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Application of Internet of Things in Smart Grid Power Transmission

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Abstract—**Utilizing Internet of Things (IoT) technology in smart grid is an important approach to speed up the informatization of power grid system, and it is beneficial for effective management of the power grid infrastructure. Disaster prevention and reduction of power transmission line is one of the most important application fields of IoT. Advanced sensing and communication technologies of IoT can effectively avoid or reduce the damage of natural disasters to the transmission lines, improve the reliability of power transmission and reduce economic loss. Focused on the characteristic of the construction and development of smart grid, this paper introduced the application of IoT in online monitoring system of power transmission line.**

Keywords-Internet of Things; Smart grid; Power transmission

I. INTRODUCTION

Internet of Things (IoT)[1, 2] is a large network consist of all kinds of information sensing devices such as radio frequency identification (RFID) devices, infrared sensors, global positioning system (GPS), laser scanners and the Internet. IoT employs a variety of smart devices to sense and identify physical world. Based on Internet and communications networks, it utilizes computing facilities and software systems for information processing and knowledge digging. By using IoT technology, we can achieve human-thing and thing-thing information exchange and seamless linkage of information flows, thus accomplishing real-time control, accurate management and scientific decision-making of the physical world.

Power Internet of Things (PIoT) is the application of IoT in smart grid. PIoT can achieve reliable information transmission through wired or wireless communication network and smart information processing in power grid system. PIoT can be widely applied in every aspect of smart grid, such as power generation, transmission, transformation, distribution and consumption.

Overhead high-voltage transmission lines are vulnerable to weathers (such as wind, snow, etc.), resulting in damage to power transmission line, influence in security operation of power transmission facilities, paralysis of large area power supply, and significant loss of the national economy.

Wind vibration and wind deviation are common pitfalls of overhead high-voltage transmission lines, and are the main reasons of transmission line broken. Once conductor galloping caused by strong wind, it usually lasts for several hours and will bring great damage to the high-voltage transmission lines. The rainy and snowy weather may cause icing to transmission line, and the asymmetric pulling force will lead to leaning of the transmission tower, which is the potential risk to the safety of transmission line.

The country region of China is vast, the fault points of power transmission line are scattered, remote and difficult to monitor and maintenance. The monitoring record provided by the meteorological station of specific time of an area cannot accurately reflect the weather conditions of the transmission corridor. In addition, the historical weather data of the transmission corridor is almost blank, which brings some difficulties for fault diagnosis, prevention and research of the power transmission line. The application of IoT technologies in online monitoring of power transmission line becomes the key to solve the above problems.

The rest of the paper is organized as follows. Section II presents the architecture of IoT. Section III discusses key technologies of IoT in smart grid. The applications of IoT technology in online monitoring system of power transmission line is introduced in Section IV. Finally, Section V concludes the paper.

II. ARCHITECTURE OF POWER INTERNET OF THINGS

Power Internet of Things can be divided into three layers[3]: perception layer, network layer, and application layer.

The perception layer consists of two-dimension code tags and readers, RFID tags and readers, cameras, GPS, a0ll kinds of sensors, sensor network, Machine to Machine (M2M terminals, and sensor gateways, etc. Perception layer includes perception control sub-layer and communication extension sub-layer. Perception control sub-layer realizes intelligent perception of the physical world, information acquisition and processing and automatic control; while communication extension sub-layer connected the physical things to the network layer and the application layer with communication terminal module directly or through the extension network composed by the terminal modules.

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The network layer consists of converged network formed by all kinds of communication network and the Internet. The concept of network layer has been widely accepted due to its mature technologies. Besides, the PIoT management centre and information centre are parts of the network layer. That is to say, the network layer can not only operate the network, but also can operate the information. Network layer mainly realizes information transmission, routing and control, including the access network and core network. The network layer can rely on industry-specific communication networks as well as the public telecommunications networks.

Application layer is a combination of IoT technologies and industry expertise to achieve a broad set of intelligent application solutions. Application layer includes application infrastructure/middleware and a variety of applications of IoT. Application infrastructure/middleware provides information processing, computing, and other common basic services, capacity and resources interface for IoT. The key issue of the application layer is information sharing and information security. Through the application layer, IoT can achieve deep integration of information technology with the industry. It will have great effect on economic and social development.

