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# Design of Intelligent Control Platform for Electric Power Informatization Based on Intelligent Data Analysis

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ABSTRACT

In order to improve the intelligent processing capability of the server of the electric power information platform, the intelligent control platform of electric power informatization based on intelligent data analysis is designed. Taking the regional electric power headquarters as the base point, deploying the electric power informatization intelligent management and control workbench, connecting the necessary systems for electric power operation through the telecommunication management network (TMN), and completing the platform hardware structure design. Divide the platform monitoring function into four parts: query instruction issuance, feedback data reception, data parsing, and data storage, and monitor power data in real time. Deploy data collection algorithms on the data collection server to collect power data such as power harmonics, effective voltage and current, active and reactive power, and harmonic distortion. And Deep Belief Network (DBN) is used to train the anomaly detection model, which realizes the detection of abnormal behavior of the system. Determine the experimental methods and steps, and test the results: the server of the intelligent control platform for electric power informatization designed in this project passed the pressure test of the number of clicks per second and throughput of 100 and 500 simulated users, and has superior traffic processing capability. Application test of the platform, through the test to achieve the design requirements of the system's various functional modules, in the distribution network line and equipment operation status monitoring, fault precision judgment, fault time statistical analysis and daily repair and other work has achieved certain results.

*Keywords:* intelligent data analysis, intelligent control, power data, deep belief network, anomaly detection

## 1. Introduction

With the development of intelligent substation, the unattended working mode of power system has become the main working mode of power system. Based on this, the State Grid has put forward new

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requirements for power system management, with a view to achieving the purpose of effectively integrating power system information resources, deepening the management of power equipment operation status, and improving the transmission and power supply capacity of the power system. However, at the same time as the new requirements, the State Grid has also implemented the "three sets of five" system. Although the overall quality of the power system has been improved under this requirement, the operating environment of the power equipment has gradually deteriorated, and the unattended mode is unable to meet the actual control needs of the power system. Therefore, it is imperative to design a power informationization intelligent control platform with intelligent data analysis capability.

In recent years, in order to realize the intelligent leap of the power system, the country has studied the intelligent grid scheduling technology support system, with real-time monitoring and warning, power scheduling, safety calibration and other functions, forming an integrated scheduling system [1]. However, with the development of the power system, the technical support system has been difficult to meet the power system control needs, there is an urgent need to develop an integrated information platform covering all aspects of the power system, to meet the power system flattening, integrated monitoring needs [2-3]. The power information technology intelligent control platform can be used to analyze and process data, as the management center of the platform, scheduling platform modules, analyzing and processing power data in other modules of the platform, so as to enhance the platform's ability to control and respond to the state of the electric power equipment, climatic conditions, emergencies and other electric power data that must be controlled and responded to [4-6].

The ultimate design of the power information intelligent control platform is to ensure the stability of power operation, so that the power system meets the operation and maintenance requirements of intelligent substations. Literature [7] designed a power information control platform and lightning positioning system based on edge computing and cloud platform technology, which can not only monitor the user's power equipment online, but also provide intelligent analysis support for multi-source data, with high-performance and highly intelligent power information control level. Literature [8] developed a smart grid resilient information architecture platform (RIAPS) applicable to microgrid control system, control algorithms can be implemented and deployed to distributed microgrids through this platform, and the proposed distributed microgrid secondary control algorithms are synchronized and proportionally compensated for voltage imbalance, which verifies the effectiveness of the RIAPS platform. Literature [9] integrates information technology to develop a set of integrated power network command system with refined intelligent management functions, introduces DDQN algorithm and attention mechanism to construct the system's scheduling engine and state monitoring and warning module, significantly improves the system's real-time response rate, decision-making optimization capability, and security and defense performance. Literature [10] shows that the development of large-scale distributed energy sources and energy storage devices puts forward requirements for the data processing and optimization control capability of the power system, and puts forward a power supply and use interactive service platform based on cloud architecture, which is equipped with intelligent and highly efficient data collection and processing capabilities, and fully meets the needs of power grid scheduling and operation management. Literature [11] evaluates the feasibility of online decoupled training-simulation logic for intelligent control simulation of nuclear power plants under the real-time communication framework, and utilizes the Simulink control simulation platform to predict the operating conditions of nuclear power plants within the real-time communication framework and provide feedback compensation for the control loop, based on which the intelligent PID control can obtain the optimal control parameters in real time to improve the control performance of nuclear power plants. Literature [12] uses a Yd transformer with Steinmetz Intelligent Control System (SICS) to improve the Railway Current Controller (RPFC), which realizes the optimal transfer method of active and reactive power of each traction substation through the coordination with the internal control system and improves the energy management and power quality control in the electrified railroad network. Literature [13] proposes an automated intelligent system supported by a network of wireless sensors and actuators, which is able to collect relevant information from sensors and energy markets and automatically make decisions according to the actual situation to improve the efficiency of energy utilization, with significant improvements in energy and cost savings. Literature [14] studied the power intelligent dispatch control technology based on multiple information, with the help of deep neural networks and machine learning algorithms to build the power supply business data model, to achieve the visualization of power supply information monitoring and publishing and reporting functions, to ensure the safe and stable operation of the power system. Literature [15] adopts the intelligent control platform of primary and secondary inverters based on the communication system to realize the maximum utilization of renewable energy in the microgrid, in which the control strategy in the microgrid is optimized by the particle swarm optimization algorithm to reduce the dynamic fluctuation of the loads and the distributed power supply, and the simulation experiments show that the intelligent control platform has the characteristics of fast damping, improved error detection accuracy and fast response. Literature [16] examined virtual inertia-based master-slave control in microgrid systems and proposed online trained recursive probabilistic wavelet fuzzy neural networks instead of conventional proportional-integral controllers in the microgrid host group to improve the voltage control performance of virtual inertia microgrids.

This paper details the main technologies that make up the intelligent control platform for power informatization, as well as the hardware composition and software implementation of the system. The system can be used for power data collection, which can obtain a better sampling rate and collection accuracy, including power harmonics, active power, reactive power, peak factor, and so on. It also combines deep learning methods (deep belief network) to train the anomaly detection model end-to-end to achieve the detection of abnormal system behavior. The overall architecture, software architecture, network architecture and functional architecture of the power informatization intelligent control system are designed, and the power informatization intelligent control platform operation architecture is proposed to integrate the power data information and realize the power informatization control.

## 2. Main relevant technologies

### *2.1. Data interconnection technologies*

Data interconnection is the technical basis for data interconnection and information sharing of the intelligent control platform of electric power informatization, and the research mainly includes the standardization of data exchange content, data exchange process, and the realization of interconnection and sharing of work order processes such as communication overhaul, mode, and fault, as well as the data of spare parts, communication resources, and alarm performance. Data exchange realizes various data exchange modes such as single-point to single-point, single-point to multi-point, and multi-point to multi-point through various exchange modes such as data-oriented and service-oriented, so as to realize data interconnection and information sharing between the horizontal and vertical aspects of the system. The main technologies involved in data exchange include data standardization technology, interface adaptation technology and Web Services technology. The integrated application of the following technologies to the development process of the data exchange system can realize the intensive interconnection of data.

1) Data standardization technology. It is the basis for data exchange and sharing by defining the content of data exchange, data exchange model, data format, interface and coding specification to shield the differences between systems and realize data standardization.

