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Research on Fault Prediction and Health Management System of Power Electronic Devices Based on Computer Deep Learning Algorithm

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Abstract: - This paper proposes a power equipment maintenance management system based on network and deep learning algorithm. First of all, the actual power network equipment maintenance and maintenance management of the power company, so as to clarify the tasks to be completed by the system. ASPNET technology is used to realize the management of business form data and various transaction processes of each system, and the related technology of process engine is applied to the maintenance of each equipment. A load forecasting method of power system based on SVR is proposed. It makes the operation and maintenance work of this system more intelligent. Each function module of the whole system is designed in detail. The system basically meets the needs of power equipment maintenance and repair management.

Keywords: Operation and Maintenance; Electric Power Installation; ASPNET; Failure Prediction; Workflow; Deep Learning

I. Introduction

Alongside the swift advancement of China's economic and societal landscape, the quality of life for its populace has experienced notable enhancement. Concomitantly, the burgeoning power sector has escalated the requirement for maintenance and upkeep, thereby unveiling substantial developmental opportunities within the power equipment maintenance industry. Nonetheless, the accelerated urbanization trajectory in China has divulged a spectrum of issues within the blueprint of certain power systems. Coupled with the evolution of power systems and the inauguration of novel grid blueprints, these factors have engendered augmented complexities and challenges within the realm of power system operation and maintenance. Presently, the swift evolution of information technology is heralding a novel paradigm in the maintenance of power systems [1]. The integration of computer technology within the power system operation and maintenance sphere promises to significantly augment the efficacy and economize the human capital invested in maintenance and upkeep activities. Maintenance and repair of grid infrastructure constitute a pivotal facet of power enterprises, with its operational proficiency and expenditure having a direct and consequential impact upon the overall power supply operations of the grid enterprise collective.

In the 1970s, Western advanced countries represented by Europe and the United States have applied it to the condition monitoring of power systems [2]. Through fault analysis of power system, a fault diagnosis method of power system based on information entropy is presented. Since then, this method has been widely adopted and referred to in the world, and has promoted the research and practice of equipment maintenance and repair. At present, advanced countries such as Europe and America have carried out beneficial exploration and practice on the operation maintenance and repair of power system [3]. The first takes it as an important part of the maintenance work to optimize and simplify the maintenance work. Research in the United States shows that the existing power system maintenance mode in China has poor initiative, incomplete fault maintenance, no standardization of maintenance experience, too many conservative maintenance projects for preventive maintenance, unclear maintenance goals, insufficient sharing of similar maintenance experience, and too much reliance on manufacturers for maintenance processes [4]. To this end, the existing power network maintenance management system in the United States is to solve the above defects and make some improvements and optimization. In recent years, Germany has been conducting maintenance and maintenance at the source of the power system, and has conducted research on different types of power systems from the aspects of full maintenance, cost-oriented maintenance management, reliability-oriented maintenance, and online maintenance of power transmission equipment for the power system.

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At present, the equipment maintenance and repair management system of China's electric power enterprises takes the network as the platform to realize the sharing of data information about the operation and maintenance of various network facilities. With the rapid development of big data technology, some companies have forecast and analyzed the load in their operations to maximize the prevention of equipment failure in the power system [5]. In order to further improve the efficiency of power system operation and maintenance, it is necessary to establish a unified and standard system, and use network technology to share the experience of system operation and maintenance, so as to reduce the difficulty of operation and maintenance. In this paper, a set of power network equipment maintenance and repair management information system with high information and intelligent level is researched and developed [6]. This software can well solve some problems existing in the operation of most power grid companies. The efficiency of operation and maintenance are realized. The key functional modules of the platform are designed and implemented by using ASPNET and workflow.

II. Design of power equipment operation and maintenance and health management system

A. *Software Architecture*

ASPNET technology is combined with workflow to present the power maintenance management system in the form of network. Figure 1 shows the software architecture of the system (image cited in Defect knowledge graph construction and application in multi-cloud IoT). Through the comprehensive analysis of the architecture, the architecture can be divided into business display layer, business logic layer and data access layer [7]. The hierarchical method can effectively reduce the coupling between each functional module and enhance the robustness and scalability of the whole system.

