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Research and Prospect of 5G Power Application

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Abstract. This paper investigates the 5G power application status in China, and compares the mainstream communication technologies of the existing power system, such as wired, 4G, wifi, 5G and so on. Effectively combined the advantages of 5G technology with power applications, the paper clarifies the application scenarios of 5G in the power system. The research focuses on typical power applications under the background of new power system construction, including intelligent inspection, distribution network protection and control, distributed energy grid connection and dispatching stability control, and analyzes the technical indicators and economy of various typical applications. Finally, this paper analyzes the challenges faced by 5G power application, and proposes solutions, as well as prospects for 5G power application.

Keywords. New power system, 5G technology, inspection, power distribution network, distributed energy resource.

1. Introduction

China first proposed to build a new power system on March 15, 2021. Compared with the traditional power system, the new power system presents a development trend of "massive terminal access, frequent information interaction, and control extension to the end". It is urgent to build the collaborative interaction of "source network load storage" to improve the intelligence of the power system and improve the stability of the power system.

5G is highly compatible with the business needs of new power systems and has high application potential. At the same time, in order to promote the commercial development of 5G, the ministry of ten departments such as ministry of Industry and Information Technology, jointly issued the "sail" 5G application action plan (2021-2023), the National Energy Administration and other three departments jointly issued by the "5G application implementation plan in the energy field", clear requirements in the field of electric power to achieve 5G scale application, explore a new mode of the 5G application, which will be easy to reproduce and promote to support high-quality development of the energy industry. Driven by the national 5G strategy and the internal demand of the new power system, The State Grid Corporation launched the 5G scale demonstration application project in 2021, vigorously promoting the integration and innovation of 5G and the power grid, effectively enabling the construction of the new power system and the company's digital transformation.

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2. Status Quo

Power system is mainly divided into five links, such as generation, transmission, transformation, distribution and use, each link needs the support of communication technology. Chinese power communication network has formed a backbone network frame with optical fiber communication as the main body, which has achieved full coverage of voltage grade 35kV and above. However, in the distribution network with voltage grade 10kV and below, there are still communication blind areas without optical fiber or wireless communication, due to the complexity of the network frame and the wide range of points. In view of these communication blind areas, if optical fiber laying is adopted, the cost is too high and the flexibility is poor. If 4G wireless public network is adopted, the security isolation is insufficient and the performance and security requirements of carrying power monitoring services are not met.

The application of 5G network can connect the acquisition and control equipment on the distribution side to build a power Internet of things system with comprehensive perception, data collection and intelligent decision-making, meet the demand of lean management of distribution network and open up the "last kilometer" of low-voltage distribution communication network [1].

In addition, in the transmission and transformation process, the intelligent level of power equipment inspection still needs to be improved due to the transmission delay and bandwidth of 4G, WiFi and other wireless communication technologies. Since 2019, SGC and China Southern Power Grid Corporation has carried out 5G power application exploration [2], and in new energy grid technology, intelligent power grid, power transmission and transformation technology, intelligent power distribution, information and communication technology, intelligent electricity technology, support the development of electric vehicle power grid technology has carried out a wide range of technology research and demonstration project construction [3].

For example, by adding 5G network slicing technology to unmanned aerial vehicle（UAV）, more hd videos or photos related to actual circuits can be taken, so as to quickly locate the fault points of transmission circuits and improve the efficiency of solving circuit problems [4]. Through 5G network access, all kinds of resources such as distributed power supply, energy storage and load scattered in the power grid are aggregated to conduct global optimization and coordinated control of "source-network-load-storage" [5]. Typical scenarios of 5G application in all aspects of power are shown in figure 1.