2) Interface Adaptation Technology. For the access of system data, data extraction and data conversion are carried out by using adapters, and the communication data in the system is converted into the standard format defined by the data exchange system through adapters to realize the access function to the system.

3) Web Services technology. The data transmission of data exchange uses Web Services technology, which is a web-based, distributed modular component that performs specific tasks and adheres to specific technical specifications that enable Web Services to interoperate with other compatible components [17]. Web Services is a distributed architecture consisting of providers and users of the service A service can have multiple users. Web Services are described using WSDL (Web Services Description Language), which describes the location of the service, the interface, the inputs and outputs of the messages, and so on. The two parties interact with each other through SOAP (Simple Object Access Protocol) based on HTTP protocol to transfer data in text format. Through Web Services technology, interoperability between software developed on different hardware and software platforms and in different development languages is realized.

### 2.2. *Power Data Acquisition*

The data acquisition system of the platform is composed of a box as shown in Figure 1, the system will be the data on the power line through the voltage transformer current transformer will be the voltage parameter on the power line, current parameter into a weak electrical signal (data acquisition of the data volume can be a lot of power lines on the other part and this part of the same). Then, after the processing of precision wave detection and time division multiplier, the processed data will be sent to the high-precision A/D converter into a digital signal quantity, which will be supplied to the digital processor to carry out all kinds of digital processing, and then the digital signal processor will categorize and save the processing results or transmit or display them, and it can be used for human-machine interaction through the human-computer interface.

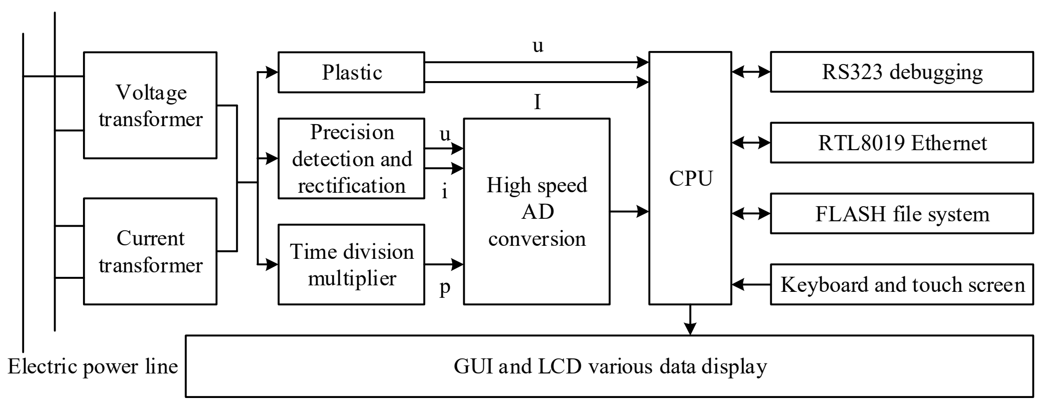


**Fig. 1.** Block diagram of the data acquisition system

2.2.1. Power harmonics. In the power system, power harmonics are generated if the quality of the generation source is not high, the transmission and distribution system, and the power-using equipment. Among them, power equipment generates the most harmonics. Power harmonics will reduce the capacity of the power grid, damage the power-using equipment, affect the accuracy of power measurements, but also affect the human brain magnetic field and cardiac magnetic field, to accurately grasp the operating status of the power system, to reduce the occurrence of the above situation, the power data acquisition, detection, and reduce the harmonic damage has a certain degree of significance of the study [18].

Fourier series is an effective method to study and analyze harmonic distortion. The Fourier decomposition enables the examination of various components of the distorted waveform.

In general, any periodic waveform can be expanded into a Fourier series, i.e:

$$f(t)=a_0+\sum_{n=1}^{\infty}\left(a_n\cos n\omega_1 t+b_n\sin n\omega_1 t\right) \tag{1}$$

where $a_0$ is the DC component with zero frequency and the value of the coefficient in Eq.

$$\begin{cases} a_0=\dfrac{1}{T}\int_{-T/2}^{T/2}f(t)dt \\ a_n=\dfrac{2}{T}\int_{-T/2}^{T/2}f(t)\cos n\omega_1 tdt \\ b_n=\dfrac{2}{T}\int_{-T/2}^{T/2}f(t)\sin n\omega_1 tdt \end{cases} \tag{2}$$

2.2.2. Harmonic distortion. The linear network in a balanced power system responds to different harmonics in opposition to each other, and this property allows us to treat each harmonic separately. That is, an equivalent circuit (in the frequency domain) is built for each harmonic to solve for current and voltage separately. The total response can be obtained by summing all the harmonic components in the time domain.

Expanding a distorted periodic current or voltage into a Fourier series can be expressed in the following equation:

$$i(t)=\sum_{h=1}^{\infty}I_h\cos(h\omega_0 t+\phi_h) \tag{3}$$

$$v(t)=\sum_{h=1}^{\infty}V_h\cos(h\omega_0 t+\theta_h) \tag{4}$$

where, $I_h$ - $h$ nd harmonic peak current.

$V_h$ - $h$ th harmonic peak voltage.

$\theta_h$ - $h$ th harmonic voltage phase.

$\phi_h$ - Phase of the $h$ th harmonic current.

$\omega_0$ -Fundamental corner frequency, $\omega_0=2\pi f_0$.

$f_0$ -Fundamental frequency, 50Hz or 60Hz.

2.2.3. Voltage and current rms values. As:

$$F_{rms}^2=\frac{1}{T}\int_0^T f^2(t)dt=\frac{1}{2}\sum_{h=1}F_h^2=\sum_{h=1}F_{h_{rmz}}^2 \tag{5}$$

Thus it can be seen that the expressions for the rms values of voltage and current are:

$$V_{rms}=\sqrt{\sum_{h=1}^{\infty}V_{h_{rms}}^2} \tag{6}$$

$$I_{rms}=\sqrt{\sum_{h=1}^{\infty}I_{h_{rms}}^2} \tag{7}$$

2.2.4. Distortion factor of voltage and current. The voltage distortion factor VDF also becomes the total harmonic distortion of voltage THDV and is defined as:

$$THD_V = \frac{1}{V_1}\sqrt{\sum_{h=2}^{\infty} V_h^2} = \sqrt{\left[\frac{V_{rms}}{V_{1_{rms}}}\right]^2 - 1} \tag{8}$$

It is worth noting here that for power systems 69 kV and below, the IEEE 519 standard, "IEEE Recommended Measures and Requirements for Harmonic Control in Power Systems," attempts to limit harmonic voltages at a single frequency to 3% of the fundamental voltage, and the total harmonic distortion of voltage to 5%.

Similarly, the current distortion factor CDF, also known as the total harmonic distortion of current THDI, is defined as:

$$THD_I = \frac{1}{I_1}\sqrt{\sum_{h=2}^{\infty} I_h^2} = \sqrt{\left[\frac{I_{rms}}{I_{1_{rmz}}}\right]^2 - 1} \tag{9}$$

where, $V_1$ - the peak value of the fundamental voltage.

$I_1$ - Peak fundamental wave current.

