Research on Application of Network Slicing Technology Based on 5G in Smart Grid

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Abstract: 5G technology has been continuously promoted and has become a key driving force to promote the development of all walks of life and assist the national strategic decision-making. In the era of Internet of Everything, 5G network slicing technology, with its advantages of low latency, high security and scheduling, can better realize the rational and efficient scheduling and allocation of network resources, and fully improve the effective utilization rate of resources. This paper systematically summarizes the network slicing technology, analyzes the application of 5G network slicing technology in different power Internet of Things business scenarios and communication requirements, and puts forward the challenges that 5G network slicing technology in smart grid may face in the future, aiming at providing theoretical basis for the further development of 5G technology and promoting the continuous development of 5G smart grid application.

1. Introduction

In recent years, the application of the fifth-generation mobile communication technology (5G) has gradually become a hot topic. 5G technology has promoted the development of all walks of life and become a key technology to help formulate national strategic decision-making[1]. 5G communication technology boasts advantages of high bandwidth, low latency and massive connectivity user experience. In addition, it can closely integrate with other wireless communication technologies to form a new mobile communication network[2].

5G can not only provide convenient and flexible network services for traditional network operators, but also meet the differentiated needs of various vertical industries and penetrate into all aspects of social life[3]. The smart grid business, as one of the senior representatives of the vertical industry, has brought a lot of challenges to the communication network with its rich and diverse business types and differentiated industry needs. The massive user data of smart grid holds very strict requirements on the power communication network to have the advantages of convenience, flexibility, scheduling, low latency and strong reliability[4]. The 3GPP 5G power demand standard jointly developed by various enterprises and communication operators in the power industry as well as the release of the White Paper on 5G Assisted Smart Grid Application testify that in order to better develop and operate the power grid business, 5G technology must be used to meet the high-standard communication needs[5].
As one of the unconventional 5G technologies, the network slicing technology can divide the physical network into several independent, isolated and demand-based logical networks, which can ensure the efficient customization and smooth-going of various service needs[6]. It is pointed out in the report 5G Network Slicing Enables Smart Grid that the power business has strong differences and needs, and the application of 5G network slicing technology in smart grid can achieve flexible and efficient results[7]. In 2018, the State Grid Corporation of China, together with China Telecom, Huawei and other communication companies, reported the first smart grid business based on 5G network slicing technology that can effectively improve the end-to-end service level agreement guarantee, business isolation and operation independence[8]. In June 2019, the end-to-end slicing with SA (standalone) as the infrastructure was preliminarily verified[9]. Promoting the application of 5G network slicing technology in the power industry has become an inevitable trend for the development of smart grid so as to better serve the ever-changing power scenarios and create customized network services for the industry[10-11].

Based on the diverse and customized service needs of smart grid, this paper summarizes the 5G network slicing technology, analyzes its application mode in different scenarios, and predicts the development trend and challenges for the network slicing technology in smart grid.

2. Overview of 5G network slicing technology

2.1 The concept and characteristics of network slicing

As one of the most important key 5G technologies, 5G network slicing technology has attracted much attention due to its independence and high scheduling[12]. In practical application, a complete 5G communication network can be divided into several different parts by using network virtualization technology, and each part is a virtual end-to-end network[13]. In 5G communication network, the wireless network, transmission network and core network in each virtual network are not hybridized, but rather perfectly isolated from each other, which can guarantee the independence and non-disturbance on the logical level. Therefore, even if a part of the network fails, it will not affect the operation of other parts of the system[14-15]. 5G network slicing technology can process and integrate network resources according to different user needs and scene characteristics, and provide users with exclusive customized services[16]. Therefore, it can be said that 5G network realizes the differentiated and personalized communication network service, and this advantage can ensure that different vertical industries and customers with different needs can be completely independent and isolated in the differentiated scenarios and business, and enjoy the customized network services.

3GPP working group protocol offers a detailed arrangement for the management and scheduling of network slices. The results are shown in figure 1. It has three main functions as follows: (1) Communication service management function; (2) Network slice management function; (3) Network slice subnet management function[17].

![Figure 1. 3GPP standard definition slice management architecture](image_url)
According to the different user needs for communication network and isolation requirements by differentiated services, 5G network slicing technology can flexibly select rational slices, tailor different network information and provide differentiated communication services[18]. Wireless network slicing technology can realize the application of network slicing technology by isolating or sharing the spectrum of the air interface, baseband processing and high-level protocol stack[19]. In terms of hardware, the purpose is mainly achieved by TMD time slot crossing, while in terms of software, it is accomplished by VLAN and QoS[20]. The realization of core network slicing technology needs to be based on the virtualization technology of network functions, which mainly includes two ways: one is to physically isolate the core network through independent hardware resource pool, and the other is to share hardware servers and at the same time call multiple virtual machines to differentiate services[21].