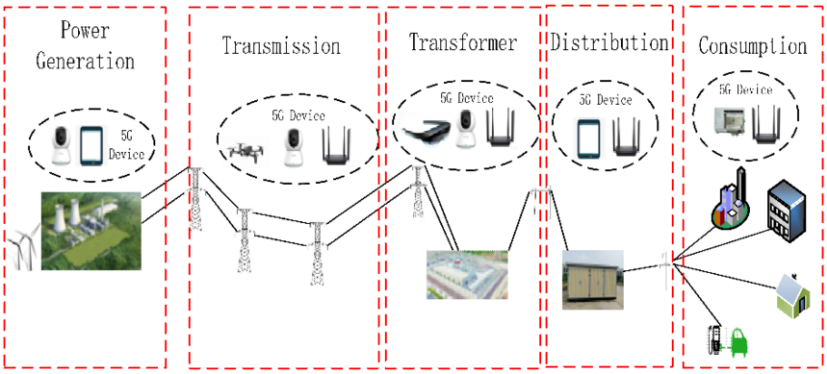

Figure 1. Typical scenarios of 5G power application

3. 5G Power Application Analysis

Optical fiber communication which has the best transmission performance can't meet the requirements of vast distributed flexible access terminal. Power line carrier communication cannot realize network and cross voltage level transmission. 4G and previous cellular wireless communication cannot meet the requirements of multi-terminal interaction, low latency, high reliability and high security communication. Low power iot communication cannot meet high bandwidth requirements. 5G has the advantages of large bandwidth, low latency, high reliability and wide connectivity. Using 5G technology can solve the problems that the original communication mode cannot solve and realize the further development of power services. Generally speaking, the power business is mainly divided into control and acquisition, which can be further subdivided according to the amount of data collected. This paper takes three typical 5G power application scenarios as examples to introduce the role of 5G in power application, and the comparison of its communication modes is shown in table 1.

Table 1. Comparison table of communication modes required for power applications

serial number	Demand for the new power system	Wire communication	4G/wi-fi communication	5G communication	result of contrast
first	Intelligent inspection	Not Applicable	The Wifi switching dropout rate inspected by the robot is high, with delay >200ms and 100Kbps transmission rate	Uav/robot inspection bandwidth ≥2Mbps, delay <200ms	5G is better
second	New distribution network protection and control	The cost of optical fiber laying is high	Second level control delay, hour/minute level acquisition cycle, 100kbps level transmission rate	Millisecond level control delay, minute/second level acquisition cycle, 4-100Mbps transmission rate	5G is better
third	Distributed power grid connection and dispatching stability control	Scattered distribution points, high cost of optical fiber laying; The BANDWIDTH in PLC mode is small and unstable	Second level control delay, hour/minute level acquisition cycle, 100Kbps level transmission rate; The public network has security risks	Millisecond level accurate control, minute/second level acquisition cycle, 4-100Mbps transmission rate; Network slicing ensures the security of transactions	5G is better
fourth	others	……	……	……	……

3.1. 5G Intelligent Inspection

3.1.1. Technical Requirements and Applications.

Intelligent inspection includes uav intelligent inspection, robot intelligent inspection, and AR/MR inspection.

UAV intelligent inspection based on 5G technology: Manual inspection is difficult, inefficient and has a long inspection cycle due to the high voltage level, complex terrain and high towers of transmission lines. Traditional line inspection UAV can only transmit 1080P video, which will lead to the failure to identify the tiny defects of

transmission equipment. However, UAV inspection based on 5G technology can realize the whole process of automatic flight and shoot 4K high-definition video safely and send back in real time. Several provincial-level units of state Grid have deployed 5G UAVs to carry out remote, autonomous and intelligent inspection of power transmission lines.

Robot intelligent inspection based on 5G technology: Traditional substation inspection robot has to patrol the equipment in the station along the established track, while the intelligent inspection robot based on 5G technology can patrol without the established track, automatically identify and bypass obstacles, and realize automatic autonomous inspection. The low-delay characteristics of 5G network ensure the precision of robot patrol, which can not only guarantee the freedom of patrol line, but also prevent inspection robot from entering live area. The large bandwidth of 5G network can realize real-time transmission of HD video and remote real-time monitoring and analysis of equipment operating conditions. In addition, defect analysis and early warning can be realized by adopting two deployment modes of core layer UPF and sunken UPF to carry out edge computing and intelligent analysis applications. Several provincial units of state Grid have carried out pilot applications in substation scenarios.

AR/MR inspection of substation based on 5G technology: Inspection personnel collect image information of on-site equipment and environment in substation through smart wearable devices, and send the collected data back to the background for timely processing. By comparing and identifying image information, relevant equipment information can be correctly judged.

3.1.2. Economic Analysis.

The economy of intelligent inspection based on 5G technology is mainly reflected in saving manual inspection and vehicle use time, and improving the efficiency of equipment fault handling.

Taking the inspection of a 220kV substation as an example, if the inspection cost per person per hour is C, the inspection time is T, the number of inspectors is P, and the annual inspection frequency is N, the annual inspection cost Y can be expressed as follows:

$$Y = C*T*P*N \tag{1}$$

According to the routine inspection of the substation, C is 50 yuan, P is 2 people, N is 365 days, and each manual inspection time T_1 is 4 hours, while the intelligent inspection time T_2 based on 5G is 1 hour, so the inspection reduce cost Yr can be expressed as follows:

$$Yr = C*(T1-T2)*P*N = 109{,}500 \tag{2}$$

High-definition real-time image transmission can effectively improve the efficiency of power operation and maintenance personnel in discovering equipment defects and troubleshooting, and effectively reduce the incidence of power outage accidents. In addition, intelligent robot inspection through edge calculation and intelligent analysis, can realize analysis and early warning, help operation and maintenance personnel quickly find equipment defects, timely treatment, effectively improve the efficiency of substation equipment defects processing.

