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RESEARCH ON POWER LINE COMMUNICATION BASED ON DEEP LEARNING FOR ELECTROMECHANICAL EQUIPMENT ELECTRICITY ACQUISITION TERMINALS

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Abstract. The purpose is to use power line communication technology to re-optimize the power acquisition terminals of electromechanical equipment and improve the efficiency of information acquisition and management of the system grid. This paper analyzes the power and signal composite modulation mode of power line data communication in distributed power grids. Combined with the topology of the communication network in the power transmission process, the management mode of integration of power lines and wireless communication equipment is redesigned. Firstly, the characteristics of power line communication and wireless channel are analyzed. Aiming at the problem that most communication network operators use the fixed relay for communication, the main network communication mode is selected for optimization. Then, the information fusion method is adopted to integrate the network structure of the enterprise, network, and physical layer. The management of wireless communication equipment is carried out by reasonably allocating power resources. Additionally, the structure of the power acquisition terminal model is designed based on strict standards and practice. Finally, the communication fusion method is used for experimental simulation. The results show that when the input current is 1A, the experimental, theoretical value of the system is 3A, and the actual instrument output is close to 5A. When the input current is 6A, the instrument output of the system is 7.5A. Therefore, loading a reasonable load impedance value in the system can optimize the current output value of the model. The paper has important reference value for optimizing electromechanical equipment and power acquisition terminal.

Key words: power line communication, electromechanical equipment, power acquisition terminal, management efficiency, communication integration

1. Introduction. WWith the development of power line communication technology and the Internet of Things (IoT), the management and collection of energy resources have begun to develop in the direction of intelligence [1]. Based on the re-optimization of wireless networks and power infrastructure, the efficiency of information exchange and resource exchange of power, transportation, and the IoT can be greatly improved. At present, the existing power communication network structure in China is complex and widely distributed, which brings great inconvenience to the use of individual users and the collection of power consumption information. Therefore, optimizing electromechanical equipment management strategy using power line communication is the key to solving the power problem.

Power line communication technology has the advantages of small investment, strong flexibility, and wide coverage. It is widely used in communication and data transmission between the power grid and the IoT [2]. However, due to the power grid's serious electromagnetic interference and channel attenuation, the communication quality is relatively poor. In order to solve the problems such as coverage and reliability of the power line communication network of the distribution grid, power line communication can be combined with the collection of electrical information from mechanical and electrical equipment. By designing the corresponding power line communication protocol, networking process, and route reconstruction strategy, the automatic networking and dynamic maintenance of the network can be realized, which is of great significance in improving the reliability of the power line communication network [3].

This paper makes an intelligent evaluation of the power line communication system based on relevant literature. Electromechanical equipment is used to optimize the relevant structure of the acquisition terminal.

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According to the power grid intelligent sensing technology requirements, the combined network distribution strategy of power equipment and intelligent power acquisition terminal is optimized. Section 1 introduces the background of power line communication technology and the development of IoT networks. Section 2 sorts out the literature on power line communication technology and power acquisition terminals of mechanical and electrical equipment and finds the practical application scenarios of power consumption monitoring in large power system networks. Section 3 analyzes the characteristics of power line communication and wireless channel and uses information fusion to design a power load management system and data acquisition terminal. Section 4 compares and discusses the simulation results of the electricity acquisition terminal. Section 5 analyzes and discusses the experimental results and draws experimental conclusions. This paper has practical reference value for promoting the digital and intelligent transformation of electromechanical equipment in the power grid.

2. Recent related work.

2.1. Relevant research on power line communication technology. Oliveira et al. (2018) [4] studied the access control protocol of power line communication media. They studied the design of new requirements related to the media access control layer and physical network system through the analysis of the time-varying behavior of load in the power system and high-power impulse noise. The results show that the development of power line communication technology can solve the problem of network resource sharing by comparing the access control protocols of smart grids and multimedia devices. Ghasempour (2019) [5] studied the architecture and application of the IoT in the smart grid and built a dynamic global network based on Internet entities with network services. The results show that IoT devices have limitations in computing and storage. Therefore, it is necessary to design or use security solutions so that IoT devices can safely conduct power communication transmission. Matheus et al. (2019) [6] studied the concept, application, and challenges of visible light communication. They explored the security architecture of power line communication by improving mobile communication architecture and wireless service infrastructure. Based on the redesign of the IoT communication architecture, the results show that the proposed model can promote the optimization of wireless networks.