III. KEY TECHNOLOGIES OF IOT

The key technologies of applying IoT to smart grid include:

A. *Sensor technology*[4]

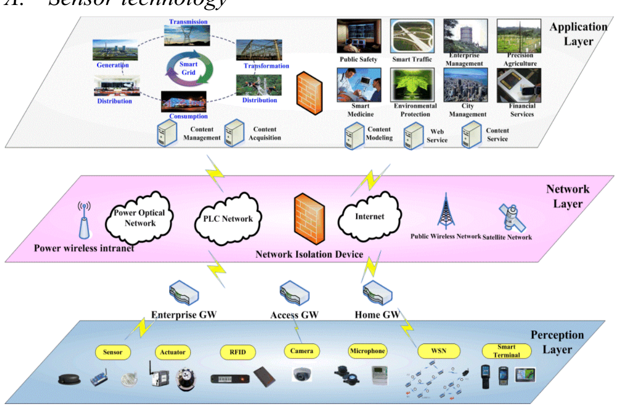

Figure 1. Architecture of Power Internet of Things

Sensors can be considered as the “sense organs” of the material world, and provide the raw information for information processing, transmitting, analyzing and feedback, including heat, power, light, electricity, sound and signals. Sensors can be divided into various types in terms of materials, output signal types, and manufacturing technologies, etc. Recently, nanotechnology has been utilized to provide high performance sensitive material and new sensor production methods, such as Micro Electro Mechanical Systems (MEMS) technology which greatly extends the application field of sensors and promotes the development of sensor industry.

B. *Information and communication technology*[5]

Based on information and communication technology, the transmission and collaboration of the perception information can be realized, thus the state of the power grid devices can be sensed. According to the range of transmission, information and communication technology can be divided into two categories: short range communication technology and wide area communication technology. In wide area communication network, IP based Internet, power line carrier, Optical Fiber Composite Low Voltage Cable (OPLC), power information wireless network, public 2G/3G mobile communication network, Time Division Long Term Evolution (TD-LTE) 4G network, and satellite communication nework can achieve long-distance information transmission. For short range communications, IEEE 802.15.4 (ZigBee), Bluetooth, and Ultra Wideband (UWB) represent the mainstream technology. Due to the characteristics of low-power, low-rate and short-distance, ZigBee is suitable for the IoT devices with constraint of computation and storage capacity.

C. *Data fusion technology*[6]

The resources for IoT terminals are usually limited, including battery capacity, processing ability, storage capacity and bandwidth. In the process of gathering information, it is not appropriate to send all data to the cluster node because it would waste bandwidth and energy. In order to keep the efficiency of information gathering, data fusion technology can be utilized to collect data thus more effective and useful data can be combined.

D. *Reliable communication for smart grid under the complex application environment*[7]

There are several requirements of IoT applications in different environments, such as reliability, self-organization, signal penetration, hybrid communication technology and self-healing. Since the performance of IoT highly relies on the actual environment, IoT technology needs to be carefully designed to overcome the adverse environmental factors. For example, when a small portion of devices fails to transmit data, the route and transmission strategy would be reselected by self-healing technology, thus the reliability of the whole network would not be affected.

E. *Power acquisition technology*[8]

Due to the energy of IoT devices are usually supported by battery, power acquisition problem is very essential for the application of IoT, such as the power transmission line monitoring system, various sensors, backbone nodes and video cameras set up in the transmission lines and the transmission towers. If the energy supply problem of IoT can be solved, the applications of IoT in smart grid would be greatly extended.

F. *Environment compatibility with high-voltage and strong-electromagnetic*[9]

Since IoT terminals are often deployed in outdoor power transmission lines, substations, and even more severe electromagnetic environment in smart grid. In order to

prolong the lifetime of the sensing terminal under the above severe environments, the sensor and its chip manufacturing process need to embed new technologies, such as waterproof, dustproof, anti-vibration, anti-electromagnetic, anti-high-temperature, anti-low-temperature and others.