3.2. 5G Distribution Network Protection and Control

3.2.1. Technical Requirements and Applications.

5G distribution automation "three remote" : distribution automation business terminals are widely distributed in 10kV lines, and there are problems such as difficult coordination, long construction period, high cost and complex operation and maintenance for laying optical cables. The 4G network does not have physical isolation and security, so remote control cannot be implemented. Distribution automation "three remote" terminal through embedded 5G module or 5G CPE gateway equipment access 5G special slice network for power system, communication with the distribution automation master station, to achieve the safe and efficient operation of "three remote" service. Several provincial-level units of State Grid carry out the transformation of distribution network automation 5G network access to realize the wireless "three remote" of distribution network automation terminals.

5G distributed feeder automation: a high proportion of new energy power will change the power structure of the power grid, and the randomness and volatility of new energy will make it more difficult to determine the location of fault points. 5G distributed feeder automation (hereinafter referred to as 5G distributed FA) is one of the development directions and trends of future distribution network automation. 5G distributed FA can realize intelligent judgment, analysis, fault location, fault isolation and power supply recovery in non-fault areas by distributing the processing logic down to the feeder automation terminal, so as to realize automatic fault processing and reduce the time and scope of fault outage as much as possible. Several provincial-level units of the State Grid have carried out 5G distributed FA pilot applications, effectively shortening the time for troubleshooting lines. Key communication indicators of intelligent distributed distribution automation is shown in table 2.

Table 2. Table of key communication indicators of intelligent distributed distribution automation

Research Content	Key communication indicators	
Intelligent distributed distribution automation	Bandwidth	≥2Mbps,10 units per square kilometer
	Time delay	Remote measure<30 seconds,Remote communication<60 seconds, Remote control<2 seconds
	Reliability	99.999 percent
	Security isolation	Physically isolated Area I/II from Area III/IV with exclusive resources(E2E hard section)

5G differential protection of distribution network: After the widespread access of distributed new energy, the demand for differential protection of distribution network increases sharply, so as to achieve rapid location and isolation of fault areas. However, differential protection has high requirements for communication. A horizontal network at both ends or multiple ends of the distribution network and a longitudinal network from the terminal to the master station are constructed through 5G channel instead of fiber channel. Several provincial-level units of the State Grid deployed 5G differential protection applications to effectively shorten the failure time and improve the reliability of power supply in the distribution network. Key communication indicators of differential protection of distribution network is shown in table 3.

Table 3. Table of key communication indicators of differential protection of distribution network

Research Content	Key communication indicators	
Differential protection of distribution network	Bandwidth	≥2.7Mbps,10 units per square kilometer
	Time delay	<15 milliseconds (The bidirectional delay of adjacent nodes requires UPF sinking)

	Jitter	50 microseconds
	Reliability	99.999 percent
	Security isolation	Physically isolated Area I/II from Area III/IV with exclusive resources(E2E hard section)

3.2.2. Economic Analysis.

The economy of protection and control of distribution network based on 5G technology is mainly reflected in saving the cost of cable laying and shortening the time of fault handling of distribution network. Compared with traditional optical fiber communication, the adoption of 5G communication reduces the investment of hundreds or even tens of millions of yuan. In addition, 5G is used to communicate between distribution terminals and realize distributed intelligent distribution automation, which can complete fault location and isolation of lines and automatically restore power supply in non-fault areas within 200 milliseconds, shortening the time for fault handling of distribution networks from minutes to milliseconds.

3.3. 5G Distributed Energy Grid Connection and Dispatching Stability Control

3.3.1. Technical Requirements and Applications.

5G distributed power supply group regulation and group control: The characteristics of new energy station distribution and decentralized layout and explosive growth trend have brought big challenge to power grid regulation. Using 5G technology to achieve group regulation and group control of distributed power supply, the blind area of regulation can effectively be eliminated and the grid coordination and interaction and new energy consumption level can be improved. State Grid Shandong Electric Power has completed the monitoring and dispatching of more than 10,000 distributed photovoltaic power plants based on 5G in 16 cities of the province, saving cable construction costs of about 2 billion yuan. State Grid Hebei Power Pin pilot application of "5G add new energy" in Zhangbei National Scenery Storage demonstration project, State Grid Fujian Power completed 10 stations of power signal access to the grid automation master station system.

5G Precise load control: Precise load control refers to the friendly interaction of source network load through precise control of decentralized massive power users' interruptible load, so as to achieve instantaneous balance of power supply and demand and support large-scale optimized allocation of energy. State Grid Shandong Electric Power Has carried out 5G precision load control pilot application in Qingdao. State Grid Zhejiang Electric Power Co., Ltd. carries out the application of second-class interruptible load service based on 5G. State Grid Fujian Electric Power Co., Ltd. carried out the scientific and technological project research on Precise Control Technology of Source Network Load and Storage Based on 5G Technology.

