Internet of Things Technology and its Applications in Smart Grid

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Abstract

Smart grid is the latest trend of development and reform in today's world, and it is also a major technological innovation and development trend in the 21st century. Internet of Things technology is a new information processing and acquisition method, and it has been widely used in intelligent transportation, environmental monitoring and other fields. Internet of Things is an important technical mean to promote the development of smart grid. Using Internet of Things technology can effectively integrate the infrastructure resources in communications and electrical power system, increase the level of power system information, and improve the utilization efficiency of infrastructures in the existing power system. In this paper, the concept of smart grid and Internet of Things are briefed, thus the urgency of its applications in smart grid are pointed out. Meanwhile, a research and design in the construction of smart grid which is based on Internet of things are made, and the design and implementation in typical application links, including wind power prediction, condition monitoring of overhead transmission lines, power monitoring, smart home and asset management are elaborated emphatically. Finally, the problems in applications and future research direction are also analyzed.

Keywords: smart grid, internet of things technology, power prediction, smart home, asset management

1. Introduction

Internet of Things (IoT) technology is a new information processing and acquisition method, including radio frequency identification technology, sensor technology, smart technology, nanotechnology and other technologies. It has been considered as the third wave of the information industry after computer, Internet and mobile communication network. Now it has been widely used in intelligent transportation, industrial monitoring, environmental monitoring, defense and military, digital family and other fields [1-2]. For electrical power system, smart grid is the latest trend of development and reform in today's world, and it is also a major technological innovation and development trend in the 21st century. The implementation of smart grid must rely on the line monitoring and real-time control in all aspects of the grid important operating parameters, and the basic characteristics are grid information, automation and communication. Meanwhile, Internet of Things technology also has many characteristics, such as comprehensive perception, reliable transmission and intelligent processing, so they two have good space to fusion [3].

At present, the application research of Internet of Things technology in smart grid has been a hot research topic in the global field. In June 2009, the United States announced a smart grid standards and interoperability principles called "ieeep2030", it would largely promote the applications of Internet of Things technology in smart grid. Under the U-Japan strategic conception, Japan further proposed the I-Japan to vigorously develop the Internet of things and built smart grid. In 2010, the World Expo successfully held in Shanghai. Through a variety of simulation, it made people experience the smart and convenient which are after the perfect combination of Internet of Things technology and smart grid. Therefore, If China want to build a strong and smart grid, which treats UHV power grid as the backbone with the coordinated development at all the levels of power, the research about applications of IoT technology in smart grid is imperative.

This paper introduces Internet of Things technology and its applications in smart grid. Section 2 describes the concept of smart grid and Internet of Things which are highlighting the

urgency of its application. In Section 3, the construction of smart grid based on Internet of things is presented, thus the basic structure, the design and implementation in typical application links are analyzed emphatically. Finally, Section 4 concludes the paper, and analyses the problems in applications of Internet of Things technology in smart grid and the future research direction.

2. The Concept and the Urgency
2.1. The Concept of Smart Grid and Internet of Things
Smart grid is a new and modern power grid, which is highly integrated with advanced sensor measurement technology, information and communication technology, analysis of the decision-making technology, automatic control technology, and energy power technology and grid infrastructures. Compared with the traditional grid, smart grid has been improved distinctly in the optimization of power control, the flexibility of grid structure, optimizing the allocation of resources, and improving the power quality of services. Therefore, smart grid has many characteristics including strong, self-healing, compatibility, economy, integration and optimization and so forth [4-7].

Internet of Things, namely "the Internet in which the things connected to each other", is the extension and expansion of Internet-based network. According to the agreed protocols, with IoT key technologies: radio frequency identification technology, sensor technology, smart technology and nanotechnology, the communication information can be exchanged, and the intelligent recognition, positioning, tracking, monitoring and management can be achieved [8-10].

