Smart Grid Service Transmission Accuracy Optimization Technology Based on 5G Technology

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Abstract. Smart grid needs to have high stable transmission control accuracy, fast dynamic response performance and strong anti-interference ability. Conventional technology transmission of smart grid services, data transmission delay is long, in order to solve this problem, the design of smart grid service transmission accuracy optimization technology based on 5G technology. Build the general structure of the smart grid business transmission, define the business end of communication, specification data storage format, optimized algorithm for data transmission retreat, build 5 g network slice application scenarios, meet the requirement of smart grid, all kinds of business, and according to the business terminal sends commands, identify business communication resources, control of business information data transmission. The experimental results show that compared with the conventional technology, the design technology can reduce the waiting time and execution time of power network service transmission, and shorten the delay of data transmission.

Keywords: 5G technology · Smart grid · Service transmission · Communication technology

1 Introduction

The State Grid Corporation of China has taken the construction of world-class energy Internet enterprises as the construction goal, and continuously improved the construction level of information and communication networks. With the deepening of the construction, various business departments have built up some typical applications of the Internet of Things based on the actual needs through the use of terminals and networks. The number of terminals serving the production business of power grids has reached more than one billion, and the power Internet of Things has taken shape [1]. However, during the construction of the Internet of Things, the gradually exposed deficiencies have not been completely solved.

In reference [2], in order to solve the control parameter optimization problem of hybrid HVDC system, a new meta heuristic algorithm, whale algorithm, is introduced. Aiming at the problem that the global search ability of the algorithm is poor, the hybrid optimization theory is introduced and improved by using simulated annealing and

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League selection mechanism. The improved algorithm effectively balances the global search and local development ability, Taking the bipolar two terminal hybrid HVDC test system as the research object, the improved whale algorithm is used to optimize the proportional integral (PI) parameters in the rectifier side constant current control and the PI parameters of the inverter side DQ axis double loop controller, and the algorithm is realized by the joint simulation of MATLAB and PSCAD software. In reference [3], a double closed-loop control method based on network current feedback is proposed. The control method based on pole assignment is used to improve the inverter instantaneous voltage PID controller. The simulation results show that the PID control method based on pole assignment makes the inverter dynamic response fast and output voltage thd low. The large design method based on pole assignment is applied to the inverter voltage current double loop control system. In reference [4], an optimal configuration method of flexible AC transmission equipment based on adaptive particle swarm optimization is proposed. The optimal configuration method takes the optimal voltage stability, maximum available transmission capacity and minimum comprehensive cost as the objectives, establishes the optimization model, and uses the adaptive particle swarm optimization algorithm based on the improvement of distribution entropy to determine the optimal configuration scheme. However, the above traditional methods all have the problems of long waiting time and execution time of power grid service transmission, resulting in long delay of data transmission.

In order to solve the above problems and provide personalized and deterministic service support for different services, we shall, on the basis of the study of typical smart grid business scenarios of 5G, focus on tackling the collaborative and efficient transmission technology of ubiquitous service end networks of smart grids based on 5G so as to form effective solutions and relevant research results. Meanwhile, we shall pull through operators to verify the relevant business, explore the feasibility of 5G in the power industry and lay a foundation for the large- scale application of 5G. 5G has three application scenarios: ultra-high bandwidth, high reliability and ultra-low delay, and ultra-large scale connection. It can comprehensively improve the operation efficiency and intelligent level of traditional vertical industries, and is highly compatible with the needs of smart grid communication business. The agility and customizability of 5G network slicing technology can perfectly connect and fully meet the requirements of diversity and isolation of grid business, and create exclusive networks for different business needs of smart grid.

2 Optimization Technology Design of Smart Grid Service Transmission Accuracy Based on 5G Technology

2.1 Build the Overall Structure of Smart Grid Service Transmission

The overall structure of smart grid service transmission is constructed, and the service terminal communication method is defined. The overall structure of power grid service transmission is composed of five functional modules, namely, data collection module, information data control module, public cloud platform, terminal and network communication. The data collection module is used to collect the information data for transmission in real time, send the information data to the control unit, and use the control module to store the received information data. The control unit is made up of MicroinoduCore with the size of 26.36 mm × 28.93 mm × 31.53 mm, with the ATMEGA328P microcontroller as the core chip, powered by MICRO and by USB serial communication, so that the control unit has a compatible and standard peripheral interface and responds to the interactive commands sent by the cloud platform. The network communication module is composed of ENC28J70 Ethernet transceiver chip and RJ63 interface, which provides support for real-time communication between cloud platform and terminal, converts transmitted information data into corresponding information interaction commands, and business terminals download and receive information data to realize information interaction.