The RMS values of voltage and current can now be expressed in terms of THD:

$$V_{rms} = \sqrt{\sum_{h=1}^{\infty} V_{h_{rms}}^2} = V_{1_{rms}}\sqrt{1 + THD_V^2} \tag{10}$$

and:

$$I_{rms} = \sqrt{\sum_{h=1}^{\infty} I_{h_{rmz}}^2} = I_{1_{rmz}}\sqrt{1 + THD_I^2} \tag{11}$$

2.2.5. Active and reactive power. For active and reactive power there is the following equation for active power of $p(t) = v(t)i(t)$ and its average value:

$$P = \frac{1}{T}\int_0^T p(t) = \frac{1}{2}\sum_{h=1}^{\infty} V_h I_h \cos(\theta_h - \phi_h) = \sum_{h=1}^{\infty} V_{h_{rms}} I_{h_{rms}} \cos(\theta_h - \phi_h) \tag{12}$$

Reactive power is defined:

$$Q = \frac{1}{2}\sum_{h=1}^{\infty} V_h I_h \sin(\theta_h - \phi_h) = \sum_{h=1}^{\infty} V_{h_{rmz}} I_{h_{rmz}} \sin(\theta_h - \phi_h) \tag{13}$$

2.2.6. Peak factor of voltage and current. The peak current CCF and peak voltage factor VCF are defined:

$$CCF = \frac{\sum_{h=2} I_h}{I_1} \tag{14}$$

$$VCF = \frac{\sum_{h=2} V_h}{V_1} \tag{15}$$

Neglecting the phase, the total peak current or voltage can be expressed as:

$$I_{peak} = \sum_{h=1} I_h = I_1(1 + CCF) \tag{16}$$

$$V_{peak} = \sum_{h=1} V_h = V_1(1 + VCF) \tag{17}$$

The standard value increment corresponding to the total peak current or total peak voltage is:

$$\Delta I_{peak_{pw}} = \frac{\Delta I_{peak}}{I_1} = \frac{I_{peak} - I_1}{I_1} = \frac{I_{peak}}{I_1} - 1 = CCF \tag{18}$$

$$\Delta V_{peak_{pu}} = \frac{\Delta V_{peak}}{V_1} = \frac{V_{peak} - V_1}{V_1} = \frac{V_{peak}}{V_1} - 1 = VCF \tag{19}$$

Note that $I_{peak} / I_{rms} = \sqrt{2}$ holds only for purely sinusoidal waveforms, and the same is true for voltages.

2.2.7. Power factor. Power factor is the ratio of active power to apparent power. Therefore, there is:

$$pf = \frac{P}{S} = \frac{P}{S_1\sqrt{1+THD_V^2}\sqrt{1+THD_I^2}} = pf_{disp}\,pf_{dist} \tag{20}$$

$$pf_{dist} = \frac{1}{\sqrt{1+THD_V^2}\sqrt{1+THD_I^2}} = \frac{V_{1_{rms}}}{V_{rms}} \cdot \frac{I_{1_{rms}}}{I_{rms}} = \frac{S_1}{S} \tag{21}$$

where, $pf_{disp}$ - Displacement power factor.

$pf_{dist}$ - distortion power factor.

Note that do not be misled by the power factor of 1 on the nameplate, the power factor of 1 may only be obtained in the case of a purely sinusoidal waveform, and the actual displacement power factor indicated on the nameplate. When harmonics are present, the actual power factor is:

$$pf_h = \min\left[\frac{1}{\sqrt{1+THD_V^2}}, \frac{1}{\sqrt{1+THD_V^2}}\right] < pf_{disp} = \frac{P}{S_1} \tag{22}$$

### *2.3. Abnormal behavior detection*

In this paper, based on a large number of system kernel call subsequences, sensitive system kernel call instances in the system call subsequences are extracted based on the information gain theory, and the subsequences are represented based on statistical characterization. Finally, a detection model for abnormal system kernel call sequences is trained by employing a deep belief network, and anomalous behavior detection is implemented based on this model. This deep belief network consists of Restricted Boltzmann Machine (RBM) and Multi-Layer Perceptron (MLP), the original statistical representation is encoded by Restricted Boltzmann Machine to optimize the data representation, and the input data representation is processed by Multi-Layer Perceptron for the degradation and classification process, and the process of anomalous behavior detection is shown in Fig. 2 [19].

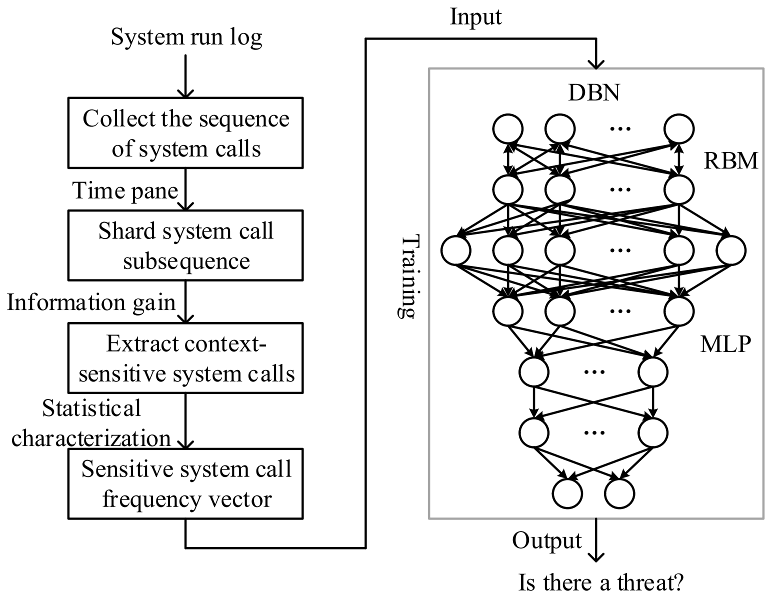


**Fig. 2.** Abnormal behavior detection method based on deep belief network

2.3.1. Behavior Extraction and Representation. For this reason, this paper considers the frequency of system calls as well as the contextual semantics, and adopts the system call binary frequency to represent the probability distribution between system behaviors and the contextual local semantics as shown in Figure 3. The reason why local semantic characterization is adopted is because when global semantic characterization is adopted for too long system kernel call sequences, it will lead to the loss of a large amount of semantic information and affect the accuracy of the model. In this paper, a two-dimensional matrix is used as the data structure of the system call binary, and each element $F_{ij}$ of the matrix represents the co-occurrence frequency of two consecutive system calls in the system call subsequence.

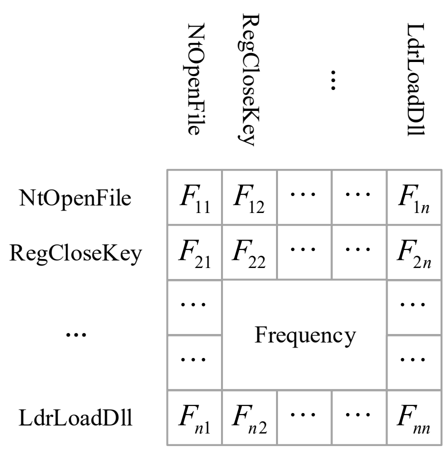


**Fig. 3.** Frequency of system call binary

Although the system calls existing in abnormal behaviors also exist in normal behaviors, the probability distribution of system calls in abnormal behaviors is different from that of system calls in normal behaviors, and for the system calls with more significant probability of appearing in abnormal behaviors, they are defined as sensitive system calls in this paper. Considering the existence of contextual semantic associations between system calls, the sensitive behavior in abnormal behavior is represented by extracting the sensitive system call binary. In order to be able to extract the sensitive system call binary, this paper calculates the degree of significance of the sensitive system call binary by comparing and analyzing the probability distribution of the sensitive system call binary in the abnormal and normal behaviors, and adopts the information gain to calculate the degree of significance of the sensitive system call binary:

$$p(x_{ij}) = \frac{F_{ij}}{\sum F_{ij}} \tag{23}$$

where $x_{ij}$ denotes the system call binary, $y$ denotes the anomaly sample, and $p(x_{ij})$ denotes the probability of the system call binary.