In practical applications, there are many scenarios with very high requirements on the transmission security and isolation. In this case, the completely independent end-to-end slicing technology can be adopted. The wireless network, transmission network and core network with strict logic stratification can identify the data flow of different services. When transmitted to the corresponding platforms, the data flow between each service is completely isolated, independent from each other, and does not interfere with each other[22]. Therefore, sliced network technology can rationally allocate network resources according to different requirements on the delay and bandwidth and provide different network services. Of course, there are some services that are not very strict with security. Then, as long as the core network service data is isolated, the wireless access network and the transmission network can share services, or only slice the core network in the slicing process to achieve the same purpose[23]. The above method can reduce network traffic and slicing network business volume and reduce the difficulty of management while ensuring the completion of business. It can make full use of the network carrying capacity to solve the business problems with less strict requirements, as shown in figure 2.

![Figure 2. 5G network slicing mode](image)

**2.2 End-to-end 5G network slicing system**

5G end-to-end network slicing system, as shown in figure 3, is divided into four parts: “cloud, pipeline, terminal and security” , and the four parts together constitute the whole slicing system[24]. Among them, cloud refers to the network platform using application virtualization technology. It can help power users build an open and convenient independent management platform. In the smart grid, the cloud is divided into two parts. The first part is the traditional power business platform, with the main functions of distribution automation, metering automation and dispatching system[25]. The second part is the communication management support platform, mainly to manage the terminal, business, information, slicing and information scheduling[26]. The two parts can be connected through interface to realize the opening and sharing of the operational capability between the two parts. The communication management support platform can share terminal, business and monitoring functions with the traditional power business platform, and carry out data collection and analysis on the business so as to manage and control the power communication network through the cloud[27]. The pipeline part refers to the network part of the 5G communication, and it can be divided into three parts: wireless network, transmission network and core network. These three parts can realize
network slicing to provide services for smart grid[28]. In addition, on the basis of these three kinds of network slicing, personalized slice subnet service can be further realized. The slice subnet service can realize efficient operation of business and ensure that all parts of business are independent and do not interfere with each other. Through the docking of various services and modules in the smart grid, the power terminal and master stations can be linked to form an interconnected network system of everything. Through opening the interface, the operator network creates a channel for communication and sharing between massive network information and terminals, and realizes the secondary operation of slice network[29].

The terminal part refers to the general name of the remote devices in the communication network, such as smart meters, high-definition cameras and unmanned aerial vehicles. Different terminals correspond to different business needs, so different requirements on delay, bandwidth and security are put forward for the communication network. These requirements can be realized through 5G network slicing technology, which can ensure the efficient execution of services, and at the same time, isolate the services with a high degree of security.

The security system in the 5G network slicing system protects the cloud, pipeline and terminal. Before the power production business and control-type business are connected with the cloud, relevant national departments will put forward requirements on its security and adopt physical methods or logical isolation methods to keep the absolute security distance between businesses. The security mechanism of 5G smart grid focuses on the pipeline and terminal. In order to ensure the security of the connection between the pipeline and terminal, the following kinds of high security authentication are selected: unified authentication through 5G network, security management mechanism of multiple-level network slice, strict secondary authentication and encryption measures, and LAN security and firewall functions.

![Figure 3. 5G end-to-end network slicing system](image)

3. Application of 5G network slicing technology in smart grid

3.1 UAV smart grid inspection function

Due to the widely distributed transmission lines and complex network system, it has been difficult for the power sector to locate the security problems in transmission lines in a timely and quick manner. At present, the power grid departments are dependent on the on-the-ground inspection by staff, and for in-the-air inspection, they use low-flying helicopters to inspect the lines[30]. With the advancement of science and technology, the power sector is also using the products of modern science and technology to carry out power grid inspection. The use of UAV has solved the difficulty in power line inspection. As a product of modern science and technology, UAV has been widely promoted and used in the power grid industry with its compact, flexible and operable inspection machine. It is not only lightweight and flexible, but also can avoid the danger that may occur in human inspection and reduce the high cost of helicopter inspection. Therefore, by using UAV to complete the power grid inspection,
we can conduct a detailed investigation of the transmission line, avoid the risks of the transmission line, and greatly improve the efficiency of the line inspection. In addition, the biggest advantage of UAV inspection is that it can capture remote images in high definition and transmit them to ground departments. The application of UAV in smart grid puts forward the requirements on communication network slicing technology. The communication network needs to maintain ultra-high throughput to realize the transmission of high-definition images; UAV business boasts a wide range and high coverage, so the communication network must satisfy the needs of its wide range and high mobility. Unmanned Aerial Vehicle (UAV) has a long operation time, and it also needs to meet the requirements of high-intensity energy efficiency for communication. The eMBB slice of 5G slice network can meet the above requirements, help UAV receive information and commands transmitted by users more efficiently and quickly, and capture and transmit high-definition videos and images back. In addition, 5G slicing technology can also reasonably and sensitively customize different bandwidth and delay according to the different requirements of UAV up-down going, so as to ensure more efficient and safe data transmission.

