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Retraction

Retracted: Power Grid Intelligent Energy Dispatching Interactive System Based on Virtual Reality Technology

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] W. Hu, Y. Yang, B. Liu, S. Guo, and K. Zhang, "Power Grid Intelligent Energy Dispatching Interactive System Based on Virtual Reality Technology," *International Transactions on Electrical Energy Systems*, vol. 2022, Article ID 8008461, 8 pages, 2022.

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Research Article

Power Grid Intelligent Energy Dispatching Interactive System Based on Virtual Reality Technology

Wenjian Hu[1], **Yang Yang**[1], **Baoan Liu**[1], **Siyan Guo**[1], and **Kuizhong Zhang**[2]

[1]*State Grid Shijiazhuang Power Supply Company, Shijiazhuang 050200, Hebei, China*
[2]*Shijiazhuang Kelin Electric Co,Ltd., Shijiazhuang 050000, Hebei, China*

Correspondence should be addressed to Kuizhong Zhang; 201903306@stu.ncwu.edu.cn

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Objective. In order to improve the intelligence of power grid energy dispatching, this study proposes an interactive system of power grid intelligent energy dispatch based on virtual reality technology. Through the introduction of the main functions of the intelligent energy dispatching visualization system and the analysis of the construction of software and hardware, as well as the application of the actual power energy dispatching real-time operation visualization system, the system is described in detail and applied. The application results show that since the application of the system, the accuracy rate of comprehensive intelligent early warning is 100%, the monthly availability rate is 100%, and the average processing time of single fault scanning is less than 2 s. *Conclusion.* The system has good application prospects and in-depth research value and provides technical support for the further development of the smart grid.

1. Introduction

In the 1990s, the marketization of power systems was developed by leaps and bounds, rapidly covering the world. With the rapid development of computer technology, the improvement of computing speed, and the efficient realization of modern computer perception technology, display ability, and drawing technology, visualization technology is also making continuous progress. Many experts and scholars have shifted their research focus to the application of visualization technology in power systems and tried to combine new computer technology with cognitive science, mine new algorithms, try new schemes, and develop a visualization platform for power system energy dispatching. From the initial single-line diagram, simple data, text, and tables are superimposed, and factors such as color, animation, time bar, geographical location, and split-screen display are gradually added. The graphics are also developed from two-dimensional to three-dimensional, forming a series of visual expressions corresponding to the power system [1]. Nowadays, with the arrival of the era of the smart grid and big data, as the core embodiment of the smart grid, intelligent energy dispatching has gradually become an important research direction for scholars. In order to meet the needs of the smart grid, the intelligent energy dispatching system should have a more comprehensive and accurate data acquisition system, have a powerful intelligent security early warning function, and pay attention to the coordination of system security and economy in energy dispatching decision-making. When the system fails, it can quickly diagnose the fault and provide fault recovery decision-making. The visualization technology can be used to comprehensively and intuitively provide the real-time operation of the power grid to the dispatcher to assist him in judging the power grid situation, formulating the operation mode, dealing with emergencies, and so on. Visualization of intelligent energy dispatching of power systems is to use visualization technology to display various attributes of power system equipment and system operation status in the form of graphics or images after being processed by various advanced algorithms and technologies, so that system operators can understand the present system operation status more conveniently and clearly, so that their operation control measures can be more effective and targeted [2].