It is calculated by Eq. (23):

$$Gain = p(x_{ij} \mid y) \cdot \log \frac{p(x_{ij} \mid y)}{p(x_{ij}) \cdot p(y)} \tag{24}$$

where $p(y)$ denotes the probability (proportion) of an abnormal sample, and $p(x_{i_j} \mid y)$ denotes the conditional probability of the system call binary if the sample is known to be abnormal.

This information gain method is used to calculate the amount of mutual information between each system call binary and the anomalous behavior, and for each system call binary $x_{ij}$ , the mutual information between that system call binary and the anomalous behavior y is calculated. When the information gain Gain tends to 0, it indicates that the correlation between that system call binary $x_{ij}$ and the anomalous behavior $y$ is small, i.e., that system call binary $x_{ij}$ is insensitive to the anomalous behavior $y$ , and vice versa, it indicates that that system call binary $x$ is sensitive to the malware $y$ .

Since the (obfuscated) exception behavior contains not only sensitive system call contexts but also a large number of non-sensitive system call contexts. In order to reduce the impact of non-sensitive system call contexts on anomalous behavior detection, this paper filters the sensitive behaviors in the system call subsequence based on the extracted sensitive system call contexts, and at the same time eliminates the non-sensitive behaviors in the system call sequence.

2.3.2. Model Training and Testing. In this paper, we will introduce the training and detection of abnormal behavior detection model for power information technology intelligent control system, using the statistical characterization of sensitive system call subsequence in abnormal and normal behavior, and end-to-end training of anomaly detection model based on the deep learning method (Deep Belief Network) to realize the detection of abnormal system behavior.

1) Deep belief network architecture. A deep belief network (DBN) is used to train an anomaly detection model by inputting the statistical characterization of sensitive system call subsequences, and the detection of abnormal system behavior is realized based on this model. This deep belief network consists of Restricted Boltzmann Machine (RBM) and Multilayer Perceptron (MLP). The original statistical representations are encoded by Restricted Boltzmann Machine to optimize the vector representations, which are inputted into the next layer of the network (the MLP input layer), and the input data representations are downscaled and classified by the Multilayer Perceptron.

2) Training process. In this paper, the restricted Boltzmann machine is trained based on the comparative hashing method, and the neurons in the observation layer and the hidden layer are trained by $n$ -time Gibbs sampling, and each neuron in the observation layer and the hidden layer is randomly activated according to a certain activation rate, and the activation function adopts the Sigmoid function, and the neurons of two neighboring layers transfer the information and share the connection weights in both directions. In this paper, the following formula is used as the energy function of the restricted Boltzmann machine:

$$E(v,h) = -\sum v \cdot b - \sum h \cdot c - \sum v \cdot h \cdot w \tag{25}$$

where $v$ denotes the input value, $h$ denotes the computed value of the neuron in the hidden layer, $w$ denotes the shared connection weights, and $b$ denotes the bias of the neuron.

The joint probability distribution function of the observation and hidden layers, is:

$$P(v,h) = \frac{e^{-E(v,h)}}{\sum_{v,h} e^{-E(v,h)}} \tag{26}$$

The conditional distribution function is calculated as:

$$\begin{aligned} P(h_j = 1 \mid v) &= \frac{P(v, h=1)}{P(v)} \\ &= \frac{P(h_j = 1 \mid v)}{P(h_j = 1 \mid v) + P(h_j = 1 \mid v)} \\ &= \frac{e^{b+w\cdot x}}{e^0 + e^{b+w\cdot x}} \\ &= \frac{1}{1 + e^{b+w\cdot x}} \\ &= sigmoid(b + w \cdot x) \end{aligned} \tag{27}$$

Weighting correction method for:

$$\Delta w = w + \alpha \cdot (E(v,h)_{data} - E(v,h)_{recon}) \tag{28}$$

After the convergence of the restricted Boltzmann machine by correcting the weights, its energy function tends to “0” (very small value). At this time, the vectors of the hidden layer are considered to be derived from the vectors of the observation layer through spatial transformation, i.e., the vectors of the hidden layer are the self-encoding of the vectors of the observation layer, which can be input into the neural network for training instead of the original vectors of the observation layer. Moreover, after $n$ Gibbs sampling, the features in the hidden layer vectors are equivalent to the projection of the features in the observation layer vectors into the $N$ -dimensional orthogonal basis space, which improves the convergence efficiency of the neural network.

3) Decision-making process. When the probability of abnormality is large enough and greater than the normal probability, then it is decided that the system behavior corresponding to this subsequence of system calls is abnormal. On the contrary, it is determined that the behavior corresponding to this system call subsequence is normal. If the normal probability is greater than 0.8 or the abnormal probability is greater than 0.8, then the determination that the system behavior is normal or abnormal is plausible.

## 3. Electric power informatization intelligent control system design

### *3.1. System design objectives*

This topic will combine with the actual work, take the electric power first-level backbone transmission network as the typical research object, investigate its network status and network management status in detail, and sort out and analyze the characteristics of the network and network management. Utilizing modern communication technology and telecommunication management network (TMN) idea, the intelligent control system of electric power communication network is built with the intelligent control system at the headquarters level as the core, connected with the intelligent control system at the provincial and local levels, covering the electric power first-level backbone in the communication network, and the system design objectives are as follows [20]:

1) Realize the intelligent and effective management of the network resources of the primary backbone transmission network of electric power. Intelligent and effective management is the foundation of the intelligent control system of electric power informatization, and the system carries out unified management of the network resources of the primary backbone transmission network of electric power, including sites, equipments, line infrastructures, fiber optic cables, transmission systems, circuits, etc., according to the classification method adapted to the requirements of electric power production. It also realizes the comprehensive analysis of the resources of the whole network in order to optimize the network operation efficiency and reduce the time interval of circuit opening, so as to realize the effective management of the network resources of the primary backbone transmission network of electric power.

2) Realization of full monitoring of electric power communication network. Establishing the first-level backbone transmission network network monitoring and management center with State Grid ICT as the core to complete the functional main body of the intelligent whole process control system of electric power communication network. The functional division of the power informatization intelligent control system, and the physical module settings, refer to ITU-T's M.3000 series recommendations. The system will utilize the interface adaptation software to incorporate the relevant professional network management of power communication networks at all levels and the monitoring system into a unified monitoring platform, and centrally monitor in real time the operation status of various types of communication equipments and communication services, the alarm situation and the performance index parameters of the equipments. And according to the collected information to analyze the cause of the fault, determine the location and nature of the fault, to determine the severity of the impact of the fault on the network at the same time. The system has sound and light alarm prompting function to discover network faults and handle them, remove serious faults in time to ensure smooth network and normal operation of communication services, and realize the full monitoring and management of the backbone transmission network of the State Grid.

3) Realization of process management of power communication operation and maintenance work. It realizes the process-oriented management of electric power communication operation and maintenance work such as fault handling, circuit scheduling, and planned maintenance, so that all kinds of operation and maintenance work orders flow in an orderly and closed-loop environment, displaying the flow of work orders among various departments, and making every link through which the operation and maintenance work orders flow traceable. At the same time, on the basis of solidifying and completing a series of operation and maintenance processes, it provides a platform that supports flexible process customization to improve the efficiency of operation and maintenance staff.