Kolade et al. (2020) [7] studied the indoor amplification, forwarding power line, and visible light communication channel model. With the help of software-defined radios, they obtain measurements in an indoor testbed from different locations between powerline communication transmitters and receivers. The results show that the error-free operation distribution and the error probability of the measurements in the proposed mixed channel are far lower than those in other models. Therefore, the effectiveness of the experimental results is verified. Yu et al. (2021) [8] studied the power and signaled composite modulation mode of power line data communication in the distributed grid. They are based on a single generator and load design of the converter, using a power spectral density approach to demodulate useful data for transmission lines. Hardware experiments verify the effectiveness of the proposed signal composite modulation strategy. Koshkouei et al. (2022) [9] evaluated the in situ power line communication system of lithium-ion batteries and combined it with the real-world dynamic drive configuration experimental files. The results show that an increase in the quality and quantity of battery characteristic data available at runtime can improve the accuracy of the system's assessment of Li-ion battery health. Fei et al. (2022) [10] used the missing value pattern and non-technical structure loss of neural structure search to conduct research and adopted a detection algorithm and supervised learning technology to process distribution network data. The results show that the analysis of the relationship between various power theft techniques and data loss can use the missing value location information to enhance the model's performance further.

In order to improve the effectiveness and reliability of power line communication, the existing research generally starts from two aspects improving the point-to-point communication quality of power line communication physical layer and data link layer and network layer performance. Therefore, in order to improve the communication speed and reliability of the power line communication network, the paper can optimize the power resource acquisition efficiency of the power acquisition terminal from the network layer.

2.2. Recent research on power acquisition terminal of electromechanical equipment. In the study of mechanical and electrical equipment and electrical acquisition terminals, Shi et al. (2018) [11] studied the data acquisition system of high-precision electrical impedance tomography. They used a high-precision digital synthesis method and digital demodulation technology with high immunity to eliminate random errors, focusing on the main problems encountered in electrical impedance tomography data acquisition. The conclusion has practical application value for promoting the intelligent development of data acquisition systems. Zhang et al. (2020) [12] studied the electrical equipment identification system based on K-means clustering in intelligent buildings. They analyzed the load characteristics of the system and extracted the electrical characteristics for equipment identification from the collected data. The successful application of the system verifies the effectiveness of the proposed identification method. Budiman et al. (2021) [13] studied the monitoring and data acquisition information system. The experiment used Codeigniter for framework construction. System tests show that the design functionally generates 79.74% value, meets good standards, and is feasible. Herman et al. (2021) [14] studied the improved method of medical mask pressure for automatic data acquisition and analysis measurement. They created a simple pressure device with a three-dimensional (3D) printing model method. They used Python and MatLab scripts to acquire real-time pressure drop data and analyze multiple samples or batches. This paper has important reference value for improving the efficiency of medical data collection and processing.

In addition, in the research on intelligent manufacturing and the use of transmission lines in the power transmission process, Parveen et al. (2021) [15] explored the possibility of enhancing power transmission and multi-terminal power systems. They proposed to increase the use of existing transmission lines in addition to the independent control of AC alternating current/ direct current (DC) power flows. The results show that their proposed scheme can also meet the increase in electricity demand by increasing the use of existing transmission lines. Jiang et al. (2021) [16] studied the current compensation control strategy of electricity collection terminals for mechanical and electrical equipment in rectifier terminals. They proposed a current DC bus compensation control scheme and applied it to the rectifier terminal. In this scheme, the DC bus impedance gain at the rectifier end is reduced to balance the impedance at both ends and improve stability and controllability. Zhang et al. (2022) [17] used the energy-saving production architecture for the intelligent manufacturing process to describe the configuration of the data acquisition network. This approach enables the combination of social manufacturing and real-time energy profiling. Additionally, the energy consumption characteristics provide the decision-making basis for the energy-saving control of intelligent manufacturing workshops. Cao et al. (2022) [18] studied the wind farm data acquisition and management system based on edge computing. Firstly, the principles and advantages of edge computing technology are introduced. Then, they proposed to apply the technology to the wind farm data acquisition so that the data acquisition and management work could be carried out normally. Finally, the application of edge computing technology in wind farm data acquisition and management is simulated. The results show that the application of edge computing in wind farm data acquisition and management can improve the data transmission difficulties of electromechanical equipment during data acquisition.

