On-line Monitoring System Design Based on the 5.8G Wireless Private Network Transmission Line

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ABSTRACT: When the transmission line passes through the mountains, rivers and other complex regional environments, it usually uses 2G/3G communication, resulting in poor quality of data transmission because the signal is weak even no signal. However, in these areas, the wireless frequency band of 5.8G is small, which has little effect by rain attenuation and suitable for long-distance transmission with the coordination of directional antenna. Therefore, the 5.8G wireless network communication is the best choice. In this paper, an on-line monitoring system for transmission line based on 5.8G is proposed, and the power supply mode and safety protection are analyzed in depth. This design has been successfully used in pilot applications and solves the problem of transmission line operation data access in non-line of cable resources or no network coverage area, to ensure the effective and reliable operation of the system.

Keywords: smart grid; transmission line; on-line monitoring; wireless private network; 5.8G

1 INTRODUCTION

As an essential part of the transmission link of the smart grid, the on-line monitoring system of transmission line can control the running state of transmission line, improve the management level of power transmission operation, and guarantee information, automation and interaction of smart grid.

At present, in the on-line monitoring system of transmission line, most of communication used public network communication and optical fiber communication. However, public network communication has poor safety, poor reliability and high communication cost in the late stage [1-2]; optical fiber communication has high power consumption, high cost, and contrary to the State Electricity, Regulatory Bureau “Electric Power Secondary System Security Protection”[3]. With the rapid development of real-time data collection, mobile patrol operations, emergency services, construction of power wireless network has become more and more urgent and important, has become one of the
important directions in the development of on-line monitoring and communication technology for transmission line.

In China, most of the transmission line is set up in the areas with poor natural conditions and complex terrain, tree growth, bird feces, etc. will cause short circuit, wear, etc. If not effective monitoring, it is easy to cause serious power network accident and irreparable economic losses. At present, the transmission line passing across the mountains, rivers and lakes, through unmanned area complex areas, usually uses 2G/3G communication but the public signal in the area is weak, and is easy to form a blind spot. The data transmission security and confidentiality is poor.

2 5.8G OVERVIEW

2.1 Application status of 5.8G

At present, 5.8G has been widely used in industry, transportation, electric power and other industries. Literature [5] uses 5.8G in the subway, makes subway accommodate more functional subsystems, and provides more services; in literature [6], 5.8G applications in electric multi-business backup communication network, realizes the integration of wired and wireless network, enhances the availability of power multi-service communication network, and improves information management level of company; in literature [7], 5.8G is used in the ETC system, when the vehicle enters the effective communication range, RSU sends a wireless interrogation signal based on 5.8G, access vehicle information and achieve fast payment; literature [8] presented application scenario of 5.8GHz wireless communication technology in the field of transmission line monitoring and emergency communication, selected Di Qing power supply bureau as a pilot, verified the feasibility of the construction of electric power communication network based on 5.8G wireless communication technology; in 2015, Chengdu Railway Bureau train station successfully used 5.8G wireless devices to achieve a HD monitor.

2.2 The advantages of 5.8G

5.8GHz band is a fixed wireless access to the highest performance price ratio of the preferred frequency band, while 5.725~5.850GHz frequency band without a permit application can be used [9]. Specific advantages are as follows:

- Big transmission bandwidth

  With sufficient access bandwidth, the largest up to 200M bps, can meet the demand of high quality video or pictures, etc., and choose appropriate bandwidth wireless devices according to business requirements.

- Efficient data transmission

  Orthogonal frequency division multiplexing sends and receives the physical diversity, adaptive modulation and other advanced technology to realize non line-of-sight transmission; the maximum transmission distance of point to point way is 50 km, the maximum transmission distance of point to multi-point is 25 km, and it has wide network coverage.

- Simple network deployment

  Along the transmission line to deploy, it doesn’t cover problems in remote areas; equipment laying is rapid, which does not affect the original network, while communication lines are not maintained in the later period; deployment is scalable and flexible, which can achieve transmission line without blind spots.

- Flexible and convenient network

  Using the point to point and point to multi-point network topology; each terminal node can be covered. In the coverage area, if you need to add new monitoring points, you can increase the terminal equipment directly, which can meet the practical application of transmission line system [13].

3 SYSTEM ARCHITECTURE

Transmission line condition monitoring system mainly includes the condition monitoring agent, the condition monitoring device, the master station system, portable android device and the communication system [14]. System architecture is shown in Figure 1.

- Condition monitoring agent

  Condition Monitoring Agent (CMA), installed on the line or station and divided into line CMA and substation CMA, can collect all kinds of sensor data in a certain area, and the intelligent data processing makes standard data communicate with supervisor system instead of the sensor. CMA can be connected to various kinds of sensors across different professional and manufacturer, and constitute to the “front end micro system structure” with sensor.
- **Condition monitoring device**

Condition monitoring device (CMD), installed in the end of the sensor device, can measure condition data based on various principle, and transmit the data to the upper level.