### *3.2. Intelligent control system design*

3.2.1. Architecture. The power communication network control system is based on the telecommunication management network (TMN) as the basic system. And TMN is one of the support systems for the operation of modern telecommunication network, which is a general term for the software, hardware system and organization system established to keep the telecommunication network in normal operation and service, and manage it effectively.The basic concept of TMN is to provide an organized network structure to obtain the interconnection between various types of operating systems as well as the interconnection between the operating systems and telecommunication equipments. It is a complete and independent management network, which is a network of various management systems for different applications interconnected in accordance with the standard interfaces of TMN. TMN mainly includes network management system, maintenance and monitoring system and so on.

In principle, the design of power informationization intelligent management and control system should be designed by using TMN functional architecture, and the internationally popular four-layer model is adopted in the logical layering, and the relationship between each functional layer and the functional modules of network management is shown in Fig. 4, and the following is a brief introduction to the logical layering and management functions of TMN functional system.

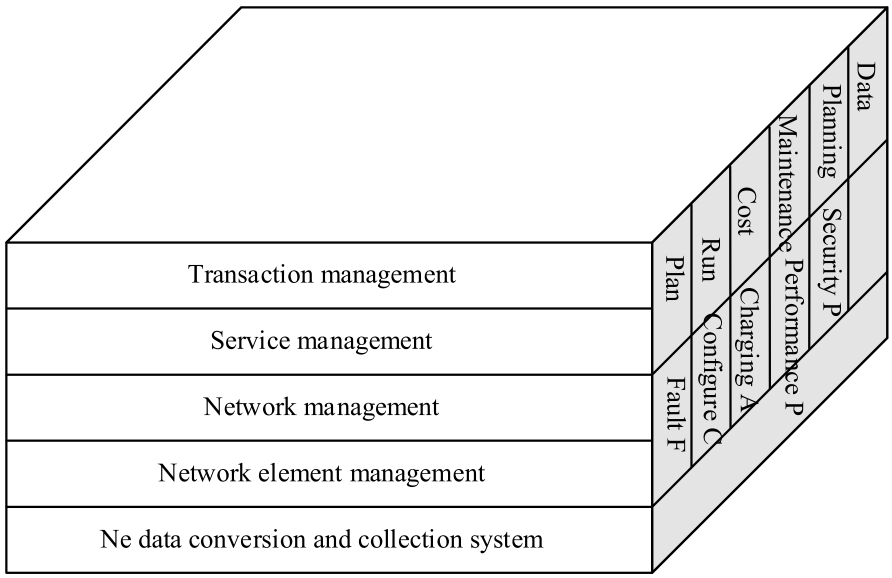


**Fig. 4.** Relationship between esight functions and modules

When using the TMN architecture to provide management capabilities for telecommunication business activities, it is important to base them on different management priorities and requirements. The management environment is divided into multiple levels according to specialized characteristics, with each level having different management objectives and technical requirements.The logical layered architecture of TMN is divided into network element management layer, network management layer, service management layer, and business management layer.

1) Network element management layer (EML). Manages each network element on an individual or grouped basis and supports abstraction of the functions provided by the network element. Network elements include many types of telecommunications equipment, as well as associated support equipment and systems.

2) Network Management Level (NML). Responsible for the management of the network under the auspices of the Network Element Management Level (EML), it is also responsible for presenting a relatively independent technical view of network resources and functions in order to serve the management level. The main functions of the network management layer include controlling and coordinating the network descriptions of all network elements within its scope or domain, provisioning, terminating, or modifying network capabilities to support customer service, and network maintenance capabilities.

3) Service Management Level (SML). Also known as the Service Management Level (SML), deals with and is responsible for the contractual aspects of the services, which are being provided to customers or are suitable to be provided to potential new customers.

4) Service Management Level (BML). Related to all decisions of the top management, this layer is concerned with the proprietary rights of the entire network and its management system.

The structural design of the power informatization intelligent control system is shown in Figure 5, which demonstrates the subsystems and brief data and application association relationships in the power informatization intelligent control platform. It can be seen that the system is mainly divided into three levels:

1) The bottom layer is the professional network management (NMS, EMS) and network element equipment layer, which can be composed of professional network management systems, or directly network element management systems, and manageable network element equipment.

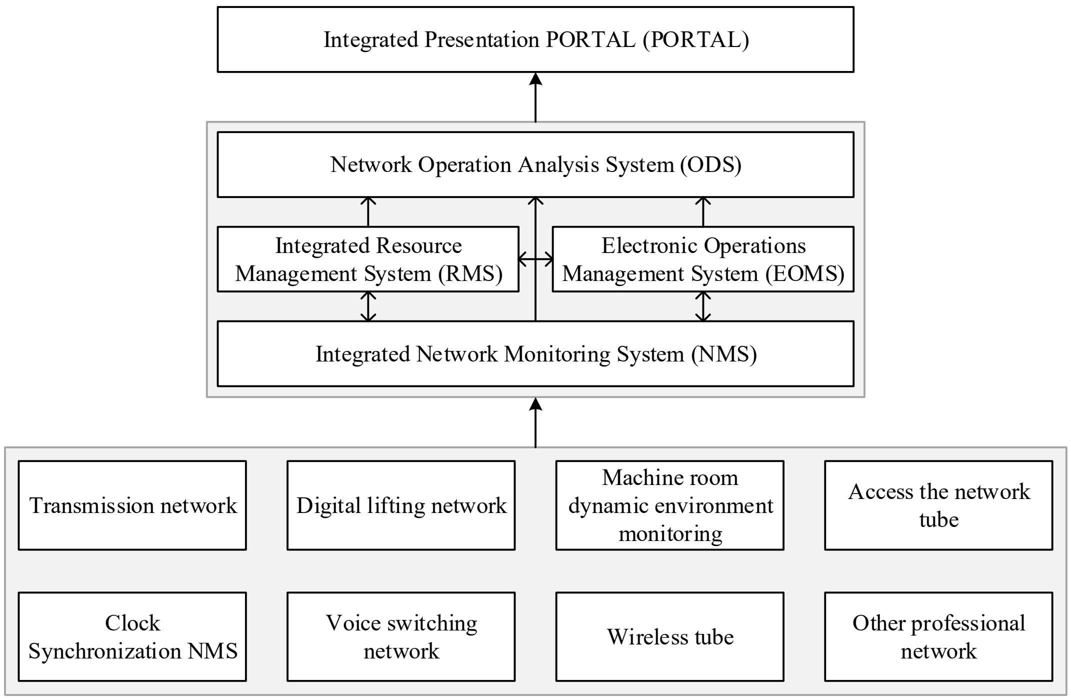


**Fig. 5.** Structure design of electric power information intelligent control system

2) The middle layer is the core part of the system blueprint, which can be summarized into four systems, including the integrated network monitoring system (NMS), the integrated resource management system (RMS), the electronic operation and maintenance management system (EMOS), and the network operation and analysis system (ODS), and the systems interact with each other through the interfaces, including the unidirectional data interfaces as well as the bi-directional data interfaces.

3) The top layer is the summary presentation layer of the system, or the comprehensive presentation portal, which at present mainly includes the functions of personal portal, single sign-on and comprehensive display.