2. Literature Review

Zaghwan and others, based on the concept of intelligent machine dispatcher (AO) proposed by Dr. Dy-Liacco and combined with the actual situation of China's power grid energy dispatching operation, proposed and studied the data mining technology based on the power grid fine rules and automatically mined the fine power grid safe operation rules through the steps of subject definition, massive training sample generation, feature selection, and rule generation. The prototype system of AO is developed, the hardware design and software structure based on cluster computers are given; and the software functions and algorithms are introduced. The AO prototype system is tested and analyzed for a provincial power system [3]. Sang and others extended the concept of energy dispatching center, put forward the concept of modern energy control center, and focused on the transformation of control centers in informatization, automation, integration, and intelligence, including applying information theory to analyze the information flow of power systems, rebuilding the original appearance of real power systems, and improving the operating conditions of power systems. It integrates the data of the existing energy control center, establishes a data warehouse, and carries out data mining for the decision support of the control center. It realizes a higher level of automation for the routine operation of power systems and the operation of abnormal and accident handling. Through the above ways, the function of the control center has developed from a single focus on safety and stability to the coordination of safety and economy, from local control to global hierarchical control, from offline analysis to online analysis, from open-loop control to closed-loop control, and from online steady-state analysis to online transient analysis [4]. Rojas and others proposed an intelligent auxiliary decision support system for accident handling based on an expert system after discussing the intelligent fault diagnosis algorithm, the principle and implementation algorithm of fault recovery decision. The expert system realizes the information interaction with SCADA, EMS, and fault information systems by using the information integration technology and provides comprehensive fault recovery decisions, so that the dispatcher can quickly locate the fault and recover the power supply in the face of complex faults [5]. Liu and others put forward a power grid operation decision support system based on multiagent on the basis of analyzing the present situation of power system operation, designing the framework of the system, and describing the functions and decision-making process in detail [6]. Sun and others introduced multiagent technology into the power market technical support system, proposed the model and design scheme of a generalized power market technical support system based on multiagent, and discussed the key technologies of agent system development [7]. Chukkaluru and others introduced the structure of the decision support system (DSS) of the Ordos power grid and the functions of each module and described the decision-making process of the system. The system combines artificial intelligence technology such as expert systems with DSS, realizes the preliminary intelligence of power grid dispatching systems, and can assist dispatchers to make more reasonable dispatching decisions. The intelligent energy dispatching decision support system is composed of five parts: database, model base, knowledge base, functional module, and human-computer interaction. The data part is a database system. The model part includes the model base and its management system. The knowledge base part is composed of the knowledge base management system and the knowledge inference engine. The functional module is a variety of analysis applications based on EMS. The human-computer interaction part is used to accept and test users' requests and call the system's application software for decision-making services, so as to organically unify the model operation, data call, and knowledge reasoning [8].

3. Research Methods

3.1. Power Grid Intelligent Energy Dispatching System. The power grid intelligent energy dispatching system takes the power grid energy dispatching system as the object and realizes the intelligent exchange of information in all links of power grid energy dispatching through continuous research, development, and application of new power grid control technology, information technology, and management technology [9]. It is a technical system to improve the security production guarantee ability and decision-making ability of power grid dispatching; improve the sharing and optimal allocation ability of dispatching resources; improve the standardized lean and intelligent operation and management ability of power grid dispatching; and provide support and guarantee for the safe, high-quality, and economic operation of the power grid. The equation constraint condition of a power system means that the active power and reactive power of the system are kept in real-time balance, which is expressed by the following equation:

$$\begin{aligned} \sum_{i=1}^{i=n} P_{Gi} &= \sum_{j=1}^{j=m} P_{Lj} + \sum_{k=1}^{k=l} P_{sk}, \\ \sum_{i=1}^{i=n} Q_{Gi} &= \sum_{j=1}^{j=m} Q_{Lj} + \sum_{k=1}^{k=l} Q_{sk}, \end{aligned} \quad (1)$$

where P_{Gi} and Q_{Gi} are the active and reactive power from the first power source in the system; n is the number of power supply nodes; P_{Lj} and Q_{Lj} are the active and reactive power consumed by the first load in the system; m is the number of loads in the system; P_{sk} and Q_{sk} are the active and reactive power loss of the k power transmission and transformation equipment in the system; and l is the number of power transmission and transformation equipment in the system.

At present, the development trend of large-scale and complex power grids highlights the problems of power grid security and economic operation, and the research and development of power grid intelligent energy dispatching systems has become the focus of attention [10]. From the existing research results, the research of power grid intelligent dispatching systems mainly focuses on three aspects: power grid state calculation (including prediction) method, decision-making system, and system platform construction.