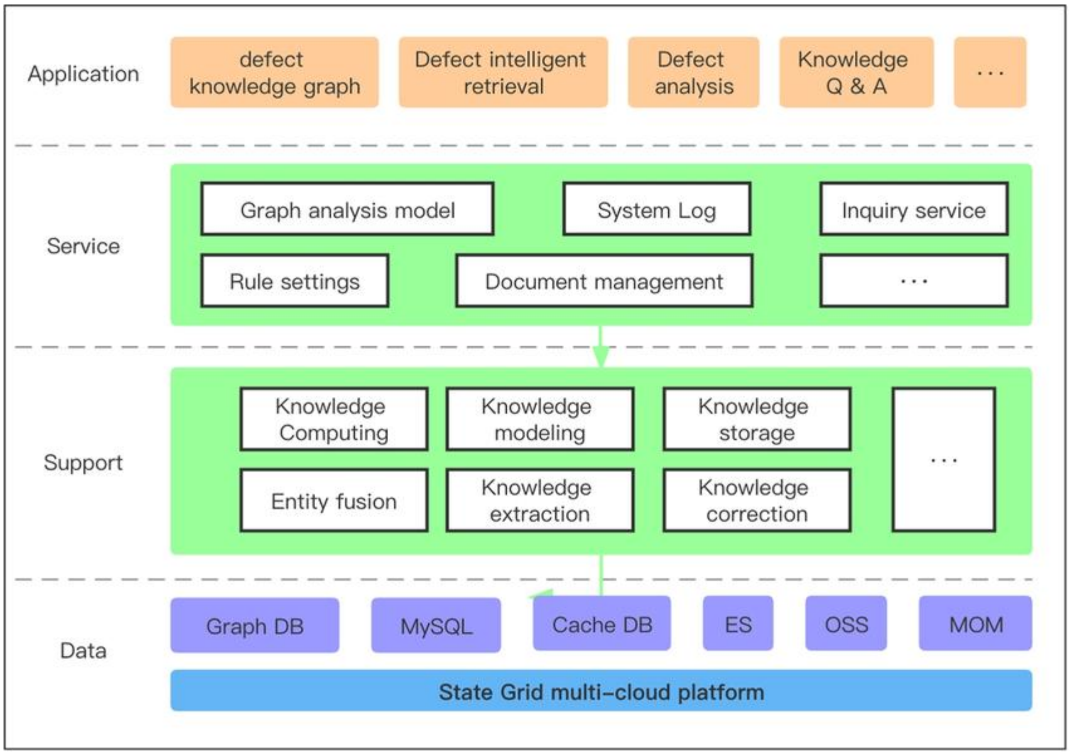

Fig. 1 Architecture diagram of power equipment maintenance system

(1) The service display layer is an interface that provides services to users, including some related interfaces, such as: system operation, system maintenance, etc. Through this commercial display layer, users can understand the functions of the operating system very directly. The data layer can also transmit the user's operation requirements to the service logical layer, and receive the service processing requirements from the service logical layer. The user's work information is instantly fed back to the user interface [8]. At the same time, many front-end functions such as form checking, permission interception, query verification and display are encapsulated.

(2) The service logic level realizes the control of each function module. In the implementation, this logical layer receives the requirements from the front-end service layer and immediately processes all kinds of background data according to the determined service process. Send processing results to the service layer. This level designs a common access interface for different applications, so that the data required by different types of users has higher security.

(3) The data access layer processes the data of the system service logic, and realizes the access and maintenance of the database through the JDBC component and the information transmission interface. The access permission to the database is set in the JDBC component, and the illegal behavior requires that the database cannot be processed. By managing the user authorization key in the background database and backing up the data in the system, the data security in the system is better guaranteed.

