL and cable modems	It is available in limited places, Installation cost is very expensive
Power line		
Power Line Carrier (PLC)	PLCC is the latest electrical power system, used for carrier relaying protection in transmission lines, communication establishment between stations to station. It is low cost, ready infrastructure and reliable solution over powerline. It provides long distance communication but at very low speed. Very good for NAN and HAN networks and supports grid and substation control function such as SCADA system The noise is generated due to corona, discharge of inductors and switching processes	The PLCC can create the disturbance in the transmission lines, provides point to point communication, communication at slow speed over long distance. There are the chances of production of reflections and attenuation in high voltage lines. These voltage lines are having transformer connections and carrier current is attenuated that affects the substation equipment. The amount of noise generated in PLCC is more in comparison to telephone lines
Broadband over Power Lines (BPL)	Broadband over Power Lines (BPL) is a technique of PLC in which high speed digital data transmission is possible in electrical distribution system. It provides long distance communication at higher frequencies and high data rate on Medium Voltage (MV) and Low Voltage (LV) lines. BPL also follows the frequencies over air communication services which are the part of radio spectrum and prevents the interference. It supports the specific requirements of Advanced Metering (AM), Demand Response (DR) and Distribution Automation (DA)	It can have electromagnetic interface, very less tolerance to noise, limited deployment and lack of standards and interoperability

Table 1: Continue

Category/Technology	Benefits	Drawbacks
Home plug power line	The home plug products are used to connect to the internet using electrical wiring, make smart home using IoT. Home plug and wifi integration makes the whole house coverage without dead spots. It also provides ultra HD video streaming. The technology is for communication over power line for DR and AMI. Its installation is quick, easy and inexpensive and very good for in premise communication	The setup of security cameras are often need in some areas of the home where the connection is very difficult to your network especially in outdoors Limited deployment, interoperability and security are major concerns. Front end converters add complexities and cost
Radio		
Multiple address system (Radio)	These are Point-to-Multipoint Microwave Systems which are helpful to provide corporations, supports specific operations and other institutions. The interference analysis and frequency selection are the part of coordination process for microwave systems. The frequency selection is very complex and difficult as the number of microwave users are increasing. MAC system supports wide variety of addressing systems such as oil and gas companies, energy companies and electrical utility The main application is the implementation of SCADA systems. It is flexible, reliable and compact system	The Frequency Coordination (FCC) needs a nationwide license C-band uplinks interference analysis, and for temporary fixed earth station operations. It has limited bandwidth and poor market penetration
FHSS spread spectrum radio	Frequency-Hopping Spread Spectrum (FHSS) is the technique to transmit radio signals very fast and switching the carrier among many frequency channels and the pseudorandom sequence is known to receiver and transmitter. It is applied as multiple access method in CDMA and called Frequency Hopping Code Division Multiple Access (FH-CDMA). It is the wireless technology in which the signal is spread over frequencies and each available frequency band is distributed into sub frequency bands. Signals change among all these very fast in predetermined order, called hop. It is point to multipoint communication in unlicensed spectrum 902-928 MHz, useful for last mile connection	It requires line of sight and continuous frequency hopping. FHSS technology is applied to end points and need fast mobility because its transmission range is small
Wireless		
3G cellular	The CDMA 2000 technology is called 3G. CDMA 2000 technology provides the ability to the subscriber to transfer and receive data packets at raw data rates of 153.6-144 Kbps It is cost effective, less expensive, quick implementation and ready infrastructure for monitoring substation performance. Universal Mobile Telecommunications System (UMTS) is 3G cellular wireless system and evolution of GSM/GPRS. The greatest feature of 3G technology is that bit supports, greater voice, high data transmission and security	It is suitable for small burst of data not and coverage area is also less It is not suitable for substation control and monitoring online base station need to upgrade regularly and power consumption is high
Wi-Fi	Wi-Fi is wireless LAN technology based on IEEE (2017) 802.11 standards that provides high speed internet and connections. The open standards for Wi-Fi are IEEE (2017) 802.11g and 802.11b. It works on 2.4 GHz for UHF and 5 GHz for SHF ISM radio bands. Wi-Fi has not any wired or physical connection between transmitter and receiver using RF technology. It is the frequency at which electromagnetic spectrum is associated with radio wave propagation. The electromagnetic field is generated when RF current is supplied on antenna and it propagates signals through space. It has high penetration and provides general 5-54 Mbps speed	Security, range (100 m), reliability and speed are the major issues of Wi-Fi. Sometimes it has poor signal reception in building
Wi-MAX	WiMAX is IEEE (2017) 802.16 standards for wireless communication which provide Media Access Control (MAC) and multiple Physical Layer (PHY) options. WiMAX standard enables the delivery for wireless broadband access at last miles and alternate way to DSL and cable. The IEEE (2017) 802.16 m is wireless MAN advanced standard for 4G and LTE advanced. It adheres to IEEE (2017) 802.16d communication standards, can provide 75 Mbps over 10-30 mile. The Backhaul media for in-premise are BPL, ZigBee and Wi-Fi	In WiMAX communication the same tower is accessed by hundred numbers of people due to that traffic intensity is increased. It is very difficult to maintain network and compromise with quality of service. WiMAX bandwidth, expensive network, low data rate, bad weather effect and wireless equipment are other issues. So, it has poor market penetration and expensive network solutions
ZigBee	It is wireless technology works in unlicensed spectrum of 2.4 GHz, require less power and low cost solutions in WSN. It is based on IEEE (2017) 802.15.4 standard. Home appliances are interoperated by Smart Energy Profile (SEP 2.0)	ZigBee has the limited range problem. The organization of different nodes following ZigBee in WSN is challenging
VSAT	VSAT (Very Small Aperture Terminal) communications system is the satellite system that serves home and business users. The VSAT end consumer needs to use box that provides the interface between antenna with a transceiver and user computer. It is widely used for control and monitoring the transmission of substation and coverage is more and implementation is fast	Installation cost is high and weather affects the performance of the system

Power line communication: It is carrier encompassing traditional power line carriers between substations and the new technology of broadband-over-power line at the distribution segments. It is used in electrical services and

effectively used in smart grid. It is the telecommunication technology which provides the signal processing with power lines. It is the crossroad between electricity and telecommunication.

CONCLUSION

The current electrical grid is going through major transformations with the deployment of smart grid technology and communication infrastructure. WSN play important role in efficient commutation. The smart grid communication and security is a major concern in consumer side. The smart grid has been proven an unprecedented opportunity to move the power industries into a new era of smart communication, availability, reliability and efficiency that will contribute a lot to our environmental health and economic growth.

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