According to the power grid smart sensing technology requirements, the current electromechanical equipment uses the power grid smart sensing terminal based on the power line and wireless communication integration technology. The designed terminal carries out power consumption monitoring and energy efficiency analysis in the large-scale power system network. Based on typical application scenarios such as power resource dispatching, power equipment, and intelligent power acquisition terminals have been widely promoted and applied.

3. Design of power load management system and data acquisition terminal based on power line communication.

3.1. Characteristic analysis of power line communication and wireless channel. At present, the topology of the power line communication network is complex and changeable. The network topology affects the transmission of communication channels in the current network, which changes with the distribution area [19]. Generally, this is a hybrid tree topology. Suppose the power communication network's distance between the source node and the target node is too large. In that case, reliable signal transmission between different nodes in the power network cannot be guaranteed. The power line communication network mainly includes a communication channel, an edge server, and a mobile base station. The structural framework of the power line communication network is shown in Figure 3.1.

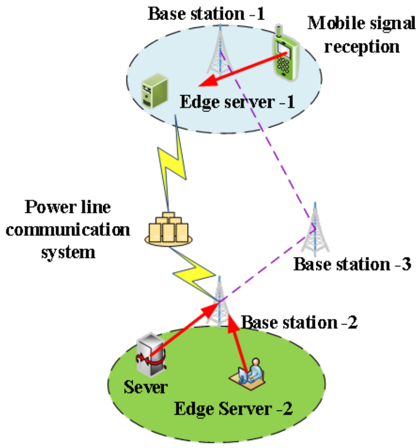

Fig. 3.1: Structural Framework of Power Line Communication Network

3.2. Management mode of power line and wireless communication equipment using information fusion. Enterprise, network, and physical layers are different levels of power line and wireless communication management structure. The existing research on power line communication combined with electromechanical equipment usually involves only one or two aspects, network or physical layers. The layer integration research on the power line and wireless network communication management model has not been fully launched. In order to improve the understanding of the complexity and reliability of network information, low-voltage line and microelectronic radio communication are deeply integrated by using multi-level and combined network and distribution strategies [20]. This is achieved by combining the concept of unified communication protocol, adopting the strategy of reasonable allocation of power resources, and understanding the network information of communication objects. For the management mode of wireless communication equipment, the structure is shown in Figure 3.2:

3.3. Structural design and research of power acquisition terminal model. Technically, the power acquisition terminal model is a centralized, spatially evenly distributed real-time computer control system. One of the technical bases of centralized monitoring of power load is the data communication between computers. A communication disk is established between the main system of the operating company and the locally distributed user data terminals to realize the centralized equipment management during the data exchange between the headquarters and the end users. Strict standards and practices must be followed; the system must receive data correctly before the timer locks. If the output power consumption data is inaccurate or lost, the timer will specify a timeout, and the system administrator will resend the power consumption data. By transmitting communication protocols between the application, data link, and physical layers, the structure of the power acquisition terminal model can be optimized. The structure of the power acquisition terminal model in the system network is shown in Figure 3.3.

3.4. Design of simulation experiment. The electromechanical power line communication equipment includes a timer and an external interrupt service program. Based on the timer interrupt service program, the data type conversion needs to be started when the timer stops in the model. A fixed number of network nodes in the weekly signal wave can be uniformly sampled. The power acquisition terminal module adopts a special power measurement chip. The power consumption can be measured by capturing the voltage and current of the integrated three-phase voltage sensor and external current sensor. The parameters of power, power supply, reactive power, and reactive voltage factor can be calculated. In the dynamic input range, the nonlinear measurement error of the chip is less than 0.1%.