G. *Information security technology*[10]

Information security technology can be utilized in three layers to avoid information leakage and loss, and protect the safety operation of the applications. Security should be considered not only in the data transmission process, but also in the process of data storage and management.

IV. IoT BASED ONLINE MONITORING SYSTEM OF POWER TRANSMISSION LINE

Power transmission line monitoring system is one of the most important applications of IoT in smart grid, particularly, disaster prevention and mitigation for power transmission lines. In recent years, natural disasters bring about many challenges to high-voltage power transmission facilities, including security, stability, and reliability. Moreover, current power transmission line monitoring operations are mainly realized by manual operations which face the problems of low efficiency, low accuracy, and long operation period.

At present, a number of monitoring systems of power transmission line have been put into operation. These systems often use wireless public network such as 3G or other wireless communication networks for data transmission of each sensor, but there are some problems such as high operation and maintenance cost, incomplete network coverage, low data transmission rate and complex network maintenance, which will restrict the development of power transmission line monitoring system, hinder the improvement of power transmission efficiency and constrain the progress of patrol of power transmission line.

In order to achieve real-time online monitoring of power transmission lines, wireless sensors about conductor galloping, micro-meteorology, wind vibration, icing, and conductor temperature are deployed on the 220kV, 500kV high-voltage power transmission lines in the experimental area.

The power transmission line monitoring system is composed of two parts. One part is installed along with the power transmission lines to monitor the status of the conductors; the other part is installed on the transmission towers to monitor the environment and the states of the towers. The communication between the IoT devices on the power transmission lines and the transmission towers is usually based on short-range wireless communication technology.

The IoT based online monitoring system of power transmission lines can transmit the information farther through multi-hop relay communication network, which can ensure effective information transmission for the large span and long distance power transmission facilities. According to different application scenes of power transmission line, the system network topology can be cluster-chain type, where several cluster networks form a chain network to cover the power transmission line. As shown in figure 2.

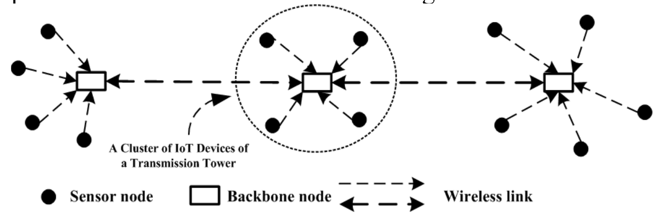

Figure 2. Network topology for online monitoring system of power transmission line

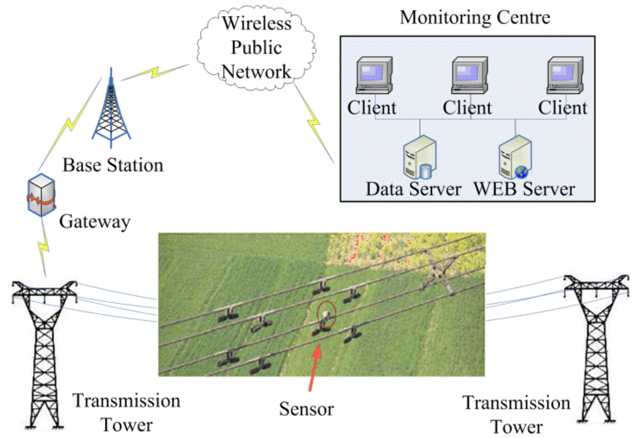

Figure 3. Data transmission network

Each sensor can communicate to the nearby backbone node directly, and the communication links between the sensors and the backbone nodes are generally unidirectional links; each backbone node can communicate to at most 256 sensors. The distance between the backbone nodes is several hundred meters, and the communication link between the backbone nodes is bidirectional link. Parts of the backbone nodes are able to access to the public network through 3G, TD-LTE or power optical network. As shown in figure 3.

The specific monitoring contents are as follows:

(1) Transmission tower leaning

The leaning sensor transmits the status of the transmission tower to the nearby backbone node, which merges the data from several leaning sensors together to form the information of transmission tower leaning and realize real-time monitoring and early warning.