B. System Network Topology

It is necessary to store the line information, equipment location information, maintenance information and other information of the power network into the background database. The background database server and Web server of the system are isolated from the external network. Any user or data entering the system from the Intranet must first pass the user's identity verification and authorization, and then carry out the corresponding functional calculation [9]. The network topology design of the power grid equipment operation and maintenance management system is shown in Figure 2 (the picture is quoted in Infrastructure and applications of Internet of Things in smart grids: A survey).

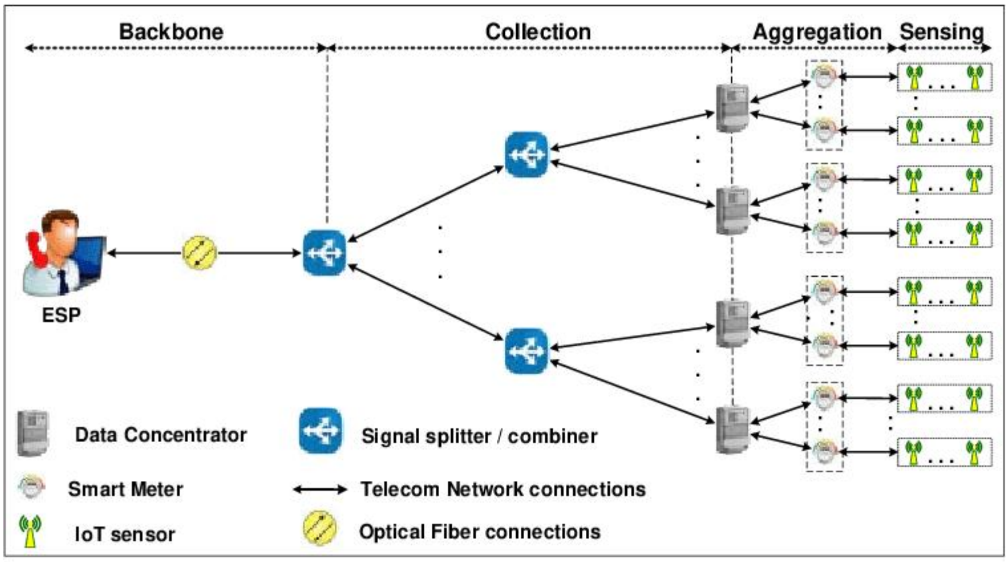

Fig. 2 Network topology of the power equipment maintenance system

C. System function structure

As shown in Figure 3, the system performs functions such as input, coding and printing, equipment query and record deletion for power network equipment (the picture is quoted in A BIM-based Framework for Operation and Maintenance of Utility Tunnels). The main contents of power system inspection are: making inspection plan, making inspection card, and making inspection registration; Maintenance management mainly includes: formulating maintenance tasks, issuing maintenance tasks, accepting maintenance tasks, maintenance records, etc. Maintenance statistics system mainly realizes fault information statistics, alarm information statistics, maintenance results statistics and report processing; The background management of the platform mainly includes the management of users, the management of logs, and the management of the background database.