3.2. Visualization Technology and Its Application in Power Grid Energy Dispatching. Visualization technology integrates many branches of computer technology, such as graphics, image processing, data management, network technology, and human-computer interface. It uses computer graphics and image processing technology to convert data into graphics or images for display on the screen, which is conducive to correctly understand the meaning of data or processes. In the present energy management system/power grid dispatcher training simulation system (EMS/DTS), in addition to a small amount of data visualization, more power system operation data are displayed in real time on the power flowchart [11]. Although the digital information display is very accurate, for a large power grid, to monitor all the information of the whole power grid in real time, the digital display alone is undoubtedly monotonous, complex, and extremely lack intuition. These data do not contain the high-level abstract information required by the dispatcher, such as global centralized representation, and the relationship between these data is not clear, and the data representation lag behind.

To sum up, simple methods such as data text display to monitor and analyze the power grid can no longer meet the needs of power grid development. There is an urgent need for some methods and tools that can comprehensively and intuitively monitor the real-time operation of the power grid, highlight the data that are critical to the operation of the power grid, identify the weak links of the system through analysis and calculation, and effectively manage and process various types of information in the power system [12]. The appearance of visualization technology provides a solution to these requirements of modern power grid operation.

3.3. Design and Implementation of the Power Grid Intelligent Energy Dispatching Visualization System

3.3.1. General Design Ideas and Principles. The existing safety monitoring and data acquisition/energy management system (SCADA/EMS) has mature theoretical basis and application experience. While learning from and inheriting its essence, it integrates many new technologies. It is necessary to put forward design ideas and principles different from the traditional ones. The main problems faced are as follows: in real-time operation systems, the interaction between the dispatcher (person) and the automation system; massive data extraction and its utility display; the validity of knowledge models and display platforms that do not completely depend on mathematical models, such as data mining methods, in the application of giant systems; and integration and opening of multisource data (real-time and historical, static, and dynamic) in many systems such as production and management [13]. In view of the above problems, this paper introduces the latest achievements in the design and research of dispatcher and automation systems and puts forward the design idea of a power grid intelligent energy dispatching visualization system with dispatcher thinking mode as the framework, visual interface as the functional model, and interactive computing as the core of the system.

The visualization system first proposes four stages of a complex man-machine system task in terms of ideas and principles: obtaining information ⟶ analysis and display ⟶ decision-making action ⟶ execution action, as shown in Figure 1.

(1) The system inherits the effective practical experience of the original SCADA/EMS
(2) The system effectively adopts the dispatcher's thinking mode in the actual scheduling. It can show the workflow in the order of scheduling principles and can work according to the dispatcher's intuition.
(3) The visual interface shall be closely combined with functions to display the visually sensitive interface that the dispatcher thinks, wants to see, and operates, so as to deepen the understanding of the system's situation and solutions
(4) The system framework is an open system, and subsequent functions can be inserted at will. The core algorithm of the system is an online algorithm with interaction and sequence coordination, which can adopt pure mathematical model algorithms, data mining algorithms, artificial intelligence algorithms, and so on.

The characteristics of the visualization system are as follows:

In the visualization system, a series of visualization interfaces and corresponding functions are designed, multiple real-time algorithms suitable for interactive computing are proposed, and the display technology of multidata source fusion is explored (Figure 2). The operation practice shows that the system performance indicators fully meet the real-time operation requirements of power grid energy dispatching, and a new way is explored for the application of the next generation SCADA/EMS.

3.3.2. Introduction to Main Functions. The visualization system is displayed in three layers according to the power grid operation status.