3.2.2. Functional architecture. The whole management and control system of intelligent communication network is constructed with the idea of hierarchy and modularization, and each subsystem is relatively independent, but it must ensure the seamless integration among each other. The application software of the control system includes four parts, i.e., data integrated network management and its comprehensive monitoring system, electronic operation and maintenance system, network operation analysis system and comprehensive presentation platform.

The main functions of the data comprehensive network management and its comprehensive monitoring system are:

1) Unified Collection and Adaptation. Through rich interface access adaptation means, unified collection and preliminary summarization of manufacturers' network management or network element equipment data information in the underlying layer of each professional network are used as the basis for realizing alarm management, performance management and configuration management.

2) Comprehensive data network management. Alarm management, topology management, traffic monitoring, configuration information management, operation and maintenance tools, statistical report management and so on.

3) Comprehensive monitoring management. Centralized alarm management, configuration management, performance management, equipment monitoring, business topology monitoring, server room power environment monitoring, correlation rule management, real-time monitoring of network management collection status, etc.

The main functions of the power operation and maintenance system are:

1) Core business functions. Mainly fault management, annual and monthly operation mode management, daily operation mode management, maintenance management, duty management, network management operation ticket, process monitoring.

2) Auxiliary management functions. It mainly contains information bulletin, data management, mobile operation management, organization management and so on.

The main functions of the network operation analysis system are:

1) Data integration and mining. Integration of peripheral system interfaces, relevant data extraction, multi-dimensional data summarization and unified view of data.

2) Data quality and data sharing. Data consistency management, data accuracy management, multi-type and multi-dimensional data sharing.

3) Analysis application. Basic functions, communication scale statistical analysis, communication network operation quality analysis, communication network capacity analysis, resource early warning analysis, communication network risk analysis, production assessment analysis.

4) Comprehensive report. Multi-perspective query statistics, operation and maintenance support report customization and automatic report generation.

The functions of the comprehensive presentation platform are:

1) Unified Portal. Unified authentication, single sign-on.

2) Unified display. Network profile display, network operation display, production control process display and performance appraisal display, etc.

### *3.3. Intelligent Data Analysis*

Data analysis is considered to be information processing data, which involves the “data flow” and “power flow” covers the whole process, power in the process of generating to use, the entire workflow involved in the whole industry chain of the power grid company. From the point of view of the data research layer, it is the entire process of data collection, IBM in the analysis of the information platform layer and division as shown in Figure 6, the intelligent data analysis is divided into several levels, and found that the most significant features:

1) A high degree of digitization, the smart grid contains a smart grid digital application system, smart grid digital management system, smart grid power transmission system.
2) On the basically consistent information platform, it can independently do the data and use fusion, provide excellent and advanced scientific and technological methods, and safeguard the information collection and transmission of the power grid company.
3) To create an integrated and advanced research platform, to enhance the intelligent data processing capability that assists in supporting the decision, to reduce the cost of electricity production, to ensure the safety of the production and use of electric power resources, to improve the efficiency of the power supply of the power company, and to gain more space for development.

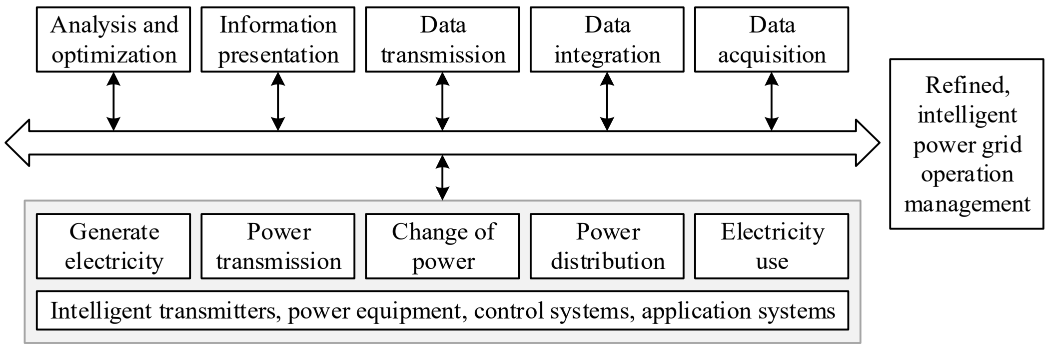


**Fig. 6.** IBM's understanding of smart grids

In the process of smart grid construction, complete information needs to be collected, which requires further expanding the scope of data collection in the process of production, transportation and use of electric power resources, and applying more powerful data collection technology to ensure the correctness of data collection. As a characteristic of China's smart grid, more attention is paid to reliability and extra-high voltage transmission safety, which requires the deployment of sensors to monitor line conditions, such as transmission line arc sag, sway amplitude, and ice dressing thickness. The collection of information also needs to be extended to the user side, including information on the user's home electricity consumption, distributed grids, and two-way interaction of information.

After the information is collected, the data needs to be processed intelligently, the content contained therein needs to be mined, and transmitted to the smart grid control room. The current grid system generally contains different departments of the power company, including the power production department, the power transportation department and the power control department, etc., each of which has its own smart grid management system, such as an ERP system. The establishment of the smart grid is essential to break through the information barriers between the various parts and build a collection that can be shared. The information is then provided according to different needs and requirements, thus integrating all aspects of production, consumption and markets. After completing the data integration, it is also necessary to process the data and determine the methods of power production and transportation based on the results of the processing. The main function of the smart grid business layer is to collect all kinds of data generated in the process of power production and transportation, analyze the current power market demand conditions, determine the price of power sales according to the demand conditions, so as to achieve the control of the entire power grid power supply load. The whole process is a closed-loop process of information flow, so the information flow must be closed, circular, two-way.

## 4. Platform validation and its application

The power informatization intelligent control platform operation architecture designed this time is configured in the power informatization control platform hardware (TMN) structure, and at the same time, the power data monitoring, data collection, data processing and other parts of the above study are deployed on the equipment monitoring server, data collection server and application server, which are combined with the intelligent data analysis platform to realize the power informatization intelligent control.

### *4.1. Platform testing and validation*

The test platform performance, will be used in the form of stress test, testing the platform in the process of intelligent control of electric power information technology, multi-user simultaneous use of the platform, the number of clicks on the platform server and throughput, to verify the platform server's ability to deal with the flow of traffic.

4.1.1. Detection methods. This platform testing uses LoadRunner software to write platform testing scripts to simulate the platform multi-user use scenario, i.e., under the condition of using the same function of the platform, the number of users is continuously increased to test the system response when the platform applies the number of users in parallel. This experiment will take the login function of the platform as the target of platform pressure detection, simulating 100 and 500 virtual users to apply the platform in parallel respectively. And in this process, each module of the system is run normally, and the platform response performance is verified by simulating the access pressure of different levels of users on the platform.

4.1.2. Detection steps:

1) Run the power informatization control platform of this design on the computer, and at the same time run LoadRunner software on the computer to simulate the user environment.

2) Utilize the VuGen function of LoadRunner software to edit the platform testing script and testing index requirements.

3) Use the Controller function of LoadRunner software to simulate the platform login environment.

4) Use the Analysis function of LoadRunner software to analyze platform testing data and output platform testing data charts.

4.1.3. Analysis of test results:

1) Platform clicks per second detection results. The number of clicks per second can reflect the processing capacity of the platform's server for business and determine the load generated by users in the process of using the platform. Therefore, the larger the number of clicks per second of the platform, the slower the response speed of its server, which can visualize the upper and lower limits of platform operation.