In order to facilitate the verification of the communication fusion method proposed, the simulation experiment is based on the following assumption. Each node can calculate the communication rate, delay, and bit

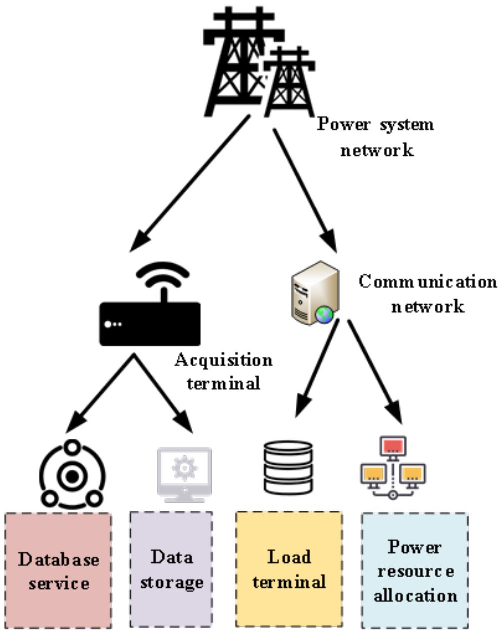

Fig. 3.2: Management Mode Structure of Wireless Communication Equipment

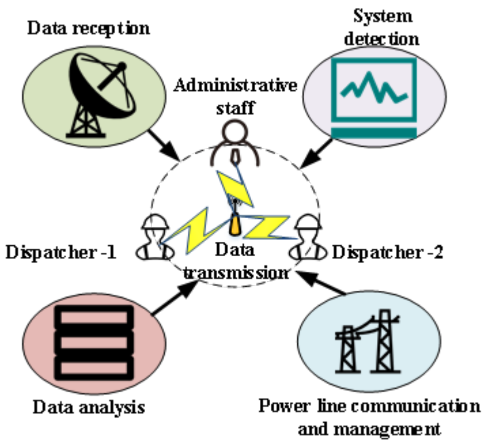

Fig. 3.3: Network structure of power acquisition terminal model

error rate between it and the previous node after receiving the data packet and storing it in the corresponding routing table. In order to research the power acquisition terminal of electromechanical equipment, Visual C++ is used as the experimental simulation environment. The modular design method is adopted, which is divided into power information acquisition, Bluetooth wireless communication, and system debugging modules. The main function is to display and verify the AC sampling value and detect other power data. The microprocessor system realizes the communication with the wireless Bluetooth HC-05 debugging communication module or serial port through the RS-232 serial interface, mainly realizing the parameter setting of the intelligent perception terminal. In addition, in order to compare the performance of power acquisition terminals, the system performance is tested under different current values, voltage values, and load impedance, and the results are analyzed and discussed. The scene structure of the simulation experiment application is designed, and the

