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REVIEW ARTICLE

A Discussion of the Communication Technologies in Smart Grid

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ABSTRACT With an increasing number of distributed renewable energy sources and higher requirements on the efficiency, reliability and security of existing power grid, Smart Grid is regarded as a significant evolution to the electric system. This paper mainly discusses the communication technologies applied in power grid from two aspects: cable technology and wireless technology. The former, such as DSL and PLC, is expensive, but it has broad deployment capability, strong communication capability, reliability and security. The latter could save the cost of installation, but it has limitation on bandwidth and security problems. In the future, grid features, system architecture, critical components, pilot projects of smart grid and its application and challenges after integrating with information and communication technology will be further discussed.

KEYWORDS
Smart grid
Communication technology
Electric system

1.Introduction

The lack of automatic analysis and situation awareness, delayed response caused by the mechanical switch, together with some extra inhibited factors, such as the demands of growing population on energy resources, global climate change, greenhouse gas emission, equipment failure and storage problems of energy resources, pose grave threats to the electric industry. In order to solve these problems, researchers proposed a new generation of electric system—Smart Grid. It is a modern grid infrastructure which integrates renewable energy with alternative one to improve efficiency, reliability and security through automatic control and modern communication technology. More importantly, by adopting the new network management strategy, smart grid could provide efficient distributed generation and distributed electricity storage with advanced sensing, communicating and computing capabilities. For smart grid, reliable and real-time information is critical for ensuring the power transmission from the power unit to the end users. Electricity interference and interruption caused by equipment failure, capacity constraint and natural disasters could be avoided by status monitoring, diagnosis and protective system of the online electric system to a large extent. For this reason, intelligent monitoring and control through modern information and communication technology has become the plan for basically realizing the smart grid [1].

2.Communication Technologies Applied in Smart Grid

Communication system is the key component of smart grid infrastructure. With the integration of advanced technology and applications in smart grid, a large amount of data generated by different applications will provide analysis, control and real-time pricing methods in the future. Therefore, it is crucial for electricity enterprises to define the communication requirements and find the best communication architecture to process output data and provide reliable, safe and profitable services for the whole system. Different communication technologies supported by two kinds of communication medias, cable and wireless communication that could be used for data transmission between smart electric meters and electricity enterprises. Wireless communication only needs to invest less capital for infrastructure construction and could cover the areas which are difficult or unable to be reached, but its transmission path may lead to signal attenuation. While cable communication is free of signal interference and battery dependence. Two solutions stated above are necessary for the transmission of information flow in the smart grid system. The former could connect sensors and electric ap-

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pliances to smart electric meters, and the latter could connect smart electric meters to data center. Some important limiting factors, such as time arrangement, operating costs, availability of technologies and specific environment, should be taken into account in the process of operating smart grid. Communication technologies applied in smart grid and their advantages and disadvantages will be analyzed as below [2].

2.1. ZigBee

ZigBee, the low-dissipation Personal Area Network Protocol based on IEEE802.15.4, is mainly used in the fields of automatic control and remote control. Its features, such as close range, low complexity, self-organizing, low-power dissipation, low data rate and low costs, make it an ideal technology for intelligent electric apparatus, energy monitoring, home automation and automatic message recording. Many suppliers integrated ZigBee into their smart electric meters. This kind of smart electric meters could communicate with and control other ZigBee integrated devices and transmit real-time consumption of electricity to their owners. ZigBee has 16 frequency bands at 2.4 GHz with the bandwidth of 5 MHz for each band. Zigbee is applied in managing fuel gas, water, electricity and other public utilities to provide load balancing, demand response, real-time pricing, system monitoring and measuring support for its simple operating procedures, strong mobility, low requirements for bandwidth, low operating cost, without authorization spectrum and simple implementation of communication. However, ZigBee also has some shortages in terms of practical, such as deficiency of processing capacity, small memory space, small delay resistance and being susceptible to interference from other electric appliances at ISM free band.

2.2. Wireless Mesh Network (WMN)

Wireless mesh network, also known as multi-hop network, is a new type of wireless network technology distinct from conventional ones. In the conventional wireless local area network (WLAN), each client accesses the network via a wireless link connected with the fixed access point (AP). Therefore, if users want to communicate with each other, they have to access a fixed AP first. This kind of network structure is called single hop network. But in the WMN, any wireless device node could act as AP and in the meantime as router, every node in the network could transmit and receive signals and could directly communicate with one or more peer nodes. WMN has features of no single point of failure (SPOF), rapid and flexible networking, high performance, Non-Light of Sight (nLOS), high-speed mobile support, integration with existing network, etc.

2.3. Cellular network

Cellular network is a good option for communication among smart electric meters, electricity enterprises and remote nodes. Cellular communication technologies that could be used in the deployment of smart electric meters include 2G, 2.5G, 3G, WiMAX and LTE. Having existing cellular communication infrastructure, electricity enterprises don't have to spend operating cost and time in building a private communication network. Cellular network solutions could also distribute smart electric meters to more capacious area. Wide application and economy make cellular network the main communication technology of the current market. In security terms, cellular network has strong security control ability to ensure the safe transmission of data. For instance, the widely used GSM technology has features of user anonymity, authentication, signal protection and user data protection. Almost 100% of the coverage of cellular network in cities and suburbs allows electricity enterprises to widely distribute smart electric meters and carry out excellent communication management. Low invested cost and operating expense, larger coverage, rapid installation and other prominent characters make cellular network the best option for smart grid communication technology. Continuous and available communication is necessary for some critical tasks of power grid, but cellular network provides services for consumers, so network performance may be reduced in case of emergency and network congestion may be induced. As a consequence, cellular network service providers may fail to ensure their works under abnormal conditions, such as natural disasters. Compared with pubic network, the private one could solve such situations with various technologies and frequency bands.

2.4. Power Line Communication (PLC)

PLC technology refers to the communication mode that transmits data information through existing power line. This technology loads high-frequency signals that contain information into the electric current, and then transmits them to the adapter of opposite terminal through electric wire and finally separates the signals from electric current to complete information transfer. At present, the data transfer rate of power line could reach 2~3 Mbit/s. Since power line is directly connected to the electric meter, so PLC is the preferred electric meter communication mode in suburbs when other communication technologies are difficult to take effect. In China, PLC system based on low-voltage network has become the research focus point of smart grid. In the typical power line system, smart electric meter connects to the data concentrator through electric wire, and then transmits data to data center by cellular network technology. The most competitive advantage of PLC technology is the transmission of data, voice and video through existing power line with no need to rewiring. Consequently, smart electric meters and other smart electrical equipment only need to be plugged in to realize communication transmission. At present, three networks, GSM, CDMA and WCDMA, have started to merge to-

gether, so there will be more requirements for PLC. The characters of power line network have brought about some technical problems. Power transmission medium is an extremely rigor and noisy environment, and its channel is difficult to be modeled. Low bandwidth character restricts the applications requiring high bandwidth in PLC technology. In addition, topology of network, amount and types of equipment connected to electric wire, distance of cables among transmitter and receiver and other factors would adversely affect the signals transmitted through power line [3].

3. Conclusion

In order to tackle the challenges in power grid, researchers proposed a new concept—Smart Grid. It can be taken as the modern grid infrastructure that improved its efficiency and reliability through applying advanced technologies such as automatic control, high-power converter, modern communication infrastructure, sensing and metering. This paper, focusing on the key problems of smart grid technology, analyzes the technologies currently applied in smart grid, such as ZigBee, WMN, cellular network, PLC and subscriber line, and their advantages and disadvantages from the perspective of data communication, and indicates the direction of studying in the future.

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