- **Master station system**

The master station system is deployed in the net province side, including information acquisition gateway (CAG), centralized database, data service, data processing and the state monitoring function module of CAG in PMS [15]. Besides, CAG is divided into line CAG and substation CAG, which are deployed in the master station, and can connect various types of CMA or CAC in standard way.

- **Portable android device**

Portable android device (PAD) is an operating terminal which uses modular design, with the function of data acquisition, data real-time synchronization, GPS positioning, video processing and so on. Patrol officers handled PAD to real-timely communicate with the master station staff, instead of the traditional repair personnel who return information through calling the phone. It can release a large number of 95598 traffic channels, reduce communication costs of repair personnel and save the cost of power supply enterprises.

- **Communication system**

The communication system includes wireless network, optical network, wireless network, etc. Through the communication system, the terminal monitoring data can be gathered to the tower sink node, then be transferred to the substation, and lastly be transmitted to the city and the provincial station by optical network, which can ensure the staff to control the real-time operating state of transmission line.

4 THE DESIGN OF 5.8G WIRELESS NETWORK SYSTEM

At present, the on-line monitoring system of transmission line is mainly subjected by two factors. One is the transmission of monitoring data, and the other one is the power supply of the monitoring device [16-17]. This paper designs a network mode to achieve safe and reliable data transmission, and use different power supply according to the installation position of the monitoring device, so that the system operates stably.

4.1 *Data transmission scheme*

5.8G wireless communication network uses hierarchical structure, which is divided into the sensor layer, access layer and master station layer, and each layer is in accordance with the unified standard of independent parallel development in the respective range. Sensor layer focuses on the development of advanced sensor principle and sensor technology; the access layer focuses on the development of a variety of reliable communication network technology and information processing technology; the master station layer develops all kinds of monitoring data application technology, such as storage, processing, display, analysis, diagnosis and prediction of monitoring information. The establishment of a hierarchical system is conducive to the development of power transmission and transformation equipment condition monitoring system. Data transfer scheme is shown in Figure 2.

- **Sensor layer**

Arranged on the sensor layer CMD and various sensors, CMD is responsible for sending commands to the sensor acquisition. After the sensor receives the command, the state monitoring data is uploaded to the CMA, which completes the collection of state data. CMD is installed on each high-voltage tower, such as micro-meteorological monitoring devices, wire wind bias monitoring device, wire temperature monitoring devices, and monitoring operating status of field devices; various sensors are embedded in a secure communication module with overall responsibility for wake, authentication, data communications and information security tasks between sensors and CMA. All kinds of sensors need not to be considered and the
underlying communication details and information security policy and other issues, which only focus on the realization of their own professional sensing technology.

- Access layer

The access layer is responsible for centralized and remote data, to solve the problem of communication between CMD, CMA and CAG. The point to multi-point and large capacity point-to-point wireless private network, are working in 5.8GHz ISM band. Access layer including tower communications network between node and substation equipment, is a focus in the study of transmission line state monitoring system for networking. The access layer is responsible for the centralized and remote transmission, which is used to solve the communication problem between the CMD, CMA and CAG. This paper uses point to multi-point and large capacity point-to-point wireless private network, working on 5.8 GHz ISM frequency band.

When monitoring span is too big, we need to select gathering node in the tower according to the mutual distance and altitude in the tower, the cost budget, topography survey select gathering node and link budget. Data collected by the sensor layer is transmitted to the tower sink nodes through point to multipoint transmission way, data fusion and processing in sink node; then transmit data to the substation in large capacity point-to-point way, under normal circumstances is transmitted to the end of the line transformer substation, and the maximum transmission bandwidth can support up to 300 Mbps.

1) When there is a demand for image or video monitor and access layer has a high demand for communication bandwidth, the access mode adopts Wi-Fi wireless coverage technology scheme. Because IEEE 802.11a works in the 5.8G band, the total 125M bandwidth, each channel has 20MHz bandwidth, which can meet the business needs.

2) When there is a need for a mobile terminal to access, the communication access mode adopts Wi-MAX communication technology. Because the 802.16a is a broadband wireless access system with 2G to 11GHz and without authorization spectrum, it has good scalability and security.

- Master station

The substation is arranged to receive the sink node and monitor data processing of each tower. It can access to state information through the MSTP/SDH transmission to the CAG. The master station system analyzes the thickness of conductor icing, galloping and so on according to the corresponding mathematical model, and provides decision-making basis for the operation of transmission line maintenance.

4.2 Node design

4.2.1 Terminal tower design

As shown in Figure 3, camera equipment sealed metal box, which can lightning, rain and dust, and remote control, adjusts the direction of the poly zoom to collect video information; infrared detectors and infrared sensors can collect equipment, wire and tower and the surrounding information. Video capture, AD sampling and intelligent data processing are achieved in CMA; central processing unit terminal converges monitoring data preprocessing, and focuses to achieve data remote transmission, built-in SCM for data authentication, data encryption and decryption, etc.. All the data after encryption module encryption processing, are sent via point to multi-point wireless way to transmission tower gathering node; UPS devices are free to choose the power supply mode, plenty of sunny or the wind, so you can directly use solar or wind power generation device for power supply to ensure real-time and reliable operation of the terminal monitoring equipment in the tower.