Under the two conditions of the upper limit of the number of users simulated by LoadRunner software, let them perform the operations such as platform login, adding power equipment problem checking and job data, and their test results are shown in Fig. 7. Summing up the number of clicks per second under the used scenario time, the total number of clicks obtained by 100 simulated users is 8625, and the total number of clicks obtained by 500 simulated users is 3618, and its average number of clicks per second $\overline{D}$ is reflected in the integral average of the area of the curve region in the figure, which is calculated by the formula $\overline{D}=\left(\frac{D_{total}}{u}\right)/t$. Where $D_{total}$ denotes the total number of clicks, $u$ denotes the number of users, and $t$ denotes the platform operation time.

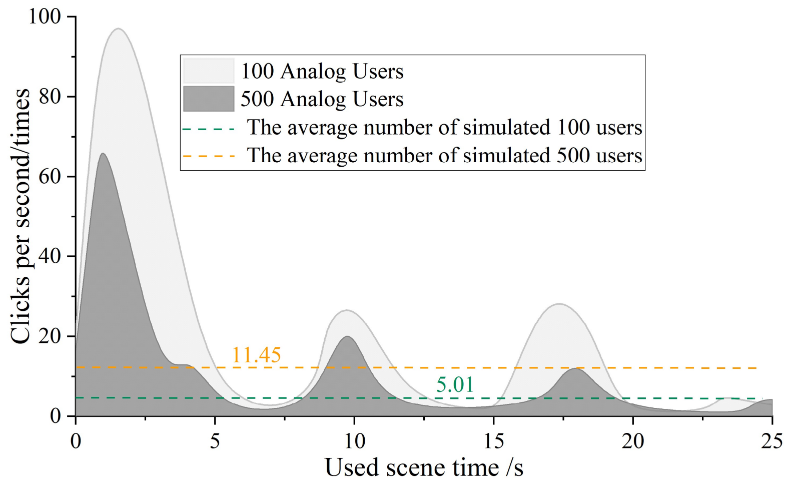


**Fig. 7.** Detection result of clicks per second on the platform

According to the above formula, the average number of user clicks per second obtained by 100 simulated users is 5.01, and the average number of user clicks per second obtained by 500 simulated users is 11.45, which is 6.44 clicks more than the average number of user clicks per second obtained by 100 simulated users. It can be seen that the greater the number of users, the greater the pressure on the platform server, and the server response speed is decreasing.

2) Platform throughput detection results. The throughput is mainly used to observe the platform load and detect the ability of the platform server to handle the traffic as the access pressure increases, as well as the maximum value of the access pressure that the platform operation server can withstand, which is calculated by the formula $T = \frac{u * Q}{t}$. In the formula, $T$ denotes the throughput, and $Q$ denotes the number of bytes generated per second when the user operates the platform.

Under the simulated upper limit of users set in this experiment, all simulated users access the platform at the same time, perform operations such as adding power equipment problem checking and operation data, and get the throughput detection results of the power informationization intelligent control platform as shown in Figure 8. Using the above formula, under the condition of 100 simulated users, the total throughput of the platform to perform user operations is 54852.4 bytes/second, and under the condition of 500 simulated users, the total throughput of the platform to perform user operations is 113,020.9 bytes/second, compared with the throughput generated by 100 simulated users to operate the platform has increased by 58,168.5 bytes/second, which is twice as much as that of 100 simulated users. It can be seen that the greater the number of users, the greater the load generated by the platform server during operation.

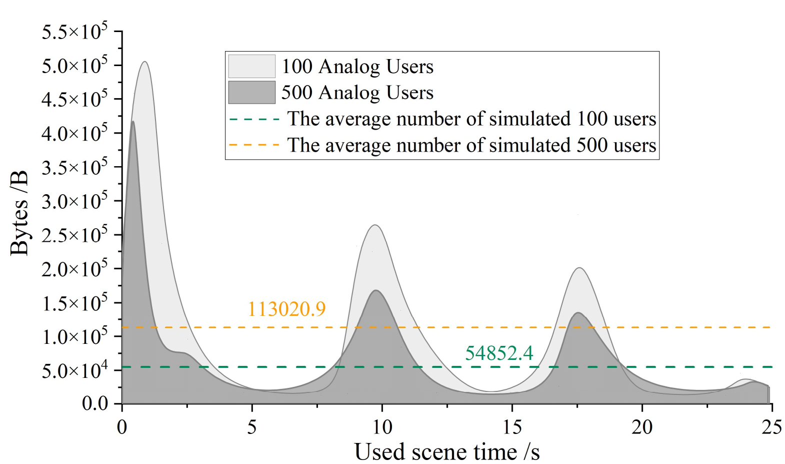

**Fig. 8.** Platform throughput test results

## *4.2. Intelligent control platform application practice*

4.2.1. Application in statistical analysis of electricity data. The intelligent control system of electric power informatization has the function of real-time monitoring the second remote of the device and the attribute data of the device itself, and realizes the function of collecting and statistically analyzing the electric power data of the line where the device is located, which is good for discovering the problems of the device and preventing the potential problems.

Table 1 collects some real-time power data of 5 devices, including effective current, effective voltage, power harmonics, distortion factor, active and reactive power and other parameters, reflecting the basic data of the line where the device is located and the signal reception of the device. It can be seen that most of the devices operate well, and all power data such as current, voltage and power are relatively stable, while there is no three-phase unbalance. However, the devices numbered 1 and numbered 4 have lower signal quality compared to the other devices, which requires the operation and maintenance personnel to check the devices in time, locate whether there are problems with the communication module and take measures to deal with them. In addition, when the device is in an abnormal situation, mostly when the device switch is disconnected, there will be a situation where the device number is 5 and each power data is 0.

**Table 1.** Real-time device data

| ID | Update time | Power harmonics (Hz) | | | Current (A) | Voltage (kV) | Power (kV) | |
|---|---|---|---|---|---|---|---|---|
| | | A phase | B phase | C phase | | | Work | Un work |
| 1 | 2023-07-18 12:06:52 | 2.12 | 1.67 | 1.34 | 5.612 | 27.57 | 33 | 18 |
| 2 | 2023-07-18 12:07:26 | 3.72 | 2.61 | 2.12 | 5.506 | 27.73 | 32 | 20 |
| 3 | 2023-07-18 12:07:49 | 43.66 | 41.45 | 42.99 | 5.244 | 27.57 | 34 | 21 |
| 4 | 2023-07-18 12:08:22 | 7.45 | 7.83 | 6.34 | 6.131 | 27.73 | 32 | 18 |
| 5 | 2023-07-18 12:09:43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

The state scoring of the device is performed according to the abnormal behavior detection method proposed in subsection 2.3, and the operating device is classified into three categories, which are normal, abnormal, and alarm states.

1) Normal state 85-100 points, the device operates stably and all state quantities meet the criteria.

2) Abnormal state 60-84 points, a state quantity of the device is close to the standard limit or exceeds the value, or several auxiliary state quantities do not meet the standard, but does not affect the operation of the device, can be viewed and processed during the regular inspection.

3) Alarm status <60 points, several main state quantities of the device exceed the standard stack limit, or one main state quantity exceeds the standard limit and several auxiliary state quantities are obviously abnormal, which has affected the performance index of the device or may develop into a major abnormality, and it is necessary to go to the site regularly for maintenance. Serious equipment can only be operated for a short period of time or be immediately taken out of service, and immediate on-site repair and replacement needs to be arranged.