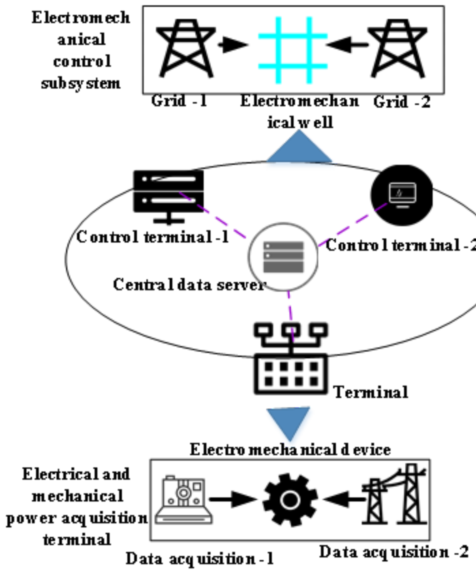

Fig. 3.4: Scene structure of simulation experiment application

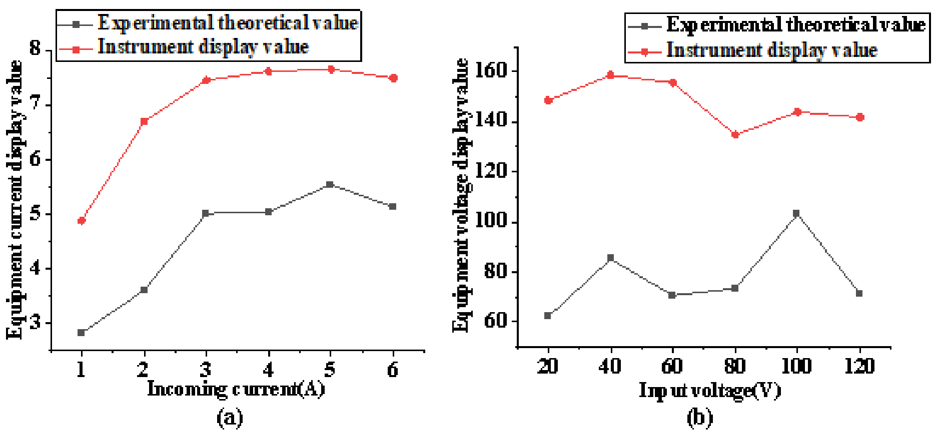

Fig. 4.1: Current and voltage value change curve of electric power acquisition terminal under different input values (a. comparison of terminal output current values under different current input values of the system; b. comparison of terminal output voltage values under different voltage input values of the system)

structure is shown in Figure 3.4.

4. Results and Discussion.

4.1. Comparison between current and voltage value of power acquisition terminal. In order to test the performance of electromechanical equipment combined with the power line communication proposed, it is necessary to compare the current and voltage value of the power acquisition terminal under different input values. Compare the results of the current and voltage values of the power acquisition terminal under different inputs, which are shown in Figure 4.1. In addition, in order to analyze the instrument power change of the power acquisition terminal, the instrument power change data of the power acquisition terminal under different current and voltage values are sorted out. The results are shown in Figure 4.2.

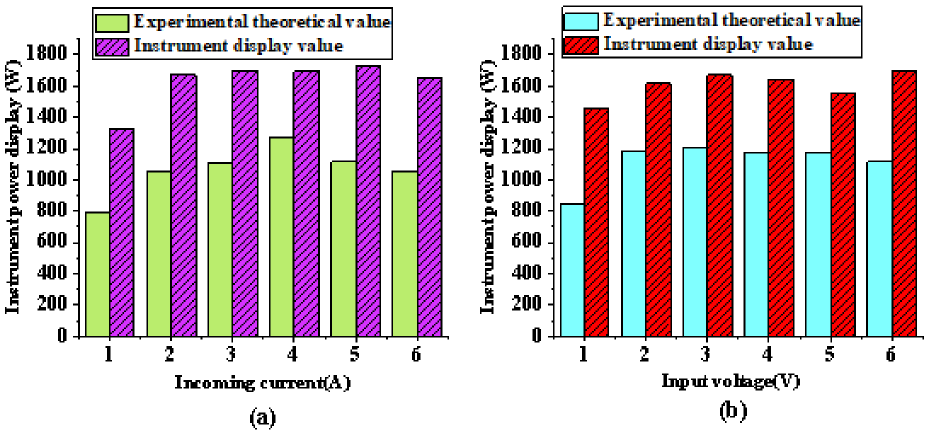

Fig. 4.2: Instrument power change curve of power acquisition terminal under different current and voltage values (a. comparison of instrument power change results of power acquisition terminal under different current input values of the system; b. comparison of instrument power change results of power acquisition terminal under different voltage input values of the system)

In Figure 4.1, when the input current value of the system is increasing, the data output results of the experimental theoretical and the instrument display value show an increasing trend. When the input current is 1A, the experimental, theoretical value of the system is 3A, and the actual instrument output is close to 5A. When the input current is 6A, the instrument output of the system is 7.5A. In addition, when the system input voltage is 100V, the theoretical output value is 110V, and the actual instrument output value is 140V. Therefore, the power acquisition terminal designed by the research can reasonably dispatch and allocate power resources.

In Figure 4.2, the theoretical output power value of the acquisition terminal and the actual instrument output value will fluctuate under different current and voltage values. When the system input current is 1A, the theoretical output value of the system is 800W, and the actual output value is 1300W. In addition, when the system input voltage is 1V, the theoretical power output value of the terminal is 850W, and the actual instrument output value is 1480W. The influence of the voltage input value on the system output power is analyzed. When the voltage input is 6V, the theoretical power output value of the terminal is 1100W, and the actual instrument output value is 1680W. Therefore, the results show that the system's output power can be effectively adjusted with the help of experimental instruments.

