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Communication Networks and Communication Technologies used in Smart Grid

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Abstract:
The communication networks and communication technologies is an essential part to design and implementing the next generation Smart grid. This paper presents the communication infrastructure and overview on the standards for communication network in Smart Grid, which is developed by IEEE and NIST.

Keywords: Smart Grid, Communication technologies, WAN, HAN, NAN, Monitoring, Power grid.

I. INTRODUCTION

BACKGROUND-

Smart grid is the next generation power grid in which electricity distribution and management is upgrade by two digital communications. This system allows for monitoring analysis, controls and communication within the supply chain to help improve the efficiency, reduce the energy consumption and cost and maximize the transparency of energy supply chain. "Various types of networking and communication technologies can be used in Smart Grid applications, including traditional twisted copper lines, cable lines, optical fiber cable, cellular, satellite, WiMAX, PLC as well"

COMMUNICATON IN SMART GRID

The communication system is key component of Smart Grid Infrastructure, with the integration of advanced technologies and application for achieving a smarter electricity grid. The functional requirement of communication infrastructure depends on the expected management tasks.

1. COMMUNICATION NETWORK

The communication network is typically composed of various segments. In which each segment is responsible for information and control message exchange with in specific region of Power Grid. Smart Grid Communication Networks can be classified as Home Area Network (HAN), Neighborhood Area Network (NAN) and Wide Area Network (WAN) as per the applications of communication technologies at different levels of smart grid deployment has been shown in below, figure 1.

1.1 HOME AREA NETWORK (HAN)

HAN is used in home automation. It is used for consumer domain and includes electronics devices and wireless sensor networks. Home Area Networks (HANs) have the coverage area of few meters. IEEE 802.15.1 (Bluetooth), IEEE 802.15.4 (Zigbee), IEEE 802.11 (LAN/Wi-Fi), IEEE 802.3 (Ethernet), Narrowband PLC (Power line communication), etc. standards can be used for Home area networks.

1.2 NEIGHBOURHOOD AREA NETWORK (NAN)

The primary function of the Neighbourhood Area Network (NAN) is to transfer consumption readings from smart meters. The NAN should also be close to real-time or real-time messages for diagnostic messages, firmware upgrades and power system support. It is anticipated that the data volume transferred from a household for simple metering is less than 100 kB[3] per day and firmware upgrades may require 400 kB of data to be transferred.

Figure.1. Classification of Smart Grid Communication Networks

1.3 WIDE AREA NETWORK (WAN)

The Wide Area Network (WAN) connects various NANs. It also enables long-haul communications among different data aggregation points (DAPs) of power generation plants, distributed energy resource stations, substations, transmission and distribution grids, control centers, etc. WAN is responsible for providing a two-way network, which is essential for substation communication, distribution automation, monitoring power quality, etc. Van can cover a very large area, that is, thousands of square kilometers and the number of widely supported devices thus require hundreds of megabits per second (Mbps) of data transmission. Data collection points are located at various places and the collected data are forwarded to central controller. The requirement of data rate is around 10–100 Mbps. Wide area network requires very high bandwidth for its operation and management. WAN is suitable for Supervisory Control and Data Acquisition (SCADA) systems for monitoring, data acquisition, control and management of power grid.

2. COMMUNICATION TECHNOLOGIES USED IN SMART GRID.

In smart grid communication network two types of communication technologies are used that are wired or wireless communication technologies; they are also further classified in their sub types which are described below**.**