2.2. The Urgency of IoT Technology Applications in Smart Grid
Internet of things used in smart grid is the inevitable result of the development of information communication technology (ICT) to a certain stage. It will be able to effectively integrate the infrastructure resources in communications and electrical power system, make the information and communication services operate for electrical power system, increase the level of power system information, and improve the utilization efficiency of infrastructures in the existing power system. Because IoT technology has been used in smart grid, the important technical support for the generation, transmission, substation, distribution, electricity and other aspects of power grid can be effectively provided, as shown in Figure 1.
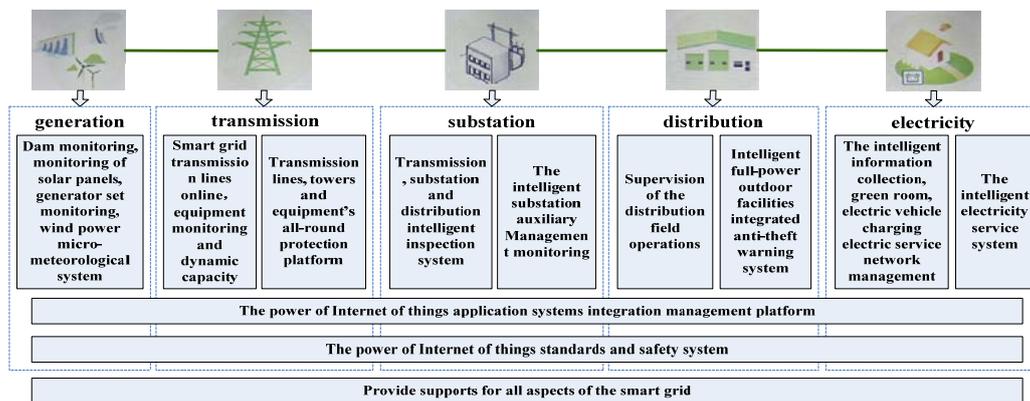

Figure1. Applications of Internet of Things in Smart Grid

3. The Construction of Smart Grid based on IoT
3.1. The Architecture of Smart Grid based on IoT
According to the current universal approved network architecture of IoT, the Internet of Things for smart grid is broadly divided into three layers: perception (sensing) layer, network layer and application layer, as shown in Figure 2.
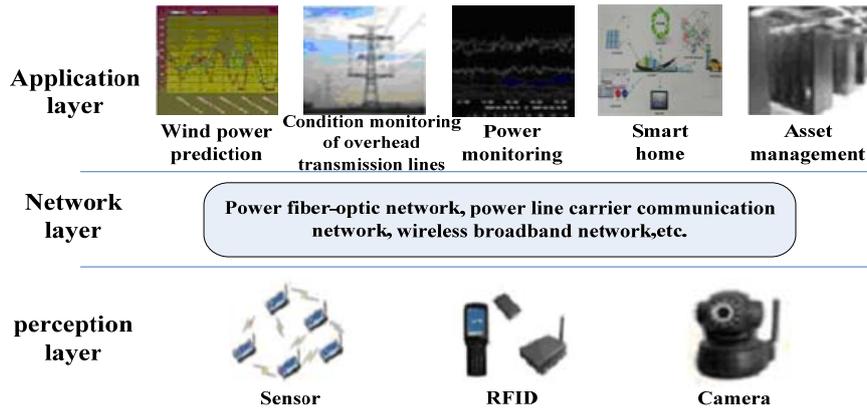
Figure 2. Basic Architecture of IoT in Applications of Smart Grid

Perception layer is usually divided into perceived control layer and communication extended layer. Mainly through the sensor, RFID, camera and other sensors, perceived control layer can perceive and gather information; Communication extended layer is coupled physical entity to the top two floors by communication terminal module or extension of the network. The technology is widely used, for power system monitoring data, it uses the way of optical fiber communication, and for the online monitoring of transmission line or electric equipment condition monitoring, in addition to optical fiber to transmit information, it also uses the wireless sensor technology in a certain extent.

Network layer is mainly used to achieve transmission of information of all kinds in the wide area between the perception layer and application service layer within smart grid. In smart grid, the network layer is based on the power fiber optic network and aided by power line carrier communication network and wireless broadband network.

Application layer is the Internet of Things system's application center or control center in smart grid. The applications of Internet of Things which is oriented smart grid are involved in all aspects of production and management, and through the use of intelligent computing, pattern recognition technology and other technologies, it can realize the grid integration of data analysis and processing, thus achieve intelligent decision-making, control and service, ultimately the level of application links in smart grid can be improved [9, 11, 12].

4. Design and Implementation in Typical Application Links of Smart Grid based on IoT
4.1. Wind Power Prediction

Internet of things technology applied in wind power prediction, mainly through the wireless sensor network (WSN), the wind data can be collected in real time, and the power change can be predicted. The specific implementation process of power prediction is shown in Figure 3.
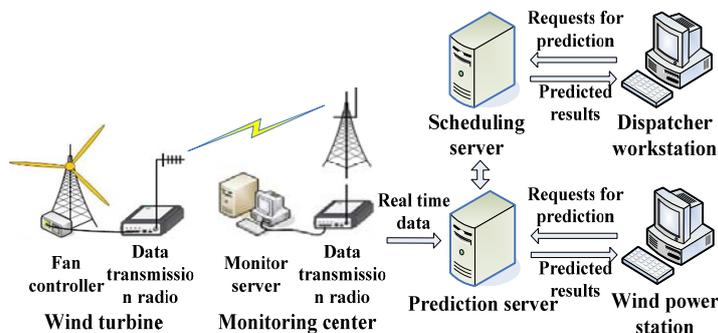

Figure 3. Wind power prediction based on IoT

Through the wireless sensor network, the monitoring center monitors the wind turbine information in real-time, and then transmits the collected real-time data to prediction server. The result that can be forecast by the processing of prediction server is transmitted to the wind power station, also can be remotely transmitted to the scheduling server, and then the scheduling server will aggregate the predicted results to dispatcher workstation. In this way, it will achieve the wind power prediction in local monitoring and remote control through wind power station and scheduling server.