(2) Conductor galloping

According to the calculation and analysis of the acceleration of the monitoring point, the number of vertical and horizontal half-waves of galloped conductor can be analyzed and the motion track can be calculated. Thus whether the conductor is in galloping danger can be determined, and the discharge between phase conductors and tower collapse can be avoided.

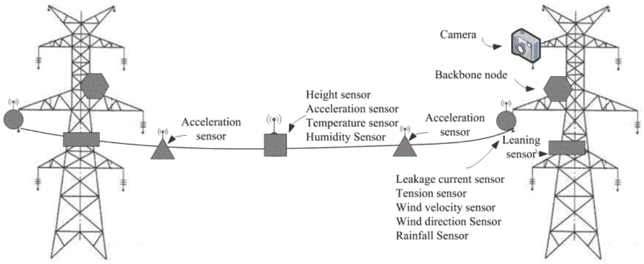

Figure 4. The sensor deployment scheme of the power transmission line and tower

(3) Wind deviation

The wind deviation can be calculated by the three-dimensional acceleration sensor deployed on the conductors. The wind deviation data results from the wind velocity sensor and the acceleration sensor can provide the field test data for the wind deviation verification of the conductor. The operation personnel can take reasonable measures to resist the wind deviation and find the discharge point.

(4) Micro-meteorology

The temperature, humidity, wind velocity, sunshine, and rainfall can be recorded by the wireless sensors along the conductor or on the tower.

(5) Conductor icing

Conductor icing can be determined according to the result of the micro-meteorology sensors and the tension sensors. The data analysis system at the monitoring centre analyzes the information collected by the sensors and makes the early warning decisions. Thus the ice flashover can be alleviated or avoided.

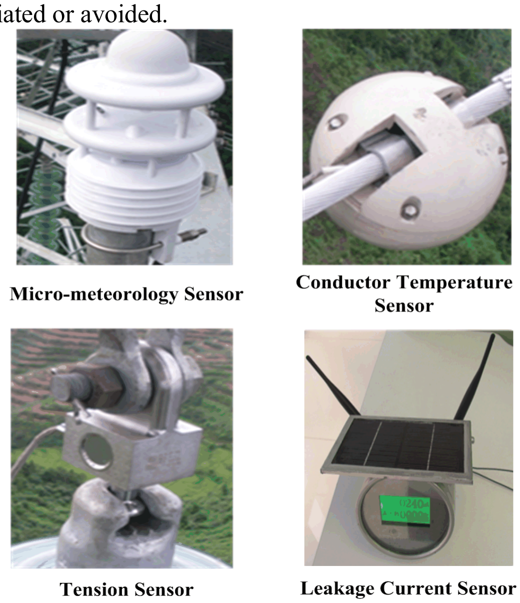

Figure 5. Wireless sensors

(6) Wind vibration

The acceleration sensors are used to detect the vibration of the conductor caused by wind. The vibration frequency and amplitude can be recorded and analyzed; the wind velocity, wind direction, environment temperature, humidity and the fatigue life of the conductor can also be analyzed.

(7) Conductor temperature

The operating temperature of conductor can be collected by the wireless temperature sensors along the conductor.

The sensor deployment scheme of the power transmission line and tower is shown in figure 4. The devices include temperature, humidity, wind and other meteorological sensor, vibration sensor, ultrasonic sensor, tower leaning sensor, infrared sensor, leakage current sensor, camera and the backbone node, which build the monitoring system for power transmission line and tower. The pictures of the wireless sensors and their deployments are shown in figure 5 and figure 6.

The backbone nodes deployed in the transmission tower collected the data from the nearby wireless sensors and transmit the merged information to the monitoring centre through the mobile communication network or power private network to achieve long-distance, flexible, convenient, high-speed information transmission and reliable and high-quality interconnection between the power transmission facilities and the monitoring centre.