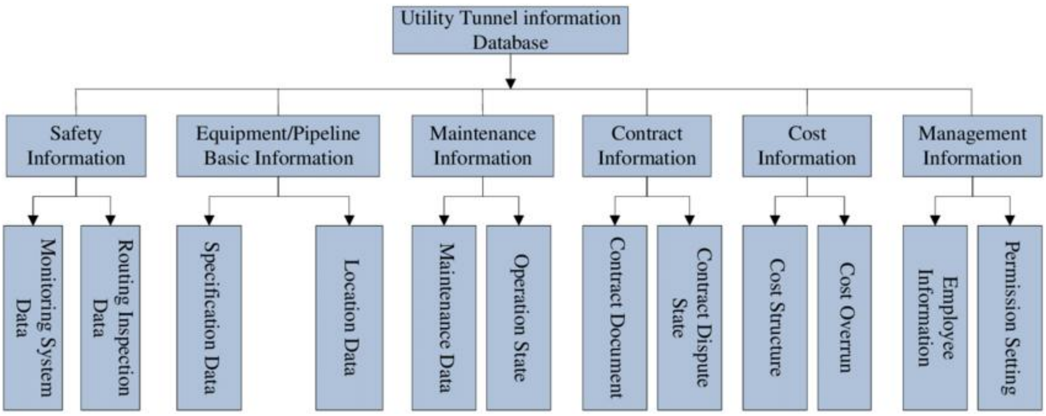

Fig. 3 Structure diagram of power equipment system function module

D. System Flow

Workflow in the power grid equipment operation and maintenance management system is mainly used for the automatic division of processes, its function is to realize the automatic division of business, but because of its various forms of data, and the actual operation process changes greatly, resulting in the maintenance and repair equipment management efficiency is low [10]. In order to overcome this difficulty, the related technology of flow engine is introduced in the development process. The workflow design of the power grid equipment operation and maintenance management system is shown in Figure 4 (the picture is quoted in the Replication and data Management-based Workflow scheduling algorithm for multi-cloud data) centre platform):

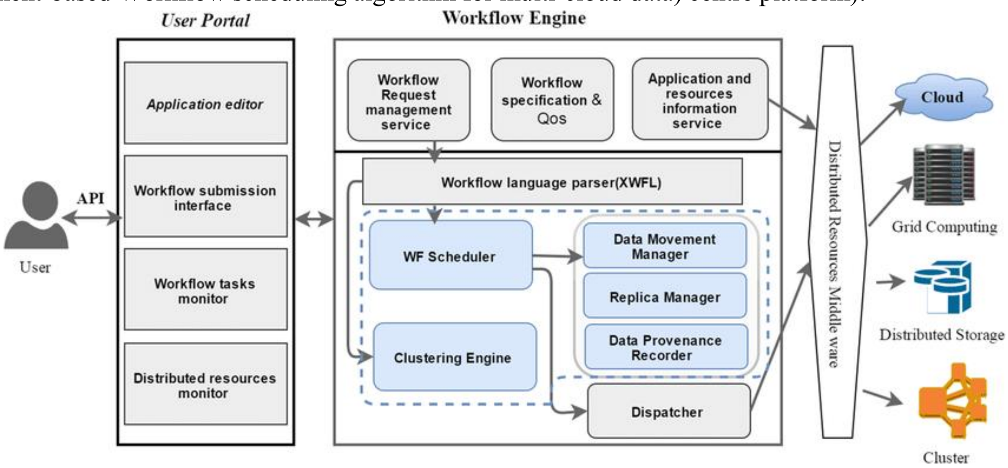

Fig. 4 Workflow architecture diagram

Using this workflow technology, the requirements for different types of new services can be realized quickly and their scalability can be enhanced. When changes are required, the workflow can be defined using the model in the workflow to identify the employee role or company in the industry, use the workflow engine to manage the data related to the work, and associate the worksheet data with the user interface [11]. Thus, the manager of this system can monitor the operation of the whole system in real time. The normal operation of the whole control system is guaranteed.

III. SYSTEM FUNCTION DESIGN

A. Power grid equipment management

The functional module of "network facilities", that is, the recording and recording of equipment that has been used or purchased in the grid. The specific structure of each part of power network facility management is given and the corresponding functional block diagram is given (Figure 5 is quoted in A generic user interface for energy management in smart homes).