2.1 WIRED TECHNOLOGIES

A) DIAL-UP COMMUNICATIONS

Dial-up is a communication option that gives the customer access to the Internet. The Internet is retrieved through the users ISP's (Internet Service Providers) using the existing installed telephone infrastructure. Although this technique is almost extinct, some utility is still using dial-up for some AMI communication. Of course this technique has a very limited amount of bandwidth. With this limitation, it makes this solution not suitable for all vendors that offer AMI technologies and other smart grid technologies. This technology uses the Internet through the ability of using public switched networks. This communication is called dial-up because it uses the telephone landlines or twisted pair wires to call into an ISP or also known as IP addresses were a dial tone is heard during the process of connecting to the Internet. Since the telephone lines are used during this process, a dial tone would be expected since that is what is heard when picking up the telephone. Dial-up communication is the slowest but cheapest communication type available today in the market. The data speeds that are presented with dial-up communications range from 10 kilobits per second (Kbit/s) up to 56 Kbit/s. In most cases a user is going to experience approximately a 40 to 50 Kbit/s Internet connection on an advertised 56 Kbit/s service. The 56 Kbit/s throughputs is the maximum data transfer speed that can be obtained in an ideal environment. Using the Internet with dial-up will also occupy one landline. So if only one landline connection is purchased, there can be no calls made with the telephone service when the Internet is being used. This communication technology is mainly used in the rural areas where there is no high speed Internet available. With the option of satellite Internet now available, higher throughput speed can be accessed nearly everywhere in which makes the use of dial-up communications extinct. Many electric power utilities will use a telephone in the substations that have no access to cellular or radio coverage. It gives the opportunity of utility to use dial-up connection at this place if the internet is used on that particular site. This technology is known to have a very poor reliability mainly due to the speed of the service If data speed drops too much, then some applications can expire potential time and cause an application failure. As discussed above dial-up provides very slow data speeds, which is considered to be one of the disadvantages of this communication option. Other disadvantages of dial-up becomes when accessing the Internet connection it takes up one line of the landline service. This can cause no use of a telephone service until the Internet connection is terminated. When the type of communication within the reliability communications system, the formation of the system, and the physical terrain where the system is located will affect reliability. Since using dial-up uses the existing telephone infrastructure the reliability is considered to be good in the aspect that the existing infrastructure can be used. Reliability is only going to get worse when equipment or telephone lines fail within the telecommunications system These lines can be ripped down during a storm or equipment might go bad, which is going to require attention from the telephone company before gaining access to telephone system. The terrain does not effect this communication, since telephone lines are threaded all over the nation. Dialup doesn't bring a great amount of advantages to the table, but the biggest advantage is the cost of the service. Dial-up will cost about 10 ten 15 dollars a month on average for one 56 Kbit/s line of service.

B) DSL/BROADBAND COMMUNICATION TECHNOLOGY

Digital Subscriber Lines (DSL) is a high speed digital data transmission technology that uses the wires of the voice telephone network. It is common to see frequencies Greater than 1 MHz through an ADSL enabled telephone line. The already existing infrastructure of DSL lines reduces installation cost. Therefore, many companies choose DSL technology for their smart grid projects. The Current Group, a Smart Grid Solution Company, has collaborated with Qwest to implement a Smart Grid project. Qwest's existing low latency, secure, high capacity DSL network will be used for data transmissions. Broadband communication is a technology that has been introduced during the new millennium, which additionally allows access to the Internet using existing infrastructure. The main difference between broadband and dial-up communications is going to be the data speeds in which they provide. Broadband is advertised to be a high speed Internet service, in which it uses different techniques to accomplish the higher data rates. DSL is a type of broadband communication that stands for Digital Subscriber Line. This technique transmits a digital data signal at a high frequency to allow faster throughput speed and large bandwidth.

C) POWER LINE CARRIER

The power line carrier (PLC) is a technology that has been used for a long period of time. Within the operation of PLC technology, there are 3 different operating modes that will get data transmission on the power line. One of these modes is using the Ultra Narrow Band (UNB) that operates in the frequency range of 300 Hz to 3000 Hz (3 KHz). The next class is going to be the narrow band (NB) which offers the higher data speeds between 2 kbps to 500 kbps. This class operates in the frequency range of 3 KHz to 500 KHz. The last class is the broadband (BB) technology in which offers access to the Internet over the power line. PLC is a technique that uses the existing power lines to transmit high speed (2 - 3 Mbps) data signals from one device to the other. PLC technology is chosen for data communication between the smart meters and the data concentrator, while GPRS technology is used for transferring the data from the data concentrator to the utility's data center. PLC can be considered as a promising technology for smart grid applications due to the fact that the existing infrastructure decreases the installation cost of the Communications infrastructure. Standardization efforts on PLC networks, cost-effective, ubiquitous nature and widely available basic structure of PLC may be the reason for its strength and popularity.

D) FIBER OPTIC COMMUNICATION

Optical fibre transmission is used both inside substations and for long-distance transmission of data. Optical fibres are often embedded in the stranded conductors of the shield (ground) wires of overhead lines. These cables are known as Optical Ground Wires (OPGW). Fiber optic is an optical tube cable that is designed to transport data threw glass over an optical light. An optical light has the ability to travel within 126,000 miles per second within the optical fiber. There are many components that make up the fiber optic cable. The optical fiber component is made up with 3 different parts: the buffer

coating, the cladding, and the core. The buffer coating, which is the outer part, provides the cable its strength and support, which helps prevent the cable from breaking. The cladding and the core both are designed to help enhance the transmission of the optical signal. Fiber optics can operate in the range of 850 nm (nanometers), 1300 nm, or 1550 nm wavelengths for data transmission. There are 2 different types of fiber optic cables that are used within fiber optic networks. One of these is the single-mode fiber and the other is the multi-mode fiber cable. The single-mode fiber carries an enormous amount of information in one direction. Single-mode fiber is used if there needs to be no return path for the communication network. Multi-mode fiber is used primarily where a sign should be transmitted and received at many places. Many applications of multi-mode fiber are used within networks in industrial or commercial buildings and around college institutions to allow for high data transmission rates.