The IEC 61850 communication mode of the service terminal is defined and applied to the overall structure of the service transmission of the power grid. The communication structure of IEC 61850 is divided into four layers: physical layer, logical layer, data attribute layer and data object layer. Each layer is equipped with several logical nodes, and all nodes are closely associated with each other, which are composed of data objects for information exchange and cooperate with the task of business transmission. When constructing the IEC61850 distributed communication structure, the parameters and attributes of the information data are extracted firstly, and the information data of the logical nodes are combined according to certain granularity rules. Then self-description configuration IEC 61850 file, hosting the overall structure of the business transmission specific extensible markup language, to achieve the transfer of data information, the configuration file will be divided into IED capability description file, specification description file, terminal configuration description file, CID description file 4 formats, in which IED and CID file describe the communication network topology connection, indicating the information template has not been instantiated. According to the logic node of DG, it provides support for data transmission, realizes the automatic description of DG, and further exports the instantiation communication file of business terminal. Finally, mapping IEC 61850 communication service to communication protocol stack, defining communication service interface, adopting web service, GOOS service, MMS protocol, IEC 60870-5-104 protocol, aggregating data through protocol stack, specifying information data transmission mode, including MMS protocol, sampling value, Ethernet type of message mapping, etc., to realize the independence of communication protocol of business information data. Thus the overall structure of smart grid service transmission is constructed.

2.2 Optimize the Backoff Algorithm of Power Grid Business Data Transmission

When the information and data communication is realized at the power grid business terminal, the backoff algorithm of the interaction mechanism is optimized to ensure the integrity of information and data transmission. The embedded development board is used as the main control component of the power grid business aggregation terminal, and the S5PV210 chip is used as the core chip of the development board to store the communication resources of the power grid business [5]. The storage format set is shown in the following table (Table 1):

Table 1. Storage format of power grid service communication resources

The name of the data	The data type	The length of the data	Instructions
Id	Varchar	8	Site longitude
Address	Int	13	Site latitude
Message	Varchar	50	The site name
Name	Varchar	20	Site number
Latitude	Int	4	Contact
Longitude	Int	50	Site type
Phone	Varchar	4	Equipment serial number
EquipmentName	Varchar	4	Operating state of equipment
Type	Int	30	Subordinate to the site
Thor	Int	10	Administrator number
EquipmentNO	Varchar	50	Administrator privileges
EquipmentStatus	Varchar	8	Note

The service aggregation terminal is used as client and the management and control center is used as server to make the aggregation terminal communicate with the management and control center through socket. The communication mode follows the C/S structure and monitors the service request of the control center in real time. When the Management and Control Center sends the grid business, it shall create the socket original socket, intercept the data business of the Management and Control Center and copy it to the buffer. When the data request reaches a certain number, it shall verify the data. When the data is correct, it shall be transmitted to the data processing thread. Otherwise, the data shall be discarded to the socket data monitoring. When a data processing thread processes the requested data, it shall remove the data part of the Ethernet frame, determine the data type actually received, determine the data source, and then bind a specific socket according to the list of power grid business resources, adopt a custom data format, check the MAC address, send the business request to the network port, and the business aggregation terminal shall parse the data request of the communication resource management thread, and respond to the business instructions of the power grid control center. After access to IEC 61850 communication technology, the service terminal is regarded as the destination node, and the terminal receives the data packets sent by the source node, replies the ACK data frame to the source node. If the information exchange fails, the access to the wireless channel media shall be stopped, the source node sending the data shall enter the competition period again, the backoff algorithm shall be implemented, the number of retransmissions of the information packets shall be increased, and the time window for competition of all source nodes shall be increased exponentially. In the process of competing for data transmission channels, the source node shall reduce the probability of successful competition of the node sending the data, increase the probability of successful competition of the node sending the data, and ensure that the information data can be successfully connected to the transmission channel [6]. In order to reduce the probability of conflict in the subsequent communication and reduce the possibility of conflict again, the backoff time of the counter is calculated by the product of the length of the time slot and a random number.

