Design and Application of Integrated Dispatching Communication Network for Intelligent Hydropower Stations

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Abstract. 5G has changed the society. Its rich vertical industry applications have changed the traditional operation and maintenance mode of hydropower stations, created a customized "industry private network" for hydropower stations, met the needs of power station intelligence, further improved the hydropower station's ability to independently control its own business and operating efficiency, and created a new intelligent, safe and efficient power station.

Keywords: Intelligent Hydropower Station; 5G Network; Intelligent Patrol Inspection; Integrated Scheduling.

1. Introduction

Intellectualization and digitalization of power stations are the key technologies for high-quality development of power industry production. It integrates AI technology, industrial Internet, Internet big data technology, 5G communication technology, etc. The intelligent power station takes data as the key production technology, modern power energy network and new generation information network as the basis, and through the deep integration of digital technology and energy enterprise business and management, continuously improves the level of digitalization, networking and intelligence. The new intelligent power station formed has the characteristics of flexibility, openness, interactivity, economy, sharing, etc., making the power station more intelligent, safe, reliable, green and efficient.

2. The Necessity of Intelligent Power Station Network Construction

2.1 Necessity of Construction

The installed capacity of hydropower in China exceeds 350 million kilowatts (The data comes from the statistics published on the official websites of State Grid and China Southern Power Grid Corporation in 2020). Most hydropower stations are located in mountainous (suburban) areas, with remote geographical location. The relatively lagging communication network system restricts the transmission of video, pictures and other data of the power station, and the realization of remote control, operation and maintenance automation. The power station lags behind in the level of Internet of Things awareness and intelligence, resulting in low efficiency of production, operation and maintenance. Through the construction of 5G wireless private network, the 5G network coverage of the hydropower station is realized. The characteristics of 5G network, such as large bandwidth, low delay, high reliability and massive connectivity [1], are used to promote the digital, networked and intelligent integration of hydropower stations to achieve "intelligent production, intelligent operation and maintenance, and intelligent management".

2.2 Construction Objectives

Through the high integration of 5G network construction and hydropower station production factors, the 5G network and its rich applications will cover production, development, operation and maintenance, management, etc., strive to build a first-class intelligent hydropower station, and promote and lead the industry standardization construction. Intelligent hydropower stations enable

power stations, reduce costs and increase efficiency, improve quality and innovate, and need to build a set of intelligent power station 5G network with comprehensive perception, intelligent analysis and collaborative control.

2.3 Construction Principle

Guided by solving problems, we should focus on the pain and difficulties commonly existing in the current production, operation and maintenance of hydropower stations, such as the difficulty in retrieving ultra-high definition video, comprehensive monitoring of motor equipment, carrying remote control applications, realizing centralized control, and middle finger real-time audio and video command and dispatching; Based on the premise of high cost performance, the network is rationally proportioned to improve the cost performance of the network according to different intelligent application needs in the region; Take investment protection as the bottom line, realize the network demand design that is advanced within 5 years and not outdated within 10 years, ensure that large-scale repeated construction is not required within 5 years, and protect investment; The construction and maintenance of the project can be carried out by either the power grid, the operator or the third party as required. Operators can provide 5G private network, 5G private network, platform and 5G private network, platform, application as required.

3. Demand Analysis of Hydropower Station Network Construction

3.1 Operation, Maintenance and Overhaul

In the daily patrol inspection of hydropower station, the maintenance workload of wired transmission equipment is increased, and a large number of detectors and sensors are installed in the water area and motor parts. Taking the third level hydropower station in southwest China as an example, the comprehensive monitoring of the operation status of the generator room, water turbine floor, air compressor room, booster station, four generators, temperature panel, power unit, governor and other equipment requires 107 sensors and nearly 16km of cables. Moreover, the cables need to pass through the equipment frequently, making maintenance difficult and intensive. By covering the 5G network on site, the Internet of Things can realize wireless sensing, simplify the system structure, and facilitate daily system maintenance and repair.

3.2 Collaborative Management

It is difficult to achieve full coverage of signals on water and underwater dams, and the lack of network does not support real-time transmission of high-definition video data, which makes it impossible to effectively coordinate scheduling and management. After the 5G network is covered, when the equipment in the underwater machine room is abnormal, the on-site operators wear smart helmets and have the real-time video call function. The 5G network is used to transmit the headlight video of all on-site operators to the ground centralized control center in real time. The management personnel watch the operation of each operator on the ground in real time, supervise their cooperative operation behavior, and timely intervene to stop hidden dangers or illegal operations.