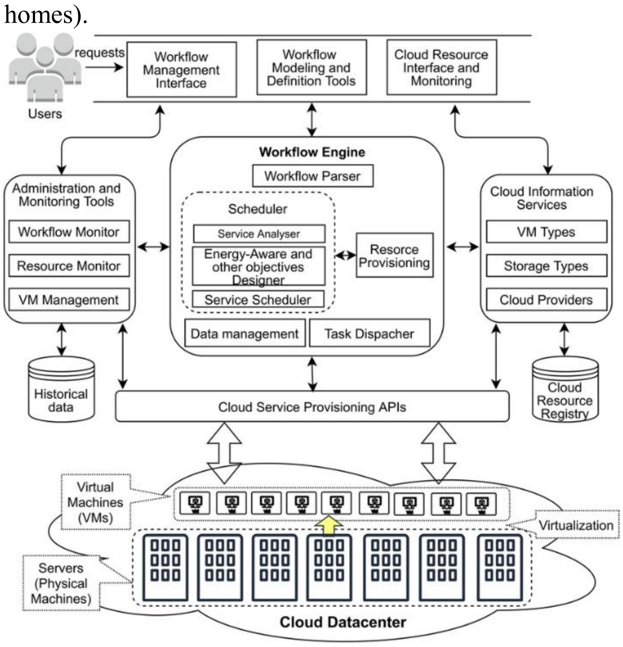

Fig. 5 Power grid equipment management function class diagram

The Account class is an abstract class for directory information. When classifying various devices in a power system, their subclasses must be instantiated. A subclass can inherit from an account's properties and can define its own functionality. In this way, all kinds of equipment can be recorded and managed [12]. The Data class is extracted from the system background record and its contents correspond to the Account class. After the business logic operation is complete, if there are changes, this data class must be processed. You can call the Maintain class with a method. In this architecture, the main class is the main class that can be used to manage the account and data classes. Do a good job of background database data update and entry work records. When entering grid equipment register information, you must first specify its type, and then use the Account class to provide an example of a device ledger type. This ledger information class is used to store the entered device registry information. Performs device information processing on the import () method of the main class. After the input of the device registration record information, the device record information is stored in the system background database using the "get" mode in the "data" class. In Figure 6, the time series of the detailed accounting information entry job is shown (image cited on Blockchain based Secure, Efficient and Coordinated Energy Trading and Data Sharing between Electric Vehicles).

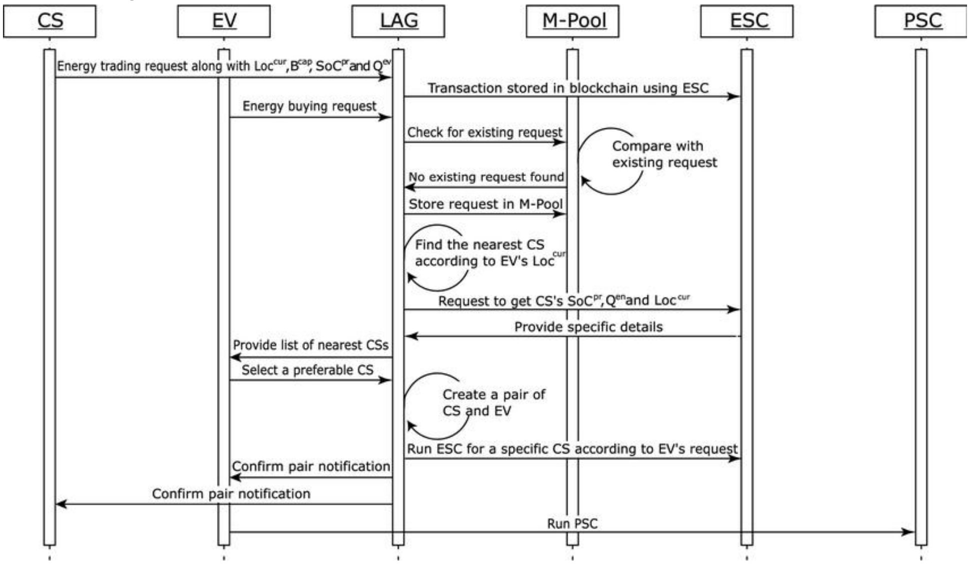

Fig. 6 Time sequence diagram of grid equipment input

B. Load control of power system

The system realizes the prediction, analysis and management of various loads in the power system. In the process of forecasting and managing the electricity market, we must first collect the electricity consumption information of electric power enterprises, and then use the relevant information to forecast the electricity market [13]. The work of this system is to complete the collection of power load, load forecast and forecast data storage. the flow of power grid Load Forecasting management is shown in Figure 7 (The picture is quoted in A Comprehensive Review of the Load Forecasting Techniques Using Single and Hybrid Predictive) Models).