The device status assessment information is shown in Table 2, Table 3 and Table 4, which list the device information under three states of normal, abnormal and alarm respectively, where the switching status includes three cases of overcurrent fault, short circuit fault and ground fault in device monitoring. It can be seen that when the communication status, transformer measurement, switch state three indicators are normal, other indicators fluctuation range is not large, the device is basically in normal operation. When there are abnormalities in the indicators of communication status, transformer measurement and switch status, combined with the fluctuations of other indicators, an abnormal state or an alarm state may occur. When the communication status is abnormal, the probability of an alarm state is higher, which has a certain relationship with the specific assignment authority size of each indicator. In addition, for different types of devices, the status scoring process may also be different, so it is necessary to make reasonable adaptations and formulate appropriate rules.

**Table 2.** Device Status Information (Normal)

| ID | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Update time | 2023-07-18 12:18:13 | 2023-07-18 12:18:34 | 2023-07-18 12:18:41 | 2023-07-18 12:18:49 | 2023-07-18 12:18:56 |
| Communication state | Normal | Normal | Normal | Normal | Normal |
| Mutual inductor | Normal | Normal | Normal | Normal | Normal |
| Switching state | Normal | Normal | Normal | Normal | Normal |
| Maintenance number | 0 | 0 | 0 | 0 | 0 |
| Equipment temperature (℃) | 39.25 | 40.37 | 42.02 | 33.15 | 37.28 |
| Voltage (V) | 28.42 | 28.27 | 28.36 | 27.92 | 27.95 |
| Status score | 95 | 98 | 98 | 92 | 95 |

**Table 3.** Device Status Information (Abnormal)

| ID | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Update time | 2023-07-18 13:12:08 | 2023-07-18 13:13:47 | 2023-07-18 13:14:28 | 2023-07-18 13:20:43 | 2023-07-18 13:16:51 |
| Communication state | Normal | Normal | Normal | Normal | Abnormal |
| Mutual inductor | Abnormal | Normal | Normal | Abnormal | Normal |
| Switching state | Normal | Normal | Abnormal | Normal | Normal |
| Maintenance number | 0 | 0 | 0 | 0 | 0 |
| Equipment temperature (℃) | -- | -- | 8.37 | 20.43 | -- |
| Voltage (V) | -- | -- | 20.05 | 18.89 | -- |
| Status score | 63 | 85 | 68 | 62 | 67 |

**Table 4.** Device Status Information (Alarms)

| ID | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Update time | 2023-07-18 15:32:37 | 2023-07-18 15:32:22 | 2023-07-18 15:32:41 | 2023-07-18 15:32:45 | 2023-07-18 15:32:50 |
| Communication state | Abnormal | Abnormal | Abnormal | Abnormal | Abnormal |
| Mutual inductor | Normal | Normal | Normal | Normal | Normal |
| Switching state | Normal | Normal | Normal | Normal | Normal |
| Maintenance number | 0 | 0 | 0 | 0 | 0 |
| Equipment temperature (°C) | -- | -- | -- | -- | -- |
| Voltage (V) | -- | -- | -- | -- | -- |
| Status score | 45 | 45 | 45 | 45 | 50 |

4.2.2. Application in power distribution emergency repairs. The intelligent control system of electric power informatization has carried out statistics on the daily repair and fault data of distribution network and low-voltage power consumption, which are divided according to the groups, and statistics on various situations of repair, including the number of distribution repair, breakdown of distribution repair faults, fault analysis report, breakdown of high-voltage and low-voltage repair faults, and statistics on the repair market. Table 5, Table 6 and Table 7 show the statistics of distribution repair team and high and low voltage fault repair data report respectively. From the July 2023 distribution repair team data statistics, according to the regional division into four teams, according to the monthly statistics of each group of fault repair number, the number of times the distribution of percentage and the average length of repair. It can be clearly seen that the power distribution emergency repair class 1 handles the largest number of faults (1,351 times), and the average length is shorter (54.07Min), with a high repair effect. The fourth class of distribution emergency repair has the shortest average duration of fault handling (48.49Min), the highest efficiency, but the least number of repairs (634 times), which can be considered to give more regional division, so as to improve the overall efficiency of distribution emergency repair.

**Table 5.** Distribution emergency repair team statistics

| Processing department | Frequency | % | Average duration (Min) |
|---|---|---|---|
| Power distribution repair team one | 1351 | 34.98 | 54.07 |
| Power distribution repair shift two | 895 | 23.17 | 67.18 |
| Power distribution repair shift three | 982 | 25.43 | 58.78 |
| Power distribution repair team four | 634 | 16.42 | 48.49 |

**Table 6.** High voltage fault emergency repair report

| Date | Public wire | Post switch | Customer head | Shunt | High pressure line break | Specific contribution | Ring cabinet |
|---|---|---|---|---|---|---|---|
| 1 | 1 | | | | | | |
| 2 | | 8 | | | 1 | 1 | |
| 3 | | 3 | | | | | |
| 4 | 2 | | | 12 | | | |
| 5 | 7 | | | | 3 | | |
| ... | ... | ... | ... | ... | ... | ... | ... |
| 31 | | | | | | | 1 |
| Total | 45 | 92 | 8 | 31 | 14 | 4 | 5 |

**Table 7.** Low voltage fault emergency repair report

| Date | Card failure | Unpaid power outage | Circuit breaker fault | Specific contribution | Low voltage line break | Bottom line break | Cable body |
|---|---|---|---|---|---|---|---|
| 1 | 13 | 3 | 31 | | 2 | 3 | 3 |
| 2 | 7 | 4 | 24 | | 3 | | 1 |
| 3 | 15 | 2 | 18 | 1 | 1 | 8 | 3 |
| 4 | 6 | | 26 | | 1 | | 4 |
| 5 | 18 | 9 | 14 | | 1 | | |
| ... | ... | ... | ... | ... | ... | ... | ... |
| 31 | 6 | 12 | 34 | | 1 | | |
| Total | 321 | 285 | 803 | 2 | 34 | 21 | 48 |

Distribution repair fault details in July, in order to days as a unit, respectively, listed all the repair fault statistics of high and low voltage. Through the table, you can see the overall distribution of high and low voltage faults occurring in a certain area at a fixed time, which is very important for the statistical content of the fault. At the same time, the distribution of robbing fault type by month for statistics, can be found in the annual or intermittent occurrence of fault occurrence pattern, the line fault cause analysis and prevention of fault occurrence has a certain value. In summary, the platform from real-time data monitoring, fault management, repair management and other aspects of the actual power business to give strong support.

## 5. Conclusion

This study of the electric power information control platform makes full use of intelligent data analysis technology as the management center of the platform, scheduling the various modules of the platform and analyzing and processing the electric power data in other modules of the platform. In this way, it enhances the platform's ability to control and respond to electric power equipment status, emergencies and other electric power must data. Stress tests are used to verify the ability of the server of the control platform designed this time to handle traffic during operation. In the future research, it is also necessary to further study the platform's function of power equipment state evaluation and data visualization, improve the platform's ability to judge the state of power equipment, as well as the monitoring function of power data, and further enhance the platform's ability to respond to emergencies and the management level of equipment state.

In the future, the development of informationization construction of smart grid will face more opportunities and challenges, and the informationization management mode of smart grid will definitely change. However, it should always be based on the needs of the company's development, actively guide the company to form an information technology-oriented development model, and fully implement the information technology process to promote the intelligent transformation of power grid companies.

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