Online monitoring system of power transmission line realizes real-time monitoring, information display, statistics and analysis through the information management system. The status of the power transmission facilities can be displayed visually. As shown in figure 7 and figure 8. The operating personnel can make decisions and issue orders according to the analytical results of the information management system, so as to detect or exclude hidden dangers as early as possible and secure the reliable operations of the power transmission facilities.

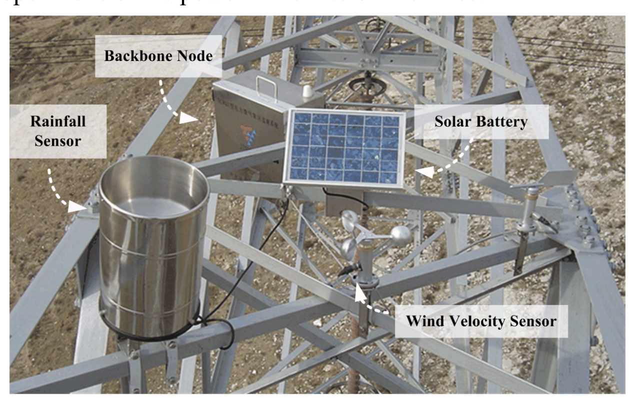

Figure 6. Deployment of the IoT devices

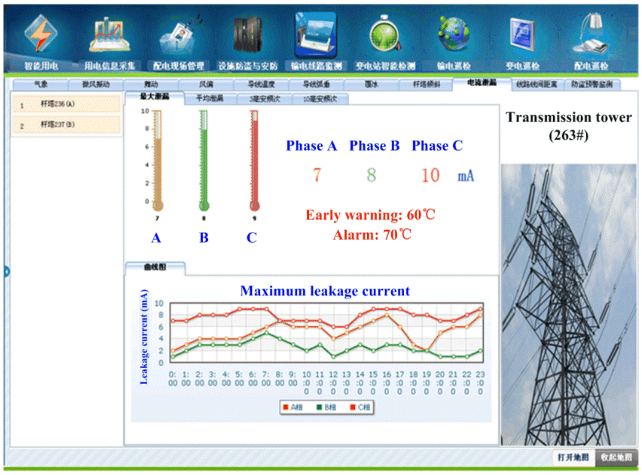

Figure 7. Display interface of online monitoring system of power transmission line

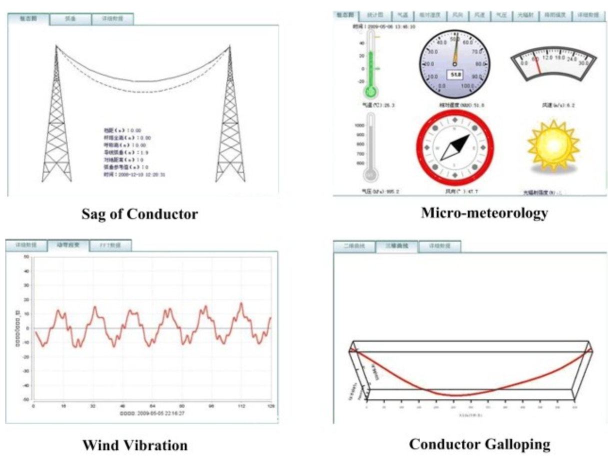

Figure 8. Functions of the online monitoring system of power transmission line

V. CONCLUSION

IoT has been considered as the third revolution in the digital technology after the computer and the Internet. Currently, the power grid is transforming towards smart grid in China, the requirements of automation and intellectualization would lead to deep integrations of IoT with smart grid[11]. Up to one trillion RMB market would be brought by smart grid, which brings great challenges for IoT technology to become more practical for industrial applications in smart grid. The mature wireless communication theory and network optimization theory have been paved the way for theoretical basis of IoT.

Through the IoT technology, the operation parameters of the power transmission line and tower, such as the micro-meteorology, conductor galloping, wind deviation, conductor temperature, icing and tower leaning can be visually displayed at the monitoring centre. Thus real-time monitoring and early warning of disaster can be realized, which will effectively resist or reduce the damage of the major natural disasters to the power grid. In our future work, the cost of our power transmission line monitoring system needs to be reduced and the reliability of our system also needs to be enhanced.

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