3.2 AMI intelligent meter reading function
As an important collection system of power consumption information, advanced measurement system is of huge application value. Compared with the traditional manual door-to-door meter reading, AMI intelligent meter reading system solves the defects of the traditional way of measurement, such as large error, time-consumption, low efficiency, high labor cost, and can collect and analyze the power consumption data in real time. In the traditional manual meter-reading mode, people cannot prepay electricity charges, nor can they carry out real-time monitoring of various rates; the collection of electricity charges needs to be carried out manually, and the charging efficiency is low, which can not prevent illegal acts such as stealing electricity and failing to pay electricity charges[31]. With the improvement of living standards, the demand for household appliances and major commercial electricity is growing. It is necessary to monitor and analyze the electricity information in real time in order to ensure continuous provision of efficient and high-quality electricity services. The AMI smart meter customized service of 5G network slice can well match the need of meter detection. It can efficiently detect the consumed electricity in real time and mark the abnormal electricity consumption in the power grid system, transmit data safely, and monitor the operation of power transformer and transmission line through the smart meter and detect the hidden danger of electricity in time. In case of any abnormality in the power grid, such as transformer overload or power stealing, leakage and other problems, the system will automatically send alarm to the staff, who can quickly locate the problem through the intelligent meter reading system, repair the power grid problems in a timely manner, and solve the problems as soon as possible, so as to provide efficient and quality services for users. AMI smart meter reading has the following requirements for 5G slice network: first, the power user base is very large, so smart meter reading needs to access massive user terminal data; secondly, the power grid has a wide range of branches, and the close connection between users requires that the communication network maintain a high-density connection; lastly, the power consumption information and electricity cost are the national confidential data, so the communication network must guarantee the absolute security of user information. The mMTC slice of 5G network can well match the above requirements. The slice network can provide high reliability, high security and open network operation environment for smart meter reading through massive connection and bring excellent services for smart grid users.

3.3 Intelligent distributed distribution automation
At present, the users are having increasingly strict requirements on the power supply of smart grid. It is necessary to ensure uninterrupted and continuous power supply for areas with high demand. The requirement of accident isolation time should be kept at millisecond to ensure that there is no power outage in each power consumption area[32]. This undoubtedly increases the requirements on the centralized distribution automation, which necessitates more centralized processing capacity and lower
delay. Intelligent distributed distribution automation has become the development direction of
distribution automation in the future. It can distribute the processing logic of the original master
station to the intelligent distribution terminal step by step, and with the help of the communication
connection between each intelligent terminal, judge and locate the fault location, quickly check the
fault, and repair and restore the power supply so as to improve the fault processing time from the
original minute to the present millisecond, which greatly reduces the loss of users caused by power
failure. Intelligent distributed distribution automation takes advantage of 5G network slicing
technology to improve the efficiency of distribution network power supply, greatly reduces the scope
and number of power outage, and truly makes users satisfied. It puts forward the following
requirements for the communication network: the communication network needs to maintain ultra-low
delay to realize the rapid response and operation of power grid control and protection equipment; it
should strictly meet the requirements on high security performance to ensure that the power grid will
not cause large-scale blackout when it is attacked; it is necessary to ensure the high density of each
terminal so that each station can have thousands of power grid control and protection equipment
connection; in addition, the communication network should have high security and reliability. The
uRLLC slice of 5G network can well meet the above requirements. The advantages of the slice
network, such as security, reliability and low delay, can make the intelligent distributed distribution
automation more sensitive and responsive.