The calculation formula of the execution function F of the retreat counter is as follows:

$$F = \xi M\text{in}(2Q, Q_{\max}) \tag{1}$$

Where Q is the competitive window value of nodes, $Q_{\max}$ is the maximum competitive window value, and ξ is the random number of [0, Q]. The idle time of the channel is detected. When the time is greater than the set threshold, the backoff counter is decremented by 1 by executing the function until the backoff count is decremented to 0, and the information data is sent again until all the information data are sent to the channel. So far, the backoff algorithm of power grid business data transmission is optimized.

2.3 Build 5G Network Slice Application Network Scenario

Application of 5g network slicing application network scenarios, so that business data transmission can meet the needs of power grid communication function.

Analysis of 5G End to End Network Slicing System
Combined with 5G network slicing mode, the 5G end-to-end network slicing system is analyzed. 5 G network chip overall architecture includes an integrated integration system of cloud, pipeline, terminal and security. In particular, cloud provides users in the power industry with the ability to build a more open, convenient and self-management platform, and cloud platforms for smart grid applications can be divided into two categories: the first category is the traditional power business platform, corresponding to the power generation control area; and the second category is the communication management support platform, including terminal management, business management, chip management, information management, dispatch management and other modules, corresponding to the power management information area. Pipelines, namely 5G communication networks, include wireless base stations, transmission networks, core networks, etc., jointly provide slicing services for smart grids, and provide exclusive sub-slicing services for different subdivisions of traditional power services, so as to ensure the safety isolation of power services and the requirements of network indicators. Reliable connection between power terminals and master stations shall be realized through the connection between various power service platforms and modules, and operators' networks shall open interfaces through network capacity to realize the opening and sharing of terminals and network information, thereby realizing the secondary operation of network chips [7–9]. Terminals refer to remote equipment connected to communication networks, mainly including intelligent distributed distribution automation terminals, intelligent ammeters, high-definition cameras, unmanned aerial vehicles, patrol robots and other special power terminals. The requirements of the terminals for network bandwidth, delay, reliability, number of connections and other requirements correspond to the three major application scenarios of 5G network slicing, and the security isolation between services is realized through

slicing technologies. The security system covers three levels, namely, cloud, pipeline and terminal. Before the power-generating business and control business are accessed to the cloud platform, physical and logical isolation shall be conducted according to the security requirements of the State and the power industry. The security mechanism of 5G smart grid shall focus on pipelines and terminals, and provide unified authentication and authentication framework, multi-level network slice security management, secondary authentication and encryption, network domain security, border firewall, etc. through the 5G network to enhance the access security of pipeline networks and terminals. Thus the analysis of 5G end-to-end network slicing system is completed.

2.4 Application of 5G Network Slice in Intelligent Network

The 5G network slicing technology is used as an entry point for operators to assist the construction of smart grid, and the network is customized according to the characteristics of grid services to meet the requirements of various smart grid services [10, 11]. Application of distributed power distribution automation, distributed power distribution automation is a comprehensive information management platform integrating computer technology, data transmission, control technology, modern equipment and management, which protects and controls the distribution network, detects the status information of distribution network lines and equipment through automatic relay protection devices, realizes intelligent judgment, analysis, fault location, fault isolation, power supply recovery in non-fault areas and other operations, realizes fault diagnosis and accurate positioning of distribution network lines and network equipment, rapidly isolates distribution network fault sections and fault equipment, and minimizes the time and scope of power outage due to faults, so as to reduce distribution network fault handling time from the minute level to the millisecond level. Precise load control, which is an important technical guarantee for precise excision of interruptible load. In the case of grid failure or unbalance of power consumption, load control will reduce load, improve the economy and security of grid operation, and enhance the investment benefits of grid enterprises by means of power stability control, emergency excision of load and low-frequency and low-voltage load shedding devices [12]. Establish a communication management support platform, provide an open interface for operating capacity, provide the traditional electric power business platform with terminal status, monitoring of business status and chip management, and achieve the manageability and controllability of electric power communication [13, 14]. Meanwhile, the communication management support platform can collect and summarize the terminal, business and network data of the traditional electric power business platform, and provide big data analysis and other advanced application functions. At this point, the intelligent network, 5G network slicing application network scene construction and application.