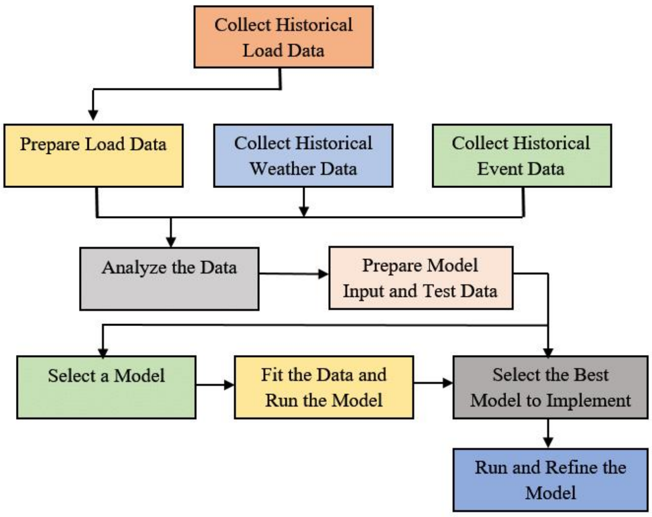

Fig. 7 Flow chart of load forecasting function

C. Power network inspection and monitoring

The inspection management module of the system aims at the process of power grid inspection, including the formulation of inspection plan, the compilation of inspection card, and the registration of inspection records. The work flow diagram of power Inspection is shown in Figure 8 (the picture is quoted in Built a power app for Machine Inspection).

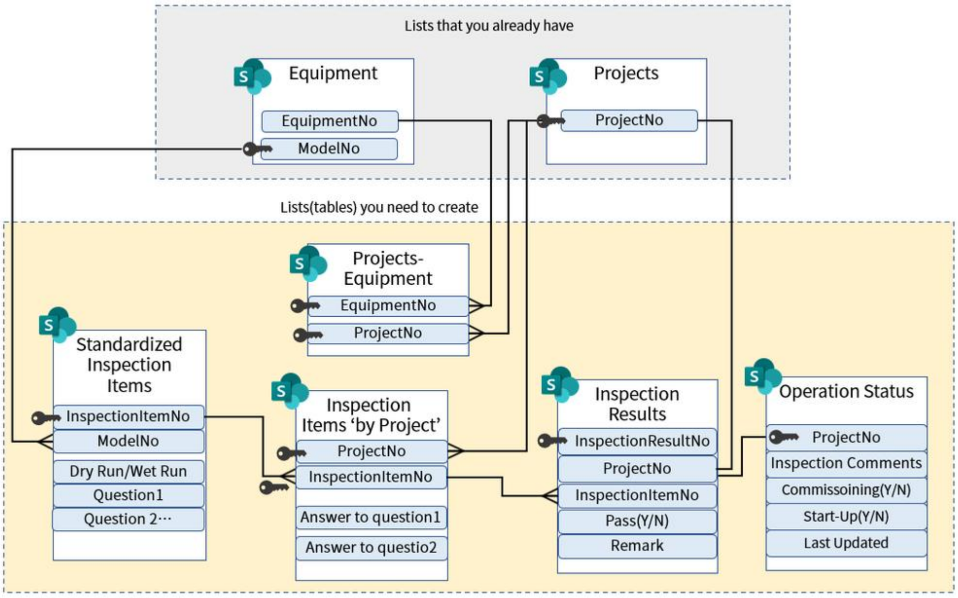

Fig. 8 Flow chart of power grid inspection management

When the maintenance personnel inspect the power grid, they can log in this system to complete the relevant work of inspection management, such as creating a inspection plan, filling in the contents of the inspection, time, place, personnel layout and so on. Fill in the inspection plan and report it to the supervisor for approval [14]. After passing the examination, inspection can be carried out on the spot. At the end of the tour, to fill in the tour log, some of the line problems in the tour to do a good job of registration, and then to the above review, after approval, will create a task library, and the tour record in the form of additional files with the task pool for future inquiries.

D. Maintenance Task Management

The management of maintenance tasks mainly realizes the formulation, allocation, receiving of maintenance tasks and the management of maintenance records. In network facility Maintenance and repair Management, the Maintenance work flow is shown in Figure 9 (the picture is quoted in Maintenance Decision Making, Supported By Computerized Maintenance Management System).