4.2.2 Monitoring master station design

The CAG deployed in the main side, can remotely receive status information for all kinds of CMA and the standardization of CAC, and standardize control...
In provincial cities or network monitoring master station, substation monitoring data through the CAG interface, are stored in a storage device in the field of streaming media and video switching, decoding image on the display terminal and the control center, which is convenient for staff to watch. In monitoring master station, they can monitor running environment and line state, which can realize remote equipment patrol, reduce the patrol number, timely grasp a dangerous point operation, and greatly increase the safety of the transmission line. Monitoring master station is shown in Figure 4.

### 4.3 Power Supply Scheme

Transmission line on-line monitoring device runs in complex environments based on the 5.8 G wireless private network of on-line monitoring system for large power consumption, so electricity supply becomes the key to the system reliable operation. In this paper, due to different device installation location and different environments, we use different ways of power supply to achieve the all-weather real-time monitor.

#### 4.3.1 Conductor and ground power supply scheme

There is rich electromagnetic energy around high voltage wire and induced current around ground wire, using these characteristics, in the place between the conductor and ground, and we use the power supply way of high voltage induction which can give priority to battery for auxiliary to supply for surrounding devices. Adopting the principle of electromagnetic induction, high voltage induction electric way gets induction alternating current through the induction coil, after rectifying, filtering processing first, and then adjust electricity through the voltage sampling and protection circuit, after the voltage regulator can output stable dc power supply voltage, as energy storage battery parts, equipment directly on the power supply when necessary. This way of power supply does not affect the power quality, which is not affected by the weather, and can solve the problem of the insulation of the solar power. The device structure is shown in Figure 5.

#### 4.3.2 The power supply scheme at tower

Energy access way on tower is given priority to with solar energy, and fan is complementary. Select magnesium based battery as energy storage mode. As shown in Figure 6: wind-light complementary controller controls the way of power generation, use wind power when light is insufficient. When the sun is shining through the photovoltaic power generation, it supplies power for communications equipment directly, and the surplus electricity is stored in the storage battery; magnesium matrix battery is chosen as energy storage system because of its high efficiency, good reliability, long service life, no pollution, etc. In spite of bad weather conditions, system can keep working.

### 5 SYSTEM SECURITY

With the increasing use of wireless security, we should pay more attention to power wireless network, to enhance power wireless network security level. The
communication link of network scheme in this paper is: video/sensor--CMA--wireless controller--wireless point to multipoint wireless network--point-to-point network--optical network--substation center data server. To carry out the general system security protection based on “smart grid information security protection scheme”, according to the “standard first, distributed access, pilot deployment, focused on the promotion of” principle, for all kinds of monitoring device used in wireless network, the security and protection work shall be in accordance with the relevant provisions of the country. System overall design framework is shown in Figure 7.

- Data transmission of power lines between CMA and host CAG should establish bidirectional encryption channel with the main security access platform to ensure the safety of the channel; data transmission using proprietary scrambler mechanism, can choose the 128-bit and a 256-bit AES encryption technology; wireless devices use encrypted internal custom data formats, to ensure the safety of the air data, wireless terminal equipment needn’t to configure IP at the same time, and wireless station equipment can distribute IP optionally.

- The substation CAC and host CAG transmit data through private network, so we should set access control to channel. Transmission line monitoring data are transmitted to the substation, which can be through hardware encryption devices (such as firewalls, network gateway), and then connect with the MSTP optical networks.

- After monitoring data transmitted to the substation, the data can be accessed to MSTP Ethernet through the two layer switch, VLAN isolation, and so on. In the process of MSTP transmission, the transmission line monitoring data should make port isolation with other data, and then the data transmits in a specific VC channel.

- In the process of MSTP transmission, the transmission line on-line monitoring data isolate with other data port; in cities and provincial dispatching center, the network also convert the data format to standard I2 interface through encryption devices. Considering the actual project cost, the router can be used as MSTP business interface. If the substation has the ready-made router, we can consider to using its spare port.

6 PILOT APPLICATION

The wireless network system has been operated in Ningxia electric power company, and all the equipment are in safe, reliable and stable operation. Through measuring mutual distance and elevation height of tower 120 #, tower 140 #, tower 145 #, tower 158 # and tower 160 #, after cost, topography and link budget comprehensive analysis, we selected tower 160# as sink node and 1 296# as relay node which can link sink node and substation. The system topology is shown in Figure 8.

The simulation results between 120# and 160# are in Figure 9, from the figure we can see that wireless link is no mountains block, simulation test can be connected and its survivability is good. Through simulation and practical test, other monitoring nodes also can be connected.

Figure 7. Overall framework of system security protection.
7 CONCLUSIONS

The application of on-line monitoring system of transmission line makes the management department of the power network have a comprehensive understanding in the operation of the power line, which can effectively improve the control level of transmission line. This design solves the problem of transmission line data access where no cable resources or no network coverage, and ensures effective and reliable operation of the system. This paper has important significance for the construction of wireless network, provides an important theoretical basis for future research on power transmission line monitoring system.

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