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Research on the Practical Strategy of 5G Mobile Communication Technology in Power Communication

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Abstract: With the acceleration of the intelligent transformation of power systems, the requirements for communication technology are increasingly stringent. The application of 5G mobile communication technology in power communication is analyzed. In this study, 5G technology features, application principles, and practical strategies are discussed, and methods such as network slicing, customized deployment, edge computing collaborative application, communication equipment integration and upgrading, and multi-technology collaboration and complementation are proposed. It aims to effectively improve the efficiency, reliability, and security of power communication, solve the problem that traditional communication technology is difficult to meet the diversified needs of power business, and achieve the effect of optimizing the power communication network and supporting the intelligent development of the power system.

Keywords: 5G mobile communication technology; Electric power communication; Network slicing; Edge computing; Multi-technology collaboration

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1. Introduction

In the construction of the smart grid and the vigorous development of power Internet of Things, the importance of power communication as the nerve center of the power system is self-evident. The traditional communication technology has gradually exposed many limitations in the face of the surge of powerful business, the diversification of business types, and the higher requirements of real-time and reliability. With the characteristics of high transmission rate, ultra-low delay, and large connection capacity, 5G mobile communication technology has brought new development opportunities for power communication. How to deeply integrate 5G technology into power communication and formulate practical strategies has become a key issue to promote the intelligent transformation of the power industry.

2. Characteristics of 5G mobile communication technology

2.1. High transmission rate

5G uses wider spectrum resources such as orthogonal frequency division multiplexing (OFDM) and large-scale multiple input multiple output (MIMO), as well as advanced modulation and demodulation technology to improve signal transmission efficiency. In power communication, the intelligent transformation of the distribution network generates a large amount of data. From the high-frequency data collection of smart meters to the real-time monitoring data of distributed energy systems, high-speed transmission is required to ensure the integrity and timeliness of the data. In the power inspection service, there is a large amount of inspection video data captured by high-definition cameras. The high transmission rate of 5G ensures that these videos can be quickly and smoothly transmitted to the monitoring center, so that operation and maintenance personnel can know the running status of power equipment in real time and discover potential faults in time. For big data analysis and processing application scenarios such as power load forecasting and power grid fault diagnosis in power systems, the high transmission rate enables a large amount of historical data and real-time data to be quickly transmitted to the analysis platform, speeding up the calculation process, and providing strong support for the optimal scheduling and accurate decision-making of power systems.

2.2. Ultra-low latency

By optimizing the network architecture, 5G technology reduces the intermediate nodes of data transmission, adopts edge computing and other technical means to achieve rapid data forwarding and processing, and reduces the end-to-end delay to milliseconds or even lower. In the power system, the distribution network automation business requires rapid response to faults to ensure the stability of the power supply [1]. When the distribution network fails, the ultra-low time delay of 5G can ensure that the fault information is transmitted to the control center in a very short time, and the control instructions can be quickly issued to the related equipment, realizing the rapid isolation of the fault and the restoration of power supply, effectively shortening the power outage time and reducing the impact on users. In the accurate load control of the power system, the ultra-low delay enables the load adjustment instructions can be timely and accurately transmitted to the user equipment, to achieve the accurate regulation of the power load and maintain the power balance and stable operation of the power grid.

2.3. Large connection capability

With the development of the power system in the intelligence and distributed direction, a large number of smart meters, distributed power supplies, sensors, and other devices are connected to the power communication network, which puts forward extremely high requirements for the connection ability of the network. In the construction of the smart grid, the large connection capacity of 5G can meet the data communication needs of many distributed energy sources when they are connected to the grid, realize real-time monitoring and regulation of distributed power sources, and promote the efficient utilization of clean energy [2]. In the application scenario of the power Internet of Things, all kinds of power equipment are interconnected through 5G networks, and a large number of equipment condition monitoring data and environmental monitoring data can be uploaded to the management platform, providing rich data sources for the status assessment and predictive maintenance of power equipment, and promoting the development of the power system in a more intelligent and refined direction.