(1) The first layer shows the overall operation status of the power grid, which is the most concerned by the operators. Under normal circumstances, only a small amount of information is displayed on the visualization interface of the visualization system. However, once the visualization system enters the early warning state, it will immediately give an alarm through a very intuitive graphical interface and use a variety of means to represent different alarm levels, such as through the change of color (light color indicates low-level alarm and the darker the color, the higher the alarm level) and through the change of color and size of the percentage pie [14]. The alarm level can be set through the configuration attribute of the visualization system.
(2) The second layer shows the macrodata analysis results of problems or aspects concerned by operators. Under normal conditions, the visualization system

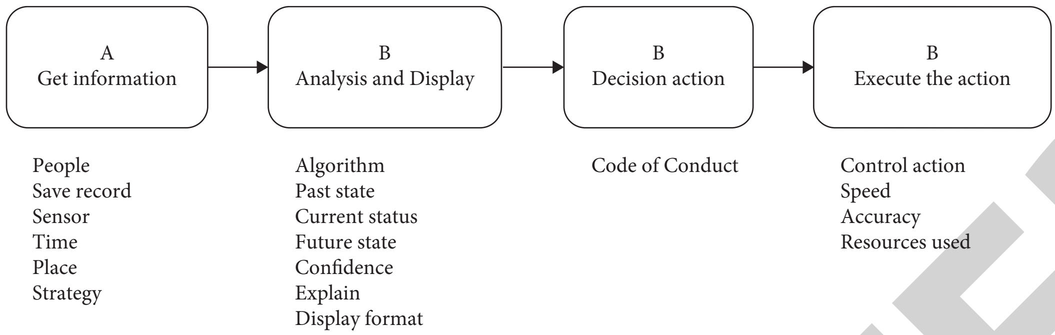

Figure 1: Four phases of complex man-machine system tasks.