2.5 Transmission and Control of Smart Grid Business Data

According to the actual content of the instructions sent by the service terminal, it identifies the service communication resources of the power network and realizes the management and control of information and data transmission [15]. The server that processes business communication resources in different regions of power communication shall be selected, and be equivalent to a virtual machine, so that the servers in the same region are located in the same local area network, the server of power communication is represented by numbers, the processing speed of the server for business resources is unified, and different virtual machine control tasks are assigned according to the identified communication resources [16]. Dynamic migration is adopted in the resource transfer mode. Firstly, the monitoring node load of the terminal is determined, and the physical nodes that need to be migrated are identified. Set a fixed threshold, and take CPU utilization as a criterion. When the node utilization exceeds the threshold, move out the appropriate virtual machine, that is, move out the communication resources processed by the server, put the resources on other nodes, and reduce the load of the node. When the node utilization is lower than the set threshold, move out all the virtual machines run by the node, and eliminate the business resources run by the node, so as to ensure the quality of power communication services [17, 18]. The smoothing index of time series is used to predict the CPU utilization of different time windows of nodes. The calculation formula is as follows:

$$Q = \alpha x_t + \alpha x_{t-1} + \cdots \alpha^{n+1} x_{t-1} + \alpha_t \tag{2}$$

In the formula, Q is the predicted value of CPU utilization, α is the prediction parameter less than 1, ϕ is a random variable with smooth exponential normal distribution, n is the time change of control time window, and x_t is the historical load weight of node at t. Through formula (2), the power communication node to be migrated is determined, the business resource data stored in the server is copied, the volume of virtual machine is measured, and the virtual machine with the smallest volume is selected for dynamic migration. The calculation formula of volume V is as follows:

$$V = \frac{1}{1 - V_1} \times \frac{1}{1 - V_2} \times \frac{1}{1 - V_3} \tag{3}$$

In the formula, V_1 is the CPU utilization rate of the virtual machine, V_2 is the memory utilization rate of the virtual machine, and V_3 is the hard disk utilization rate of the virtual machine [19]. Through the above three indicators, the utilization rate of business resources is determined. When the utilization rate is lower, the volume of the virtual machine is smaller. Determine the physical nodes and virtual machines that need to be scheduled, use the cloud computing scheduling algorithm to realize the dynamic migration of commercial resources, count the subtask completion time, computing performance and real-time network bandwidth of all virtual machines, integrate the power communication lines into the cloud, take the scheduling node as the master node, the scheduling task as the cloud task, and other physical nodes as the slave nodes [20]. So that each cloud task can only be executed on one commercial resource, the cloud tasks are numbered, and the business transmission tasks are sorted from high to low according to the priority. Set the constraint conditions of the transmission task, set the master node as i and the slave node as j, then the time constraint function formula is:

$$P = A(\mathrm{i}) + B(\mathrm{j}) + C(\mathrm{i},\mathrm{j}) \tag{4}$$

In the formula, P is the communication time from the master node to the slave node for cloud tasks, $A(\mathrm{i})$ is the time required for the commercial resource transmission of the master node i, $B(\mathrm{j})$ is the time required for the resource reception of the slave node e, and $C(\mathrm{i},\mathrm{j})$ is the time required for the resource data to be transmitted from the node i router to the node j router through Ethernet [10, 11]. The formula of reliability constraint function is as follows [21]:

$$D = \frac{\sum_{\mathrm{k}=1}^{O} M_{\mathrm{k}}}{\xi} \tag{5}$$

In the formula, D is the reliability of resource scheduling scheme, ξ is the number of business resources running by virtual machine, O is the total number of cloud tasks, and M_{k} is the possibility of commercial resources selection for the k cloud task after resource scheduling. The communication time P and reliability D of the main node i to slave node j. The optimal scheduling link is selected to allocate the traffic transmission task to the link road, and the inherent time of the virtual machine is updated [22, 23]. After the scheduling is completed, the effective processing of node j to the transmission task is calculated, the formula is:

$$\zeta = \frac{L(\mathrm{j})}{\beta} \tag{6}$$

In the formula, ζ is the processing capacity of node j for commercial resources, that is, the feasibility of downloading business resources, $L(\mathrm{j})$ is the computing length of cloud task of virtual machine, and β is the download time period of cloud task, which is the difference between the download completion time and the download start time. Adjust the calculation length of the transmission task in time to make the prediction value ζ of the effective processing reach the maximum, so as to replace the original performance parameters of the virtual machine. When the transmission task is completed, the next transmission task is assigned in real time. According to the parameter changes of the virtual machine, the priority of the transmission task is adjusted at any time to provide more reliable business resources until all virtual machines are traversed and all power is allocated Network service transmission task. So far, the transmission control of smart grid business data has been completed, and the technical design of smart grid business transmission accuracy optimization based on 5g technology has been realized.

3 Analysis of Experimental Demonstration

The optimization technology is recorded as experimental group A, and the two commonly used optimization technologies of smart grid service transmission accuracy are recorded as experimental group B and experimental group C. the smart grid service is transmitted respectively, and the data transmission delay of the three technologies is compared.

3.1 Experimental Preparation

The power simulation platform is built by using cloudsim simulation software. The infrastructure layer consists of 1000 physical nodes, each node has 55 generators and 189 lines. The power grid scale is medium, and the host configuration is shown in Table 2.

Table 2. Host configuration of power grid simulation environment

The physical machine	Memory	CPU	Resource read speed (MB/s)	The response time (ms)
1	16 GB	Single-core 2.4 GHZ	44.3	13.3
2	16 GB	Binuclear 2 GHZ	50.7	15.3
3	8 GB	Single-core 1.8 GHZ	55.1	17.9
4	16 GB	Single-core 2.67 GHZ	53.9	16.4
5	8 GB	Four core 2.1 GHZ	49.8	15.2
6	16 GB	Binuclear 2 GHZ	55.4	17.8
7	8 GB	Single-core 2.4 GHZ	49.2	14.2
8	8 GB	Single-core 2.8 GHZ	49.8	13.1
9	16 GB	Binuclear 1.8 GHZ	53.2	15.8

Multiple frames are formed into a cluster to interconnect the host server through the switch, so that the test results of the three technologies are closer to the practical application. The communication network topology is shown in Fig. 1:

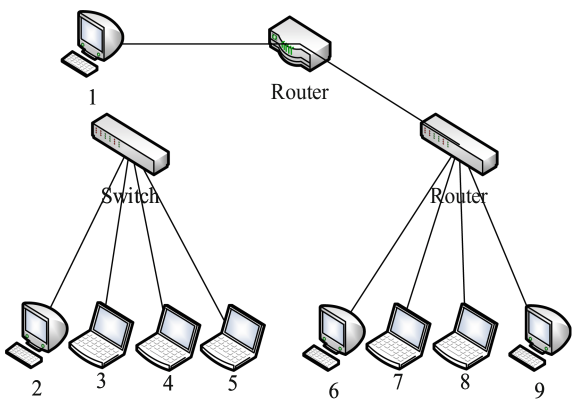

Fig. 1. Topological structure of power grid communication network

As shown in Fig. 1, host 1 serves as the control node, host 2 serves as the scheduling controller and cluster controller, and the other hosts serve as node controllers to provide communication resources for power grid business. The wireless local area network (WLAN) with IP address of 187.132.6.2, network type of 5G and public network interface of WLAN0 was selected for the experiment. The simulation platform has A total of 5 stations. Station A is the communication field station of power communication equipment A, Station B and Station C are optical cable jumping stations, Station D is the communication master station of communication equipment B, and Station S is the core master station.

Simulation parameters of 5G communication network are shown in Table 3:

Table 3. Setting of communication network simulation parameters

Parameter	Numerical	Parameter	Numerical
Simulation scene size	900 m × 900 m	Channel type	WirelessChannel
The simulation time	20 min	Channel bandwidth	15 MHz
Working frequency	6.837 GHz	Routing type	AODV
Network Interface Type	WirelessPhyExt	Interface queue type	PriQueue
Wireless transmission type	TwoRayGmund	Type of antenna	OmmiAntenna
MAC protocols	Mac802-11p	SIFS	30 μs
DIFS	40 μs	SLOT	15 μs
Minimum competition window	20	Node running speed	35/s