4. Design of Converged Communication System

4.1 Scheme Design

Chinese operators (Mobile/Telecom/Unicom) can provide 5G core network, which is connected to the hydropower station through PTN transmission network. Multiple access edge computing is deployed on the hydropower station, BBU is connected to RRU through optical cable, and the station provides CPE, 5G mobile phones, high-definition cameras, smart helmets, patrol UAVs and other terminals with security certificates. According to the current situation of the hydropower station and the network requirements, the 4G+5G integrated dispatching communication system can be deployed

for wireless signal coverage. It is designed according to the three characteristics of 5G: high bandwidth, low delay, and multiple connections. Multiple access edge computing servers can be arranged in the computer room and configured between the PTN network and the dispatching platform server for intelligent analysis of monitoring data, independent analysis, decision-making and other edge computing services. MEC cooperates with the operator's user port UPF to effectively reduce the data transmission delay.

Its overall topology is shown in the figure below:

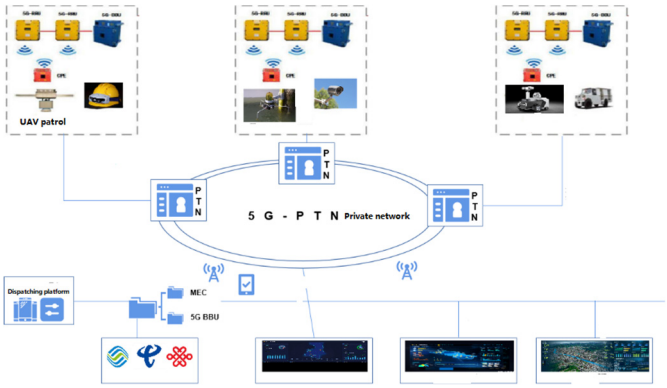

Figure 1. Overall Topology Diagram (From the network)

4.2 PTN Network

PTN sets an aspect between the IP service and the underlying optical transmission medium. It is designed for the burst of packet traffic and the requirements of statistical multiplexing transmission. Focusing on group business, it provides multiple services with low overall application cost. In addition, it has the previous advantages of optical transmission, including scalability, reliability and efficiency, scalability, efficient bandwidth management system and total traffic engineering projects, convenient and fast operation, maintenance and management, network management, high security factor, etc

In the overall network design, PTN can replace the optical fiber Ethernet ring network used by most hydropower stations in terms of networking and services provided, and the network transmission bandwidth is up to 100G, 10 times that of 10 gigabit optical fiber Ethernet [2-3], providing guarantee for the access of 5G and WIFI6 base stations.

4.3 Converged Communication Platform

The integrated communication platform is based on the intelligent scheduling system. As shown in the functional architecture diagram, it can effectively integrate the status monitoring, event advancement, security strategy, statistical report, automation, personnel trajectory, wireless, video and other systems to achieve unified scheduling, unified management, intelligent linkage, and cloud maintenance to achieve remote real-time maintenance of the system.

The unified management and scheduling of the communication network system can be realized according to the integrated scheduling software, which can determine the personnel track and lock the location of the obstacle in a short time, and use the intelligent terminal to achieve the integration and linkage with other systems at the first time. The integrated communication platform has the following characteristics: wide transmission, unified transmission, standard IP technology, decentralized deployment, flexible access, no distance limitation; Fast scheduling and comprehensive services, including video, remote control and other services can be scheduled. Massive connection, intelligent management of all kinds of connection equipment, realizing the throughout dispatching from the central control room to the level station to the equipment; Fusion, data fusion, network, power, installed equipment detection, environmental comprehensive monitoring and other data intelligent fusion analysis; Fast operation and maintenance, professional maintenance, remote

maintenance through the cloud service platform, alleviate the shortage of technical force on the station, and technical problems can be remotely guided by experts for maintenance.

4.4 Multi Access Edge Computing (MEC) Deployment

5G is a strategic infrastructure for high-quality social development, which can accelerate the transformation process of enterprises in various fields and promote a large number of new applications. The traditional centralized deployment of 5G core network cannot support the new business needs, and it has become the industry's development trend to move along the business to the edge of the network. Multi access edge computing is deployed at the edge. Multi access edge computing is usually deployed in the LAN convergence room. After the logical part is the user port function (UPF), it will reduce some of the delay and return to the Internet, eventually achieving low latency, high bandwidth communication services, such as AR/VR virtual reality technology services, mobile video monitoring systems, mobile broadcasting systems, information security and ultra clear video, etc.