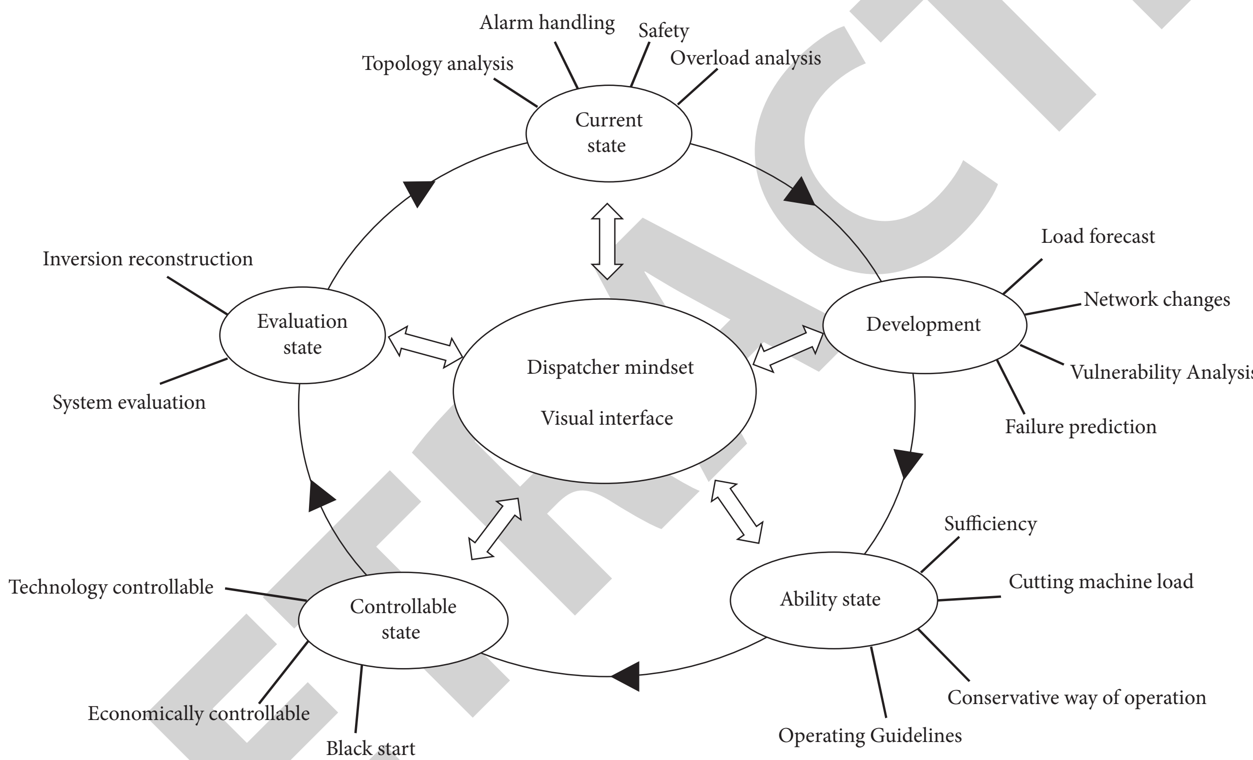

Figure 2: Display technology of multidata source fusion.

can monitor the tidal current of one or more specific sections with a three-dimensional column diagram. If the power grid is in a normal safe state, the distance from the power grid to the unsafe state shall be displayed graphically. If it is in an abnormal operation state, it gives suggestions and countermeasures to remove the unsafe state. At the same time, the system "disconnection" accident is scanned and analyzed in real-time every 5 min, and the indicators of each fault's severity are given in graphical form.

(3) The third layer shows the specific value of the quantity of interest. The visualization system can display the monitoring data of all devices.

The visualization system realizes the following functions:

(1) Realize the collection of real-time data of power grid and use dynamic display and two-dimensional images to visually express the real-time information of power grid lines, node voltages, and generator active and reactive power [15,16]. It mainly includes the contour of node voltage, load pie chart of line, contour of line load, dynamic generator, and dynamic power flow.

(2) The dynamic three-dimensional images are used to visually express the real-time information of active and reactive power reserves, such as reactive power reserve, transformer temperature monitoring,

transformer reserve, and three-dimensional rotation

(3) The sensitivity calculation and three-dimensional sequencing display of power grid lines to generators, loads, and node voltages to reactive power equipment are realized

(4) Web publishing of visual graphics: integrate the visual display function, transmit data through a special isolation device, publish the web on the network, and realize cross-platform data sharing.

(5) Visual playback, replay, and evaluation of historical data: The visualization system has the ability to accident recall and can playback and replay historical data. Different from the general SCADA/EMS, the visual system replay is to replay the graph and data at the same time on the historical network topology, use the historical data to track the power grid loss statistics, conduct comparative analysis according to the cycle, provide optimization strategies, and visually display the real-time and historical indicators.

(6) Visual display of precontrol scheme depending on sensitivity [17]: Sensitivity is actually a quantity used to describe the linear relationship between the variables of the power flow equation. It can analyze how many changes will occur to other variables when some variables change.

(7) Visual monitoring of low-frequency oscillation mode dynamic threshold of key lines: According to the data of synchronous phasor measurement unit (PMU), real-time data detect the low-frequency oscillation of the system, calculate the oscillation frequency and amplitude of the detected line, and dynamically display them on the single-line diagram and geographical wiring diagram. If low-frequency oscillation is detected, the corresponding lines on the single-line diagram and geographical wiring diagram will be displayed in the form of an oscillation curve, and flashing, color change, sound, and others will be used for limit violation warning. Under normal conditions without low-frequency oscillation, the single-line diagram and geographic wiring diagram are displayed in the normal display mode [18]. When you want to care about the details of low-frequency oscillation of a certain line, you can locally track and amplify the details of line oscillation, so as to provide timely and visual warnings for preventing the occurrence of such faults.

(8) Visualization of prewarning of total power flow of any section: The system provides a display of the total power of any section combination of the line, and the results are represented by a histogram. This function greatly reduces the work intensity of dispatchers and provides powerful technical support for dispatchers to quickly and accurately evaluate the running state of the system.