3.2 The Experimental Results

In stand-alone mode, through the host 1 business running power grid transmission task, business transmission resource set, composed of 60–200 independent tasks, task span of 20, change the number of task resource scheduling, optimization technology application three sets of grid services transmission precision, more business transmission grid average waiting time. In the process of smart grid business execution, the current common service waiting time is 1500 ms–2500 ms. The experiment result is shown in Fig. 2:

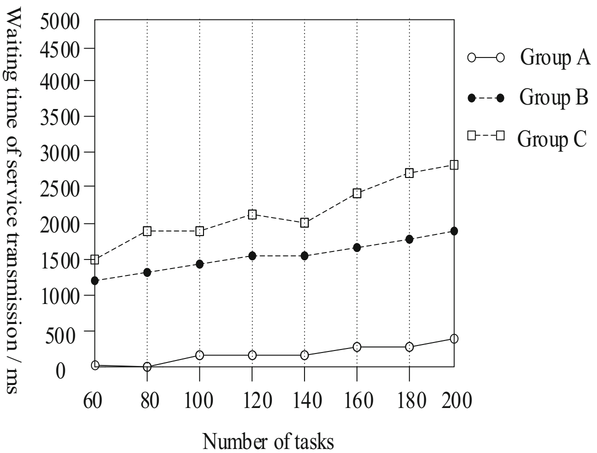

Fig. 2. Comparison results of waiting time for service transmission

The Fig. 2 shows that the experimental group A grid business transmission of average waiting time of 113 m, and the number of tasks less than 80, resource scheduling without waiting time, the experimental group B average waiting time of 1504 m, the experimental group C average waiting time for 2045 ms, compared with the experiment group B and group C, group A waiting time decreased by 1391 ms and 1392 ms respectively.

On the basis of a group of experiments, the task with high trust was selected to match with the communication resources of the power grid business, and the execution time of the three groups of technology transmission business was counted. According to the current survey of smart grid services, the average execution time of single service transmission is 3000 ms–6000 ms.

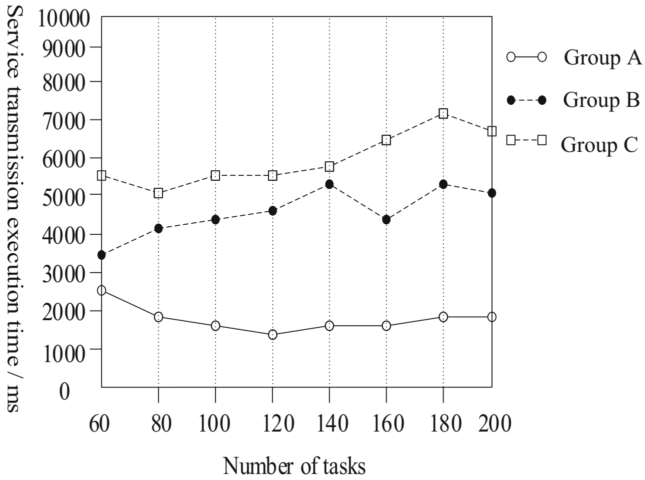

Fig. 3. Comparison results of service transmission execution time

As can be seen from Fig. 3, the average execution time of power network service transmission in experimental group A is 1826 ms, the average execution time of experimental group B is 4467 ms, and the average execution time of experimental group C is 6078 ms. Compared with experimental group B and experimental group C, the execution time of experimental group A is reduced by 2641 ms and 4252 ms respectively. To sum up, compared with the two groups of commonly used technologies, this design technology reduces the waiting time and execution time of power grid business transmission, shortens the data transmission delay of power grid business, and the transmission precision optimization effect of smart grid business is better.

4 Conclusion

The design technology gives full play to the communication advantages of 5G technology and shortens the data transmission delay of power grid business. However, there are still some shortcomings in this study. In future studies, in-chip BRAM will be adopted to make full use of digital front-end resources, improve the link transmission rate, expand the data cache space, and support larger scale power grid service transmission.