3. Application principles of 5G mobile communication technology in power communication

3.1. Security priority principle

Power communication involves the transmission of key data such as grid dispatching instructions and operation parameters of power equipment. Once the data is leaked or attacked, it will pose a serious threat to the safe and stable operation of the power system. 5G network itself has advanced encryption technology and adopts 5G new air interface (NR) encryption algorithm to comprehensively encrypt data during transmission to prevent data from being stolen or tampered with [3]. During the application process, a multi-level security protection system needs to be built, and a strict identity authentication mechanism is adopted at the network access end to ensure that only legitimate power devices can access the 5G network to avoid intrusion by illegal devices. The network traffic is monitored and analyzed in real time, the intrusion detection system is used to detect and prevent abnormal traffic in time, and the network attack behavior is prevented. In smart substations, 5G communication is used to transmit equipment status monitoring data and control signals. By strengthening security protection measures, it ensures the safe transmission of data, prevents the disruption of substation equipment due to communication security problems, affects the reliable power supply of the entire power system, and maintains the safe and stable operation of the power system.

3.2. Adaptive power service principles

The network slicing technology of 5G networks can be customized based on the characteristics of power services. For services with high latency requirements, such as distribution network automation, dedicated ultra-low latency network slicing can be created to ensure that fault information can be transmitted to the control center within milliseconds by optimizing resource allocation and scheduling policies in the slicing to achieve rapid fault response and processing. For the data acquisition business of smart meters in power marketing, although the delay requirement is relatively low, the data amount is huge, and network slices with large bandwidth characteristics can be allocated to meet the demand for efficient transmission of massive data [4]. When applying, it is necessary to reasonably plan the layout and coverage of 5G base stations according to the distribution scope and real-time requirements of the power business. In the transmission line inspection scenario in remote mountainous areas, 5G base stations are deployed to ensure signal coverage and meet the data transmission requirements of inspection devices. The edge computing technology is used to initially process inspection data locally, reduce the data transmission volume, better adapt to the actual application scenarios of power services, and improve the quality of power communication services.

3.3. Compatibility and scalability rules

Power communication system has a large number of existing equipment and communication technologies, such as optical fiber communication and power line carrier communication. In the application process, it is necessary to ensure compatibility with these existing technologies and equipment. Existing power communication equipment should be upgraded to enable it to seamlessly connect with 5G networks, and 5G communication modules should be added to traditional power communication terminals to expand communication functions [5]. In terms of network architecture design, fusion networking technology is adopted to realize the collaborative work of the 5G network and the existing communication network. The intelligence of the power system continues to improve, new business needs will continue to emerge, and 5G technology should also have good scalability and be able to flexibly adapt to business growth and changes. With the development of the powerful Internet of Things, a large number of new smart devices will be connected to the network, and the large connection capability of the 5G network and flexible resource allocation mechanism can easily cope with the increase in the number of devices.

Through software-defined network (SDN) and other technologies, network resources can be dynamically adjusted to meet the different needs of new services for network performance, and ensure the continuous development and upgrade of powerful communication systems.

4. Practical strategies of 5G mobile communication technology in power communication

4.1. Customized network slicing deployment

The power system covers a variety of services, such as distribution network automation, precise load control, and power inspection, and each business has a significant difference in demand for the network. The network slicing technology can divide 5G network physical resources into multiple virtual network slices based on different service characteristics. For services with high delay requirements, such as distribution network automation, dedicated slices can be customized to ensure data transmission within milliseconds or even shorter by setting high-priority scheduling, ensuring bandwidth resources, and optimizing transmission paths, etc., to achieve rapid response and processing of faults [6]. To transfer a large amount of video data generated by the power inspection service, slices with large bandwidth can be allocated to ensure smooth uploading of HD videos to the background, avoiding interference with other key services. In terms of slice management, an automated management and control system is introduced to monitor the running status of each slice in real time, dynamically adjust slice resources according to business volume, and improve the overall utilization efficiency of network resources on the premise of ensuring business service quality, so that 5G network can accurately meet the complex and diverse business needs of power communication.