(9) The index system of power grid operation in real-time state and the visual expression of power grid static vulnerability by virtual instrument: The real-time data transmitted by SCADA/EMS are used to classify the operating conditions of power generation systems, transmission systems, loads, and reactive power devices, and then, the weights of safety, critical state, and insecurity are determined according to their attributes. The fuzzy clustering method is used to objectively evaluate the safe operating state of the whole system, and the virtual instrument is used to display it.

(10) Visualization of “” fault early warning assessment of the power grid. The power grid operation situation changes the assessment brought by the “power grid.” The assessment is used to quickly sort the “power grid” faults, formulate the sorting indicators, and use the classification rules to express the nonconvergence and controllable conditions in three dimensions. Online “” analysis provides dispatchers with advanced analysis of possible faults, which is helpful for judgment and decision-making in the case of real faults.

(11) Visualization of intelligent energy dispatching of power grid reservoir and power generation capacity maximization: By collecting data such as generation curve, water consumption curve, and minimum water level limit of hydropower units and corresponding reservoirs, the maximum operation time of hydropower units according to the maximum, minimum, average, or user-defined generation output is calculated in real-time, and the corresponding time of hydropower unit output is expressed visually, so as to facilitate the dispatcher to fully grasp the hydropower generation capacity of the power grid.

3.4. System Application. In order to illustrate and demonstrate the specific functions and advantages of the power grid intelligent energy dispatching visualization system, the following takes the application of this system in the actual power grid energy dispatching system as an example.

3.4.1. Software Architecture. According to the previous introduction of the system functions, the software system of the corresponding visualization system for power grid intelligent energy dispatching is shown in Figure 3.

In Figure 3, CIM is the computer centralized management system, SVG is the scalable vector graphics, and DMIS is the spatial measurement interface standard.

3.4.2. Hardware Architecture. Figure 4 shows the hardware system of the power grid intelligent energy dispatching visualization system.

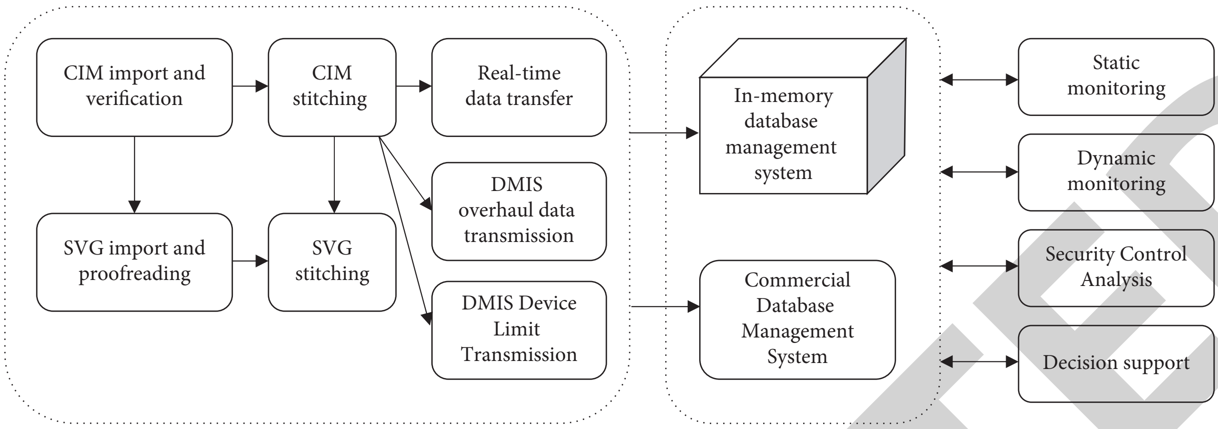

Figure 3: Schematic diagram of the power grid intelligent energy dispatching visualization system software system.