Considering many factors is closely related to the accuracy of prediction, such as air temperature, pressure, wind direction, humidity, season, location and so on, the prediction server contains short-term forecast, medium-term forecast and a series of data prediction processing methods, so that the power can be predicted timely and effective in whole system, and the accurate rate can be guaranteed especially in short-term forecast [13-14].

4.2. Condition Monitoring of Overhead Transmission Lines

In the process of transmission, overhead lines going wrong will lead to power system blackouts, thus this failure is mostly sudden, and it is difficult to find the location of the failure and repair in a short period of time. IoT technology used in overhead transmission lines can not only carry out line state monitoring, but also improve the perception of power transmission line in operation condition, including meteorological conditions, ice cover, ground wire breeze vibration, conductor temperature and sag, transmission line windage yaw, tower inclination and others. Condition monitoring of overhead transmission lines based on IoT is shown in Figure 4.
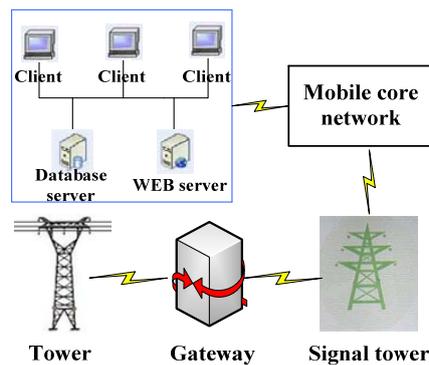

Figure 4. Condition Monitoring of Overhead Transmission Lines based on IoT

According to Internet of things' real-time monitoring and early-warning diagnostic on overhead transmission line in mechanical state information, environmental status information and running status information, we can do the corresponding fault judging, equipment maintenance and other works ahead of time, so that we can improve the equipments maintenance, automatic diagnosis and safety operation level. Also it is convenient to realize the effective management and all-round protection of power equipment, save energy, reduce transmission loss, improve the transmission efficiency and enhance the stability and the safety of power system [9, 12, 15].

4.3. Power Monitoring

Power monitoring is mainly based on the distribution network of IoT technology and electricity comprehensive data-aware management system. The system which consists of power monitor, front and computer, multi network fusion terminal, electric control center and any other things, can achieve the remote monitoring about electricity consumption of electrical equipments in the factories, enterprises and institutions and families, meanwhile can give starting and stopping control instruction to the remote equipments. As shown in Figure 5.
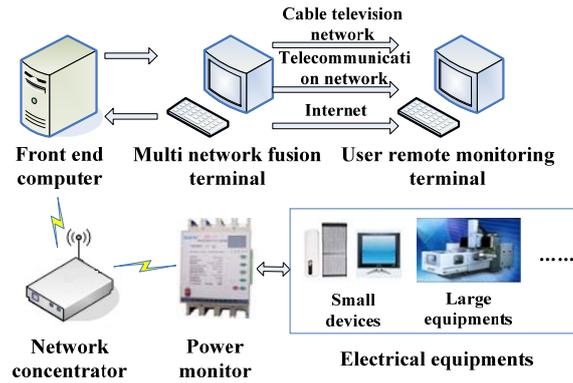
Figure 5. Power Monitoring based on IoT

By monitoring electricity equipments connected to grid, power monitor sends data, such as its load conditions, power consumption and other information, to a specific front end computer through the network concentrator and wireless communication. As the control center of power data acquisition, transmission and power equipment, front end computer sends the preprocessed data to the data communication network from multi network fusion terminal, and finally uploads to electric control center of the son station layer. Electric control center builds management information systems, analyzes and processes electricity data, and opens data interface, so that it can remote inquire the electrical equipments' operation, power consumption and so on, so as to realize the remote control [16].