3.4 Millisecond precision load control
One of the major difficulties in power operation is that the hidden danger of small-scale blackout will
expand to large-scale blackout due to the avalanche effect of overload. At present, with the rapid
development of society, the demand for electricity in all walks of life is also rising and as a result, the
existing generators cannot supply more electricity. In the future, more generators are bound to cause
higher grid load. The high-sensitivity precise load control function can well solve the problem of
power outage caused by the avalanche effect. The millisecond-level load control can flexibly perform
load terminal operations on management users. This function can not only be used as the emergency
treatment of power grid emergency, but also help the corporate user organizer to interrupt the load,
reduce the economic loss of power grid users and the adverse impact on society. The traditional
distribution network lacks the support of communication technology. When there is a fault, the whole
distribution line will have to be cut off to narrow the range of its damage. The requirements of
millisecond-level precise load control for communication network are as follows: first, ultra-low delay
to meet the millisecond-level response speed; secondly, the reliability of communication network
should reach 99.999%; thirdly, there should be more than ten million connections between the
dispersed devices or control nodes; fourth, as a production business, it needs to be isolated from
management business to ensure security. According to the above requirements, the uRLLC chip of 5G
network can accurately control the power load, greatly reduce the loss caused by power grid failure,
and sort the power functions of users according to power priority, cut off certain unnecessary power
loads, and reduce the power load, such as the charging pile of electric vehicles or the power supply of
discontinuous production in the processing industry.

4. Challenges of power network slicing technology
First, the sliced network resources should be efficiently allocated. At present, due to the influence of
wireless spectrum and the distribution density of power grid business, the demand of smart grid
business for security and business isolation is relatively high. Among them, the data acquisition
business has a certain scale of development, and due to periodicity and typicality, some application
scenarios require high reliability and low delay for the control-type business. Slice management
system needs to allocate resources and schedule the subnet slices according to the business data. The
main challenge faced by smart chip network application is how to allocate air interface resources to
reduce the impact of resource adjustment on the volatility of acquisition-type continuous business.
Similarly, the slice network also needs to make more reasonable and efficient use of wireless network,
transmission network and core network to rationally allocate resources to meet the differentiated user needs and scenarios.

Second, the current smart slicing technology still lacks practical experience. 5G network slicing technology has a certain degree of complexity in the operation, maintenance and management of power grid, so it will also bring a lot of risks. Therefore, the network slicing technology based on artificial intelligence rose to the occasion. In the process of 5G core network architecture, we should best apply intelligent analysis technology to network slicing, especially to intelligently select algorithm model for different network slicing. At present, the research on this issue is still in the stage of theorization, and has not been tested in practice.

Thirdly, the standard of intelligent slicing remains to be further improved. In the R16 standard of 3GPP, the network slice selection function can realize slice selection, and collect the performance index data of the network slice in real time through the network data analysis function. Therefore, the standard defines the network data analysis function, which has the capability to read and allocate data. However, there is still some data that cannot be obtained because the interface specification is not clear. The intelligent chip needs to further improve relevant standards to realize the accurate capture of data.

5. Conclusion
The 5G network slicing technology can well meet the different user needs and scenarios in smart grid, and provide personalized and customized services. This paper elaborates on the management architecture, slicing mode and 5G network slicing system. It summarizes the smart services provided by 5G network slicing technology in four different scenarios and needs and discusses the challenges that 5G network slicing technology may face in the future in the hope of providing some reference for more efficient and flexible application of 5G network slicing technology in smart grid.

References
[1] Su Xin, Gong Jinjin, Zeng Jie. (2017) Wireless resource allocation for 5G network slicing. J. Electronic Products World, (04):30-32.
[2] Yu Lihua, Zhang Hongyu. (2017) Analysis of key issues of future 5G network slicing technology. J. China New Communications, 19(019):85.
[3] Xiao Ziyu, Yang Xiaole. (2017) Analysis of key issues of future 5G network slicing technology. J. Telecom Engineering Technology and Standardization, 30(005):45-50.
[4] Tang Lun, Zhou Yu, Yang Youchao, et al. (2019) Prediction-based virtual network function dynamic deployment algorithm in 5G network slicing scene. J. Journal of Electronics and Information Technology, v.41(09):44-51.
[5] Ren Chi, Ma Ruitao, REN, et al. (2018) Network slice: constructing customizable 5G network. J. ZTE Technology.
[6] Li Hongyi, Zhao Yirong, Li Jinyan, et al. (2020) Research on 5G network slice management based on open capability. J. Electronic Technology Application, 043(006):47-51.
[7] Liang Xuemei. (2019) Discussion on the application of 5G network slicing technology in state grid. J. Mobile Communications, 043(006):47-51.
[8] Zheng Kuo, Wang Zuwei, Xie Yuchen, et al. (2020) Application of 5G network slice in power industry. J. University of Science and Technology, 000(004):205.
[9] Chen Feng. (2020) Application research of smart grid based on 5G network slicing technology. J. Post and Telecommunications Design Technology, (6).
[10] Li Yi, Mo Yongheng. (2019) Research on the application of 5G network slice in power intelligent service. J. China New Communication, v.21(19):117-117.
[11] Zhao Junjie, Feng Shuchen, Liu Zhihong, et al. (2020) Application analysis of 5G power network slicing technology in production control of coal-fired smart power plants. J. Energy Science and Technology, (2).
[12] Yang Delong, Mengsa Chula, Ding Huixia, et al. (2018) Analysis of energy internet application of 5G network slicing technology. J. Wireless Communication, 008(006): P.252-257.
[13] Cui Yingqiang. (2020) Research on the application of 5G network slice in smart grid. J. Information Technology and Informatization, No. 245 (08): 136-138.

[14] Wang Rui. Research on mapping and scheduling technology of network slice resources based on SDN. D. Southeast University.

[15] Lv Yuxiang, Yang Yang, Dong Yawen, et al. (2019) Application of 5G technology in current differential protection business of distribution network [C] ecologically interconnected digital power. In: 2019 Annual Conference on Informatization of Power Industry.

[16] Dai Zhenguang, Liu Yulong, Yao Wanli. (2019) Application analysis of 5G network slicing technology in smart grid. J. Guangxi Electric Power, v.42; No.180(05):67-70.

[17] Xia Xu, Yuan Xin, Liang Yun, et al. (2020) Application research of 5G network slicing technology in smart grid. J. Electronic Technology Application, 046(001):17-21.

[18] Liu Zufeng, Zheng Kuo, Gong Kefan, et al. (2020) Application of 5G network slicing technology in smart grid. J. China New Communications, (14).

[19] Huang Min, Wang Dapeng, Wu Mingming, Zou Xin and Zhang Zongxiao. (2020) Research on the application of 5G network slice in smart grid. J. China New Communications, v.22(20):126-126.

[20] Wei Xiangxin, He Tao, Li Yihang, et al. (2019) Study on the delay characteristics of 5G network slices carrying power system services. J. Power Information and Communication Technology, (8).

[21] Li Huan, Xue Dahuan, Meng Fanbo, et al. Research and application of power IOT technology based on 5G network slice. Post and Telecommunications Design Technology.

[22] Wang Ying, Wang Xue, Liu Man, et al. (2020) Forward thinking on the application of 5G network slicing for smart grid. J. Power Information and Communication Technology, (8):1-7.

[23] Zhou Xiaodong, Warren Wang. (2019) Analysis of 5G mobile communication technology and its application prospect in power grid. J. Communication World, v.26; No.353(10):259-260.

[24] Li Yaguang. (2020) Application of 5G network slice in smart grid. J. Communication World, 027(005):133,135.

[25] Wang Dongsheng, Sun Fanqing, Xiong Wei, Wang Zhihui, Li Jian. (2020) Research on the whole life cycle of power 5G business slice. J. Power Information and Communication Technology, v.18; No.204(08):106-112.

[26] Zhou Zhixun. (2020) Research on access of power mobile terminal to intranet based on 5G slicing technology. J. Yunnan Electric Power Technology, 2020(3):13-16.

[27] He Jinhong, Zhang Ganghong, Gao Jian. (2020) Intelligent management of 5G slicing technology in power Internet of Things. J. Power Information and Communication Technology, v.18; No.201(05):23-29.

[28] Wang Qiuhong, Zhu Xuetian. (2020) Research on the application of 5G network slice in public network emergency support. J. Application of Electronic Technology, 000(002):14-17.

[29] Liu Mingyue, Tu Qi, Wang Yang, Meng Sa Chula, Zhao Xiongwen. (2020) Research on resource allocation algorithm of network slice in smart grid. J. Power Information and Communication Technology, v.18; No.204(08):24-33.

[30] Li Hao. (2019) Research on the Application of 5G network slice in smart home [J]. Information and Communication, 000(012):248-250.

[31] Hou Jianxing, Li Shaoying, Zhu Ning. Application analysis of network slicing in 5G. In: 2015 Annual Meeting of China Institute of Communications Information and Communication Network Technology Committee.

[32] Wang Tan. (2020) Research on 5G slicing technology and its application in smart grid. J. satellite TV and broadband multimedia, No.512(007):12-13.