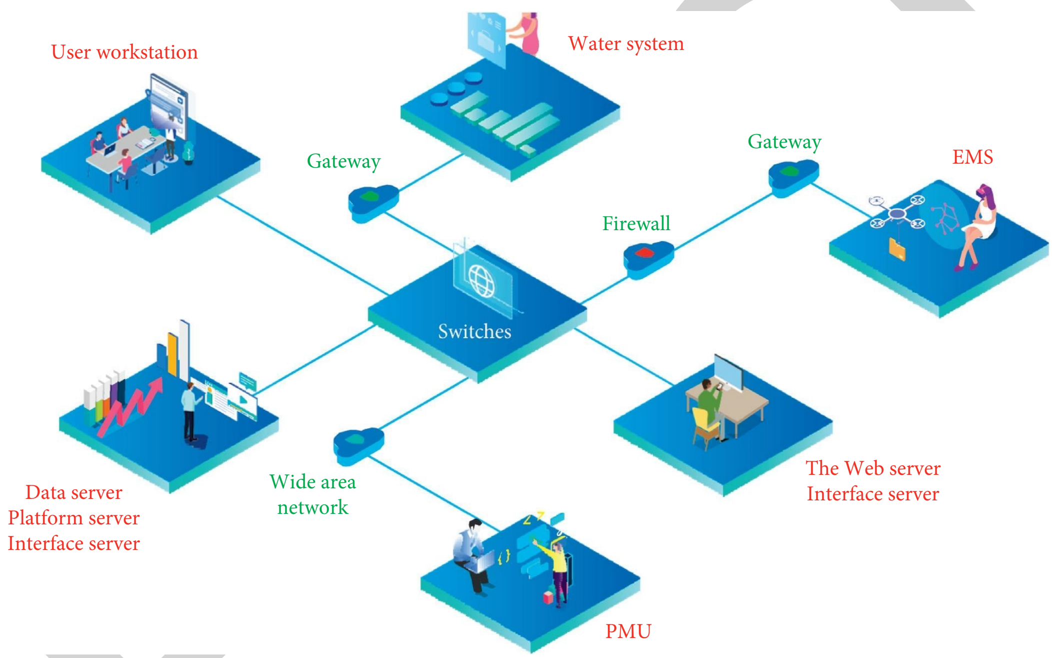

Figure 4: Hardware system diagram of the power grid intelligent energy dispatching visualization system.

3.4.3. Design Route of Interactive Calculation. The power grid intelligent energy dispatching visualization system takes the dispatcher's thoughts as the core in the design route and organically combines the power grid operation sequence, dispatcher's experience, and power system analysis functions. The visualization interface provides a platform for data display, function expression, and interactive calculation. Interactive calculation organically adds the human role to a closed-loop control system [19, 20]. This kind of interactive computing integrates the dispatcher's perception and experience and can conduct real-time computing and make corresponding verification through the interactive computing window.

3.4.4. Characteristics of Visual Technology Support Platform. In order to display SCADA data and EMS analysis results, there must be a strong technical support platform [21]. In addition to the functions of the existing energy dispatching automation system, the platform also develops an intelligent support environment based on the graphical interface and adopts the open and standardized concepts supported by the computer system. It has the following characteristics:

(1) The supporting platform emphasizes ease of use and intelligence
(2) The implementation technology adopts the object-oriented design idea
(3) The development of the supporting platform is carried out at different levels, that is, from the bottom hardware, operating systems, distributed database to the upper communication service, data service, application programming interface, and user interface, the platform is organized at multiple levels [22].

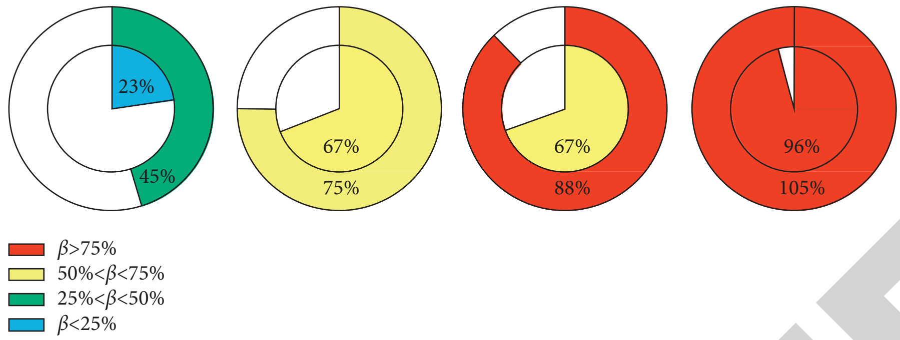

Figure 5: Visual diagram of the line load rate comparison.