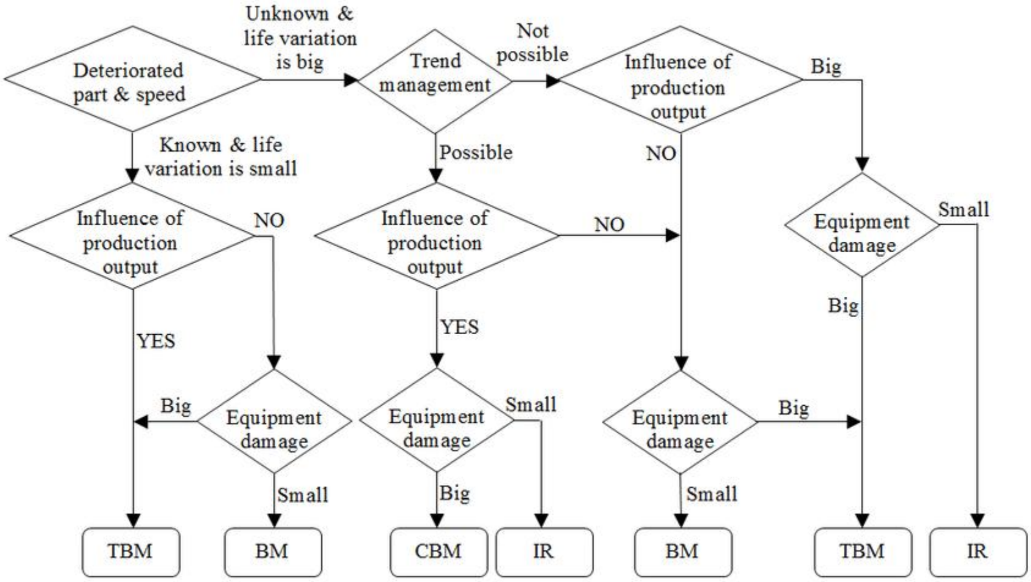

Fig. 9 Maintenance task management flow chart

As can be seen from the maintenance task management flow chart, during the maintenance task management process, the operation and maintenance management personnel need to create maintenance tasks based on the specific operation and maintenance management of power grid equipment. Enter the relevant information of the maintenance task, such as the task location, task content, etc. And assign this work to maintenance personnel [15]. After the completion of the maintenance work, the supervisor will record the completion of the maintenance work in the system and then submit it to the above for review. The responsible person will register the completion of the maintenance task in the system and submit it to the superior for acceptance. The superior will determine whether the task is completed according to the maintenance result and the actual situation. For subsequent query.

E. Maintenance statistics Management

Maintenance statistics management module has the functions of equipment abnormal statistics, alarm statistics, maintenance results statistics and reports [16]. In the maintenance statistics work, the maintenance data should be summarized and analyzed. Therefore, it is necessary to ensure that there is a certain amount of maintenance information.

F. System Management

When you encounter a problem, you can log the management function of the system to find the corresponding work records, so that maintenance personnel can find the software error [17]. At the same time, the user permissions can be set through the user management submodule of the system management function module to improve the software. The background database management submodule of the system can back up all data information and perform routine maintenance operations.

IV. DESIGN OF SYSTEM DATABASE

The E-R graph of the system consists of power plant log information entity, line log information entity, power load information entity, inspection record information entity, maintenance statistics information entity and user information entity [18]. In this ER curve, they are replaced by real users, including maintenance statisticians, task supervisors, and inspectors. In the process of running the system database, the inspection personnel focus on registering the information ontology of inspection records, searching the information of power plant logs and line logs, and completing the inspection work assigned by the supervisor [19]. The responsibility of the task manager is to carry out the preparation of the information subject of the inspection. There is a certain relationship between the inspection work information entity, the power grid load information entity, the inspection card information entity and the maintenance data entity. Maintenance statisticians perform statistical operations on maintenance data reports. The design of the detailed E-R chart is shown in Figure 10 (image cited in Analysis of Energy Consumption in Surface Coal Mining).