4.2. System performance analysis under different load impedance. In order to further analyze the system performance of the electrical acquisition terminal, the gap between the experimental theoretical value of the system and the instrument display value is compared under different load impedences. The data change curve is shown in Figure 4.3. The change curve of output power and output voltage value of the system under different input power is shown in Figure 4.4. In addition, the data receiving accuracy and data detection error rate change data of the power acquisition terminal are sorted out. The data results are shown in Figure 4.5.

In Figure 4.3, the difference between the experimental theoretical and the instrument display value under different load impedances will cause certain fluctuations. When the load impedance of the system is 20, the theoretical current of the instrument of the electric data acquisition terminal is 0.58, and the current value of the terminal data acquisition instrument is displayed as 0.98. In addition, when the load impedance of the system is 180, the current value of the terminal data acquisition instrument is displayed as 0.44. When the capacitance is removed, the load impedance range of the system changes from 100 to 600. When the load impedance is 200, the theoretical current of the instrument at the electric data acquisition terminal is 2.5, and the actual current of the terminal data acquisition instrument is 4.25. Therefore, the reasonable load impedance value loaded in the system can optimize the model's current output value and improve the resource utilization rate.

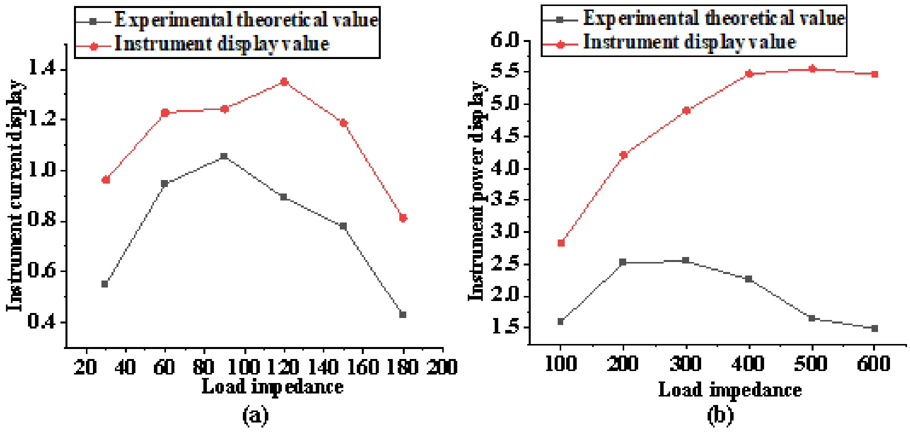

Fig. 4.3: Comparison of the gap between the theoretical, experimental value and the instrument display value under different load impedances of the system (a. the curve of the data changes between the theoretical, experimental value, and the instrument display value under different load impedances of the system after adding capacitance; b. the curve of the change of the data between the theoretical, experimental value, and the instrument display value under different load impedances of the system after removing capacitance)

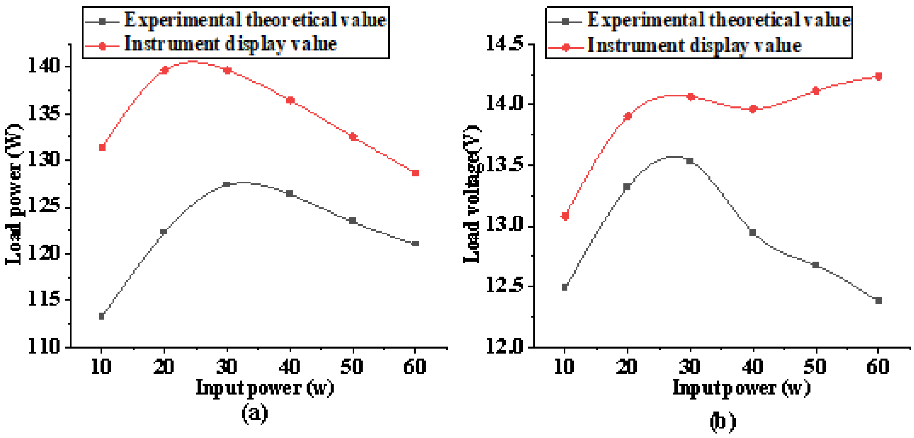

Fig. 4.4: Comparison of the system's output power and output voltage under different input power of the terminal (a. the change curve of the output power value of the system under different input power of the terminal; b. the change curve of the output voltage value of the system under different input power of the terminal)