3.4.5. Display Mode of the Power Grid Intelligent Energy Dispatching Visualization System

(1) Dynamic display and two-dimensional images are used to visualize the real-time information of power grid lines, node voltages, and generator active and reactive power. Dynamic three-dimensional images are used to visualize the real-time information of active and reactive power reserve.

(2) The sensitivity calculation and three-dimensional sequencing display of power grid lines to generators, loads, and node voltages to reactive power equipment are realized

(3) Visual playback, replay, and evaluation of historical data

(4) Visual monitoring of low-frequency oscillation mode dynamic threshold of key lines

(5) Visualization of power flow total sum early warning of any section and "" fault early warning evaluation of the power grid

(6) The index system of a power grid operation in real-time state and the visual expression of a power grid static vulnerability by virtual instrument

4. Result Analysis

In order to better serve the regulation and control joint duty mode under the large-scale operation system, the regulation and control center of a power supply company has set up a set of visual early warning system workstations in the energy dispatching work area and the monitoring work area [23]. As shown in Figure 5, concentric circles are used in this paper to show the comparison of line load rate before and after layout. The inner circle represents the scheme after layout, and the colored sector represents its line load rate (that is, the percentage of line load value in the rated value). The outer circle represents the scheme before layout, and the colored arc filler strip represents the line load rate. The arc-shaped filler strip extends clockwise from the top of the centerline. When the load rate is between 0 and 25%, the sector is blue, 25%–50% green, 50%–75% yellow, 75%–100% red, and more than 100% red with flashing. The larger the load rate, the larger the relative radius of the circle.

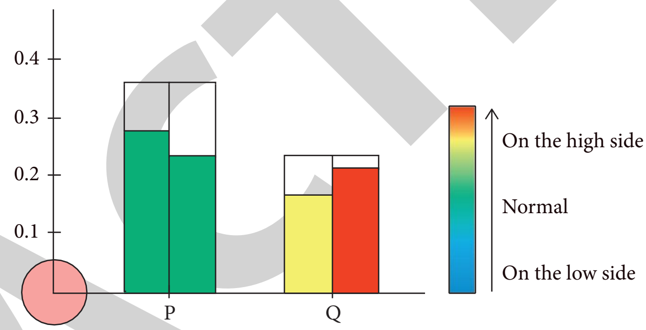

Figure 6: Visual diagram of comparison between the active power output and reactive power output.

As shown in Figure 6, the double bar graph is used in this study to represent the active output and reactive force of nodes before and after the layout. The left half of the double bar graph represents the scheme after the layout, and the right half represents the scheme before the layout. The white column is the historical maximum value and the current value of the colored column position. If the current value is within the normal range of the historical mean value, fill the green column. If the current value is greater than the historical mean value, fill the warm color system according to the degree of deviation. If it is less than the historical mean value, fill the cold color system according to the degree of deviation. The wide range of values can be set by experience.

The application of the system not only greatly improves the ability of the regulator to monitor the operation of the power grid and helps the regulator to effectively master the overall operation status of the power grid but also improves the safety production level of the power grid with significant social and economic benefits [24].

5. Conclusion

Power grid energy dispatching is the core content of power grid operation. Under the power grid development trend of building a strong smart grid, it is inevitable to research and develop intelligent energy dispatching systems, and visualization technology, as the key technology under the intelligent system, has become the research focus. This study analyzes the overall design idea, principles, and software and hardware system composition of the power grid intelligent energy dispatching visualization system and introduces the application of the power energy dispatching real-time operation visualization system.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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