4.2. Collaborative application of edge computing

In power communication, if data generated by a large number of devices is transmitted to the core cloud for processing, network congestion will occur, and it is difficult to meet the strict real-time requirements of some services. With the help of edge computing technology, compute nodes can be deployed on the edge near power devices. Edge computing devices are installed in substations, transmission towers, etc. When the devices generate data, edge computing nodes can initially process and analyze the data on the spot. Taking the image data collected by the transmission line inspection camera as an example, the edge computing device can use the built-in image recognition algorithm to quickly identify whether there is foreign body hanging on the line, whether there is damage to the equipment parts and other abnormal conditions, and only upload the key information to the core network [7]. For distributed power supply control services, edge computing can quickly make control decisions based on local power output and power load in real time, reduce the delay of data to and from the core network, and realize fast closed-loop processing of local services. The combination of edge computing and 5G network can further optimize the data transmission and processing process, the high-speed transmission capability of 5G network ensures that data can be timely delivered to edge computing nodes, and the localized processing of edge computing reduces the pressure of network transmission, and the two work together to bring more efficient and intelligent services to power communication.

4.3. Converged upgrade of communication devices

Existing equipment in power communication will be upgraded so that it can seamlessly connect with 5G networks. The access equipment of traditional power communication base stations is upgraded to a new type of equipment that supports 5G communication protocols, expands its communication frequency band, and improves data transmission rate and anti-interference ability. For power terminal devices such as smart meters and distributed

power controllers, 5G communication modules are added to give them the ability to directly access 5G networks, simplify the communication architecture, and reduce intermediate transmission links. New 5G communication equipment will be introduced to build a more complete communication system. Deploy 5G small base stations in important places such as substations to enhance signal coverage strength and ensure stable communication of equipment in the stations [8]. By using 5G smart antenna technology, the antenna beam direction can be adjusted adaptively to improve the accuracy and effectiveness of signal transmission. Optimize the hardware performance of the communication equipment, improve its data processing capability and storage capacity, and ensure that the entire communication equipment system can run stably and efficiently.

4.4. Multi-technology synergy and complementarity

Although 5G technology has many advantages, it still needs to cooperate with other technologies in some scenarios. In areas with weak 5G signal coverage, such as remote mountainous areas, satellite communication technology can be combined as a supplementary means of 5G communication to ensure the continuity of power communication. Satellite communications can cross geographical barriers to achieve long-distance signal transmission, ensuring that power equipment data in remote areas can be smoothly transmitted back to the monitoring center. In indoor or complex electromagnetic environments, Wi-Fi technology can work with 5G. The intelligent electrical equipment of the power user can use Wi-Fi to achieve short-distance high-speed data transmission, and 5G is responsible for transmitting the aggregated user data to the power core network, and the two can cooperate to optimize the user-side communication experience. 5G encryption transmission technology is combined with traditional firewall, intrusion detection, and other security technologies to build a multi-level security protection system [9]. The encryption mechanism of 5G ensures the security of data in the transmission process, and the firewall and other technologies resist external attacks from multiple levels such as the network boundary and the internal network, and the multi-technology collaboration and complementarity improve the performance, reliability and security of the power communication system in an all-round way.

5. Future technology prospects

The future technology prospects of 5G mobile communication technology in power communication are bright, and it will continue to innovate and make breakthroughs in technology and applications. With the deep integration of 5G with edge computing and artificial intelligence technology, its performance will be further optimized. The combination of edge computing and 5G allows more powerful data to be processed close to the device, significantly reducing data transmission pressure and improving processing efficiency. Artificial intelligence can help 5G networks achieve intelligent operation and maintenance, predict faults in advance, and automatically optimize network configuration through in-depth analysis of network data. In the construction of the smart grid, 5G can support the efficient access and management of distributed energy, accurately regulate energy distribution, and improve the utilization efficiency of clean energy [10]. With the vigorous development of the power Internet of Things, the large connection characteristics of 5G can meet the access needs of massive devices, realize the comprehensive interconnection of power equipment, build a comprehensive and intelligent power communication ecology, provide a solid guarantee for the stable and efficient operation of the power system, and promote the power industry to make strides toward intelligence and digitalization.

6. Conclusion

According to the above analysis, the customized deployment of network slicing accurately matches different power service requirements and improves network resource utilization. The collaborative application of edge computing reduces the pressure of data transmission and realizes the fast processing of local business. The integration and upgrading of communication equipment ensures the seamless connection between 5G technology and existing equipment, and builds a more perfect communication system. Multi-technology collaboration and complementarity to enhance the power communication system performance in all-round way. Through the implementation of these strategies, the power communication has been greatly improved in data transmission efficiency, fault response speed, and the number of equipment connections, which strongly supports the stable operation and intelligent development of the power system.

Disclosure statement

The author declares no conflict of interest.

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