In Figure 4.4, under the different input power of the electricity acquisition terminal, the system's output power and voltage value vary greatly. When the terminal input power is 10W, the theoretical output power of the system is 112.5W, and the actual output value is 133W. Currently, the theoretical output voltage of the system is 12.5V, and the actual model output voltage is 13.2V. When the terminal input power is 60W, the output power of the actual model is 130W, and the output voltage of the actual model is 14.25V. Therefore, reasonable allocation of grid resources can improve the working efficiency of power acquisition terminals and promote the rapid transformation of power resources.

In Figure 4.5, under the increasing input of the power acquisition terminal, the system's data-receiving accuracy is constantly improving, and the error results of data detection are constantly decreasing. When the

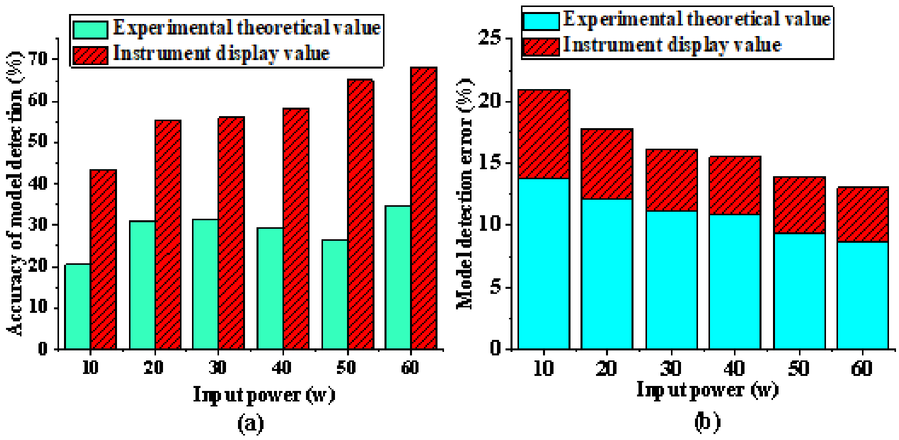

Fig. 4.5: Comparison of data receiving accuracy and data detection error of electric power acquisition terminal (a. change curve of data receiving accuracy of electric power acquisition terminal; b. change curve of data detection error of electric power acquisition terminal)

input power of the system is 10W, the accuracy of the experimental, theoretical output data is 20.5%, and the accuracy of the actual output data is 43.3%. At this time, the error rate of theoretical detection data is 13.7%, and the detection error rate of the actual data acquisition terminal can be reduced to 7.2%. In addition, when the system input power is 60W, the theoretical error detection rate of the data acquisition terminal of the system is 8.7%. The error detection rate of the actual terminal can be reduced to 4.3%, which is much lower than the previous data detection error rate. Therefore, using power line communication technology to optimize the power acquisition terminal of electromechanical equipment is conducive to improving the accuracy of power resource data transmission.

5. Conclusion. With the progress of the times and the rapid development of power supply technology, users have put forward higher requirements for power load resource management and power resource transmission. The paper adopts power line communication technology to analyze the transmission efficiency of resources in the current network. Based on the optimization of network topology, the main and fixed relay communication modes are selected to transmit power resources in the network. The electromechanical equipment type of power line communication is studied with the form of information fusion and structure optimization of power acquisition terminal model. The results show that the difference between the experimental theoretical and the instrument display value under different load impedances will cause certain fluctuations. When the load impedance of the system is 20, the theoretical current of the instrument of the electric data acquisition terminal is 0.58, and the current value of the terminal data acquisition instrument is 0.98. In addition, when the load impedance is 200, the theoretical current of the instrument of the electrical acquisition terminal is 2.5. The actual current of the terminal data acquisition instrument is 4.25. This paper has practical application value for promoting the deep integration of electromechanical equipment and power line communication technology. However, there are some deficiencies in the research. The main disadvantage is that in the actual power system network, the actual distribution network impedance is affected by many factors. Here, only a specific length of the power cable is simulated. In future research, more powerful system network data should be combined to optimize the model management strategy.

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