Multi access edge computer deployment equipment has the function of CDN, which can reduce delay, enable users to obtain content in a shorter time, and improve response speed. Compared with traditional CDN, multi access edge computing is closer to wireless network. Due to the reduction of physical distance, the delay of mobile edge computing will be further reduced, and multi connection edge computing also includes the ability to localize computing and open to the outside world, so it has low delay and intelligent system characteristics [4]. In view of the particularity of low latency service requirements, we choose to directly deploy multi access edge computing to meet the requirements of remote control, patrol and local data not being transmitted.

4.5 Mobile Terminal Security Management Scheme

The mobile terminal security management solution is used to build safe and reliable mobile work management and control. The system can provide employees with safe work specifications, and can uniformly monitor and control personnel identity, equipment and mobile phone applications through the background [5]; Provide mobile risk detection capability, conduct security management and control on terminals, networks, applications, data and operating environments, and protect mobile work security. In addition, permissions can be set in the terminal to restrict the terminal data transmission interface to prevent the disclosure of confidential information. It can also audit and file the Internet behavior of the mobile terminal. In addition, the mobile terminal also has the message publishing function, holiday management, holiday control strategy failure, etc.

5. Application of Main Business Scenarios of Hydropower Station based on 5G

It mainly includes patrol robot, transmission line UAV online monitoring, plant video monitoring, mobile on-site construction operation control, etc. The substation inspection robot aims at the comprehensive monitoring and security inspection of power equipment status within the scope of the substation. It can avoid the uncertainty caused by manual inspection, reduce the labor cost and improve the operation and maintenance efficiency.

At present, most inspection robots use WIFI access, and most of the video data they inspect are kept locally, not transmitted to the remote monitoring center. The inspection robot based on 5G wireless network can carry multiple high-definition video cameras and monitoring detectors. The monitoring data can be returned. In some cases, the inspection robot can conduct live operation, such as gate opening and closing control. The high-definition video is transmitted back at Mbps level, while the time delay for remote control of the patrol robot can be controlled at millisecond level.

The UAV patrol inspection of transmission lines mainly checks the physical characteristics of lines between grid structures, including bending deformation, physical damage, etc. At present, the effective control radius of UAV patrol inspection is small, basically within 2km, which is difficult to meet the practical needs [6]. With the improvement of UAV endurance and the maturity of 5G module,

combined with the application of MEC, the UAV is connected to the console and 5G station, and edge computing is deployed in the 5G base station to realize data calculation and return to the console. The control delay and transmission delay can be controlled at the millisecond level, and the communication bandwidth is above Mbps.

The hydropower station has ground power house, underground power house, power house in the dam, etc. There are a large number of equipment in each machine room. Each switch is mostly analog pointer type, and the operation state and switch closing state require manual investigation and logging. Although there is video monitoring, it is difficult to identify and extract the allowable state data from the video. The intelligent hydropower station is equipped with intelligent video monitoring system and flexible and movable video integrated monitoring equipment. Video and image are returned to the equipment in the machine room, and advanced AI technology is used to identify the video and extract effective information, thus avoiding tedious manual inspection. In addition, the system can meet the needs of integrated monitoring of the environment, operation and security of the entire hydropower station.

The construction requirements of electric power operation are extremely high. Mobile on-site construction operation is mainly aimed at the comprehensive management and control of electric power construction site personnel, quality and safety. It can provide remote expert support for emergency situations such as plan change fees and emergencies, and can provide functions such as accident tracing and troubleshooting. With the development of 5G stable video retrieval function, multiple mobile cameras can be temporarily deployed to monitor the construction site or maintenance site in real time, and remote experts can provide real-time guidance. The local construction site requires multiple cameras, the bandwidth requirement is about 50Mbps, and the time delay can be controlled within 200ms.

6. Conclusion

Smart hydropower station is an attempt of 5G in the power industry, and 5G also provides a better solution for smart grid. For hydropower stations, the use of 5G networks to provide safe and reliable open services for power station business can achieve low-cost, fast, convenient, safe and reliable wireless communication bearer and network management. 5G smart hydropower station is a typical 5G solution. The development of mobile power communication terminals of power enterprises, communication operators and equipment manufacturers and the establishment of a communication business management support platform can effectively promote the healthy and sustainable development of smart power stations and smart grids.

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