2.2 WIRELESS TECHNOLOGIES

A) SATELLITE COMMUNICATION

Satellites have been used for many years for telecommunication networks and have also been adopted for Supervisory Control And Data Acquisition (SCADA) systems. A satellite communication network can be considered as a microwave network with a satellite acting as a repeater. **Geostationary orbit satellite communication:** Currently, many satellites that are in operation are placed in Geostationary Orbit (GEO). A GEO satellite or GEOS is typically at 35,786 km above the equator and its revolution around the Earth is synchronised with the Earth's rotation. The high altitude of a GEO satellite allows communications from it to cover approximately one-third of the Earth's surface. **Low earth orbiting (LEO) satellite communication:** LEO satellites are positioned 200–3000 km above the Earth, which reduces the propagation delay considerably. In addition to the low delay, the proximity of the satellite to the Earth makes the signal easily detectable even in bad weather.

B) WIMAX

WiMax Worldwide Interoperability for Microwave Access (WiMax) is a wireless technology which conforms to the IEEE 802.16 standard. It provides both fixed and mobile connectivity using a technique called Orthogonal Frequency Division Multiple Access (OFDMA). The coverage of WiMax extends up to 50 km with peak data rates of 75 Mbps for fixed connections and up to 15 Mbps for mobile connections. These data rates are expected to increase beyond 200 Mbps in Uplink and 300 Mbps in Downlink with the release of IEEE 802.16m-2011. It is optimised to support mobile devices moving up to a speed of 10 km/h. Even though it supports vehicles moving up to 120 km/h, its performance degrades with the vehicle speed. It has the capability to maintain connection with stations moving at up to 350 km/h.

C) ZIGBEE

ZigBee is a wireless communications technology that is relatively low in power usage, data rate, complexity and cost of deployment. It is an ideal technology for smart lightning, energy monitoring, home automation, and automatic meter reading, etc. ZigBee and ZigBee Smart Energy Profiles (SEP) have been felt as the most appropriate communication standards for Smart Grid Residential Network Domains by Use National Institute for Standard and Technology (NIST). ZigBee has 16 channels in the 2.4 GHz band, each with 5 MHz of bandwidth. 0 dBm (1 mW) is the maximum output power of the radios with a transmission range between 1 and 100 m with a 250 Kb/s data rate and OQPSK modulation. ZigBee is considered as a good option for metering and energy management and ideal for smart grid implementations along with its simplicity, mobility, robustness, low bandwidth requirements, low cost of deployment, its operation within an unlicensed spectrum, easy network implementation, being a standardized protocol based on the IEEE 802.15.4 standard.

D) LTE

LTE is another kind of cellular protocol, besides WiMAX mentioned in the above. It is considered as one of 4G standard protocols can serve high-speed data communication on the wireless links. Till 2014, LTE standard already has been accepted as the commercial service in most countries in the worldwide. Many different bands have been covered by the LTE standard. Therefore, we can use the LTE standard to establish a low-delay and high-reliable network for data transmission and other communication applications in the smart grid. Considered the architecture of distribution grid and transmission grid in the smart grid network, the LTE standard can be settled on the upper link between terminal power consumers and utilities, and also the wireless communication links between the primary substation and secondary substation, to lead the utilities achieve more accurate scheduling in the local power supply area. Also, any power fault happened in transmission grid can be delivered back and alarm the utilities based on the features of the LTE standard. Phasor measurement unit (PMU) is a quite popular communication application in the transmission grid based on the capacity of the LTE standard, which can alarm the power error and transmit back the needed situation data to the utilities that has remote controlling requirement on the high voltage power transmission lines.

II. CONCLUSION

This paper represents the use of communication network and its technologies in smart grid. Through communication technologies, a smart grid can improve power reliability, security. This paper also shows that smart grid built on the technologies of sensing, communication and control technologies offer a very promising future for utilities and users.

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V. BIOGRAPHIES

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