3.3.2. Economic Analysis.

The economics of 5G distributed power supply group tuning and group control is mainly reflected in saving the cost of optical fiber laying.

Due to the dispersion of distributed energy regions, it is difficult and costly to lay optical fibers. Connecting distributed power to the power grid based on 5G communication can effectively solve this difficulty and achieve measurable, adjustable and controllable distributed power. The economy of precise load control based on 5G is

mainly reflected in avoiding large-scale power failure, minimizing the loss of power grid and minimizing the impact on users' power consumption.

4. The Challenges of 5G Power Application

At present, 5G power application is still in the pilot application stage, and there are still some challenges.

The maturity of 5G network in the power industry chain is insufficient. At present, the industrial chain of 5G network application in the power industry is not mature, especially in the terminal and module, with few manufacturers, high price, single form and poor service adaptation, which cannot meet the demand of power business application.

The security of 5G slice carrying power business is yet to be demonstrated by authority. According to the safety protection requirements of the power monitoring system, the services in the production control area should meet the security protection intensity of physical isolation. Although 5G slicing technology has been optimized and improved relative to 4G in terms of security isolation, whether the end-to-end security isolation capability can meet the requirements of power security protection has not been evaluated and certified by third-party authoritative institutions. At the 5G application layer, user identity security, data integrity and confidentiality have certain security risks. The server in the business related system applied in the power industry will generate, process and store a large amount of user sensitive information. If the business system has security problems and is attacked by hackers, it is easy to cause user data leakage.

The standard system for 5G application is lacking. At present, there is no clear national standard, bank standard and other requirements for the delay and reliability of 5G in power business. The lack of relevant industry standards, the lack of matching degree between 5G network of operators and the power industry, network delay, base station switching stability and other factors will affect the promotion of 5G power application.

The tariff standard for the full rollout of 5G is far higher than expected. The current 5G slicing technology is mainly in the stage of technical solution and application verification. Operators and power enterprises still have great differences on the charging mode and charging standard of special slicing. The network rental fee for 5G power virtual private network is about five times that of 4G, which is much higher than expected.

5. Outlook and Conclusions

In order to solve the existing problems, further improve the application level of 5G power and facilitate the construction of new power system, it is necessary to improve and optimize terminals, networks, applications, standards and other aspects to conform to the development direction of 5G power application.

Firstly, actively carry out cooperation to optimize 5G-related products. Power-related professionals and communication technicians shall strengthen industrial exchanges and cooperation with equipment manufacturers through long-term strategic

cooperation and other forms, refine the demand for 5G-related products, and accelerate the r&d and industrialization pace of 5G terminal equipment of power business.

Secondly, trials will be carried out to verify the safety isolation of 5G slices. In combination with 5G application scenarios of new power systems, China will explore security solutions for 5G applications that can be copied and easily promoted, and carry out pilot demonstrations, promotion and application of 5G slice security isolation. In combination with application requirements, the security capability of slices should be continuously improved, and a flexible and customizable security capability combination mechanism should be provided to achieve the goal of autonomous, secure and controllable slices of 5G network.

Thirdly, building a standard system for 5G application. Research on technical standards for 5G deterministic network, enhanced uplink rate, high-precision positioning and anti-electromagnetic interference will be carried out to meet the needs of the power industry, and the standard transformation process of innovative technologies and applications will be accelerated. We will accelerate the formulation of standards for the power industry and push for the implementation of 5G application standards.

Fourthly, we will enhance the supply capacity of 5G networks. Optimize the 5G network construction environment, provide convenient conditions for the construction of 5G base stations and access to power grids, and promote the sharing of power towers and communication base stations. At the same time, the cost of 5G electricity shall be reduced by switching from 5G base station to direct power supply and participating in the auxiliary service market of the power grid, so as to help mobile operators comprehensively improve the coverage capacity of 5G network and reduce network lease costs, thus achieving a win-win situation.

Fifthly, at present, 5G application has entered the stage of rapid development. According to the development rhythm of "use generation, construction generation and research generation" of communication technology, research on the next generation mobile communication technology (6G) has also begun. Therefore, on the one hand, the power application of 5G technology should consider promoting the evolution and development of 5G technology and improving the demand for key performance indicators as much as possible on the basis of existing 5G capability indicators. On the other hand, it should grasp the development frontier of communication technology. In view of more comprehensive performance indicators (such as ultra-low delay jitter, ultra-high positioning accuracy, ultra-large capacity, ultra-high reliability, etc.) of the future 6G network than 5G, combined with the development needs of new power system and various scenarios, promote the deep integration of power application and communication technology.

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