4.4. Smart Home

IoT technology is convenient for realization of smart home. Through fiber composite cable households and other advanced technologies, smart home organic gets the various subsystems which are related to home life together. It can not only realize resource sharing and communication within the family, but also exchange information with the family external network by home intelligent gateway. Its main goal is to provide an efficient, comfortable, safe, convenient, environmentally friendly living environment for people, which Sets system, service, management as a whole [3, 9]. For example, with the help of smoke sensors, infrared sensors, gas sensors and other sensors, which are installed in home, the family security can be achieved, as shown in Figure 6.
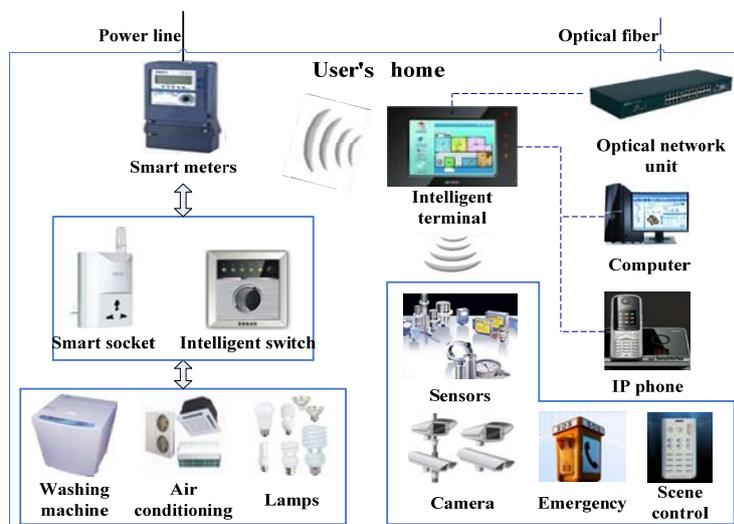

Figure 6. IoT Technology used in Smart Home

4.5. Asset Management

China's smart grid, covering all the end-users in China, uses the ultra-high voltage (UHV) as the backbone. The power grid assets are on a large scale, so requires for asset management are getting higher and higher. IoT technology has been used in asset management, asset tags written with the asset information were installed in equipment factory. For each asset operation, the readers will read the electronic tags which are on the asset and sends the information to the server for processing. Thereby it can realize the assets' tracking and management, as shown in Figure 7.
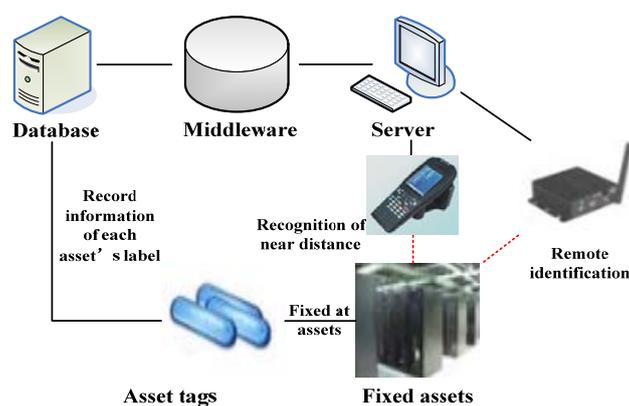

Figure 7. IoT Technology used in Asset Management

IoT technology applied in asset management uses the radio frequency identification and identification coding system in the electric power equipments. Through the full use of sensor network, recognition technology, general wireless packet technology and other technologies, it can realize identity management, state monitoring and full life cycle management of the assets; Through the automatic target recognition and access to data, it can realize power grid assets' management identification, perception and information transfer; Through the use of business application system, it can achieve the information processing of power grid asset management and the assets' data from the field data acquisition, can also organic integrate asset inventory with inspection work, so as to enhance the management level of power grid assets [3, 8, 12].

5. Conclusion

This paper mainly introduces IoT technology and its applications to be realized in smart grid, including wind power prediction, condition monitoring of overhead transmission lines, power monitoring, smart home and asset management. The development of Internet of things and smart grid are mutually reinforcing. On the one hand, Internet of things used in smart grid will play an important role in promoting the development of smart grid, and it is helpful to complete the online monitoring and real-time information controlling in the important operating parameters of all aspects; On the other hand, the intelligent network will become a powerful driving force which will develop the networking industry of Internet of Things, and will also promote the development of information and communication industry, moreover, it can influence and promote the applications of Internet of Things in other industries. There are also some problems in the application of IoT technology in smart grid. For example, the IoT industries lack core technologies with independent intellectual property rights, and industrial dispersion constraints the application of IoT technology in smart grid; With the expansion of the scale of China's power grid, the number of distribution substation electrical equipments and transaction volume has increased rapidly, the operation is complex, and the reliability is low. In view of this, the main research direction of future IoT should be put in the increase of support and development in IoT core technologies which are related to smart grid, and the formation of a more complete IoT technologies should be accelerated. Moreover, infrastructures should be invested, the transmission and communication based on network should be supplied, so that it

will make the power network more powerful and perfect, thereby enhance the reliability of the transmission communication network.

Acknowledgement

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