References

1. Liu, G., Wang, X., Huang, J., et al.: Analysis of performance for information of distribution network automation under different transmission protocols. Electr. Meas. Instrum. **57**(17), 99–105+146 (2020)
2. Liu, Q., Tang, X., Yang, J., et al.: PI parameters optimization based on improved whales optimization algorithm for hybrid high voltage direct current system. Electr. Power Constr. **40**(04), 30–37 (2019)
3. Yu, Z., Wang, W.: Optimal control of inverter power supply quality. Comput. Simul. **36**(04), 63–66+134 (2019)
4. Qi, W., Wang, Q., Chen, Q., et al.: FACTS optimal configuration of high proportion photovoltaic power grid considering voltage stability. Renew. Energy Resour. **12**, 1786–1793 (2019)
5. Liu, S., He, T., Dai, J.: A survey of CRF algorithm based knowledge extraction of elementary mathematics in Chinese. Mob. Netw. Appl. **26**(5), 1891–1903 (2021). https://doi.org/10.1007/s11036-020-01725-x
6. Lu, Z., Zhang, Y., Zhao, Y., et al.: A method to improve the reliability of relay protection service transmission channels. J. State Grid Technol. Coll. **23**(5), 33–37 (2020)
7. Liu, S., Fu, W., He, L., Zhou, J., Ma, M.: Distribution of primary additional errors in fractal encoding method. Multimedia Tools Appl. **76**(4), 5787–5802 (2014). https://doi.org/10.1007/s11042-014-2408-1
8. Lv, Y., Yang, Y., Dong, Y., et al.: Application of 5G to current differential protection of distribution network. Telecommun. Sci. **36**(2), 83–89 (2020)
9. Li, W., Fan, H., Shao, H., et al.: Research on transmission evolution strategy based on packet enhanced OTN in power communication network. Electr. Power Inf. Commun. Technol. **18** (9), 64–69 (2020)
10. Li, Y., Zhu, W.: Modern optical transmission network technology and its application in power transmission network. Commun. Technol. **53**(6), 1569–1574 (2020)
11. Yan, L., Chen, Z., Yu, X., et al.: Security interaction framework for electricity service in new-type town based on quantum key distribution. Autom. Electr. Power Syst. **44**(8), 28–35 (2020)
12. Tang, X., Liu, Q., Sun, C., et al.: Study on network structure and information transmission optimization of secondary system in smart substation. Power Syst. Big Data **23**(3), 77–84 (2020)
13. Liu, S., Liu, G., Zhou, H.: A robust parallel object tracking method for illumination variations. Mob. Net. Appl. **24**(1), 5–17 (2018). https://doi.org/10.1007/s11036-018-1134-8
14. Yang, G.: TD-LTE specialized network for distribution network service transmission performance test and analysis. Comput. Technol. Autom. **38**(4), 66–69 (2019)

15. Gao, Z., Zhao, S., Ma, Y., et al.: International business data transmission scheme based on MDI-QKD protocol. Chin. J. Quant. Electron. **36**(1), 34–39 (2019)
16. Zhang, Z., Li, L.: High-voltage DC high-efficiency detection and simulation of power transmission and distribution in communication system. Comput. Simul. **37**(4), 169–172 (2020)
17. Zhou, Y.: Research on the improvement strategy of grid user service satisfaction. Adv. Appl. Math. **08**(2), 242–249 (2019)
18. Shang, K.: Semantic - based service discovery in grid environment. J. Intell. Fuzzy Syst. **39** (1), 1–10 (2020)
19. Zhang, K., Troitzsch, S., Hanif, S., et al.: Coordinated market design for peer-to-peer energy trade and ancillary services in distribution grids. IEEE Trans. Smart Grid **11**(4), 2929–2941 (2020)
20. Liu, J.N., Weng, J., Yang, A., et al.: Enabling efficient and privacy-preserving aggregation communication and function query for fog computing based smart grid. IEEE Trans. Smart Grid **11**(1), 247–257 (2019)
21. Milievi, L.: An improved upper bound for the grid Ramsey problem. J. Graph Theory **94**(4), 509–517 (2020)
22. Hasan, M.M., et al.: Cloud-centric collaborative security service placement for advanced metering infrastructures. IEEE Trans. Smart Grid **10**(2), 1339–1348 (2019)
23. Jiang, W., Fang, X., Ding, J.: Gaussian kernel fuzzy C-means algorithm for service resource allocation. Sci. Program. **2020**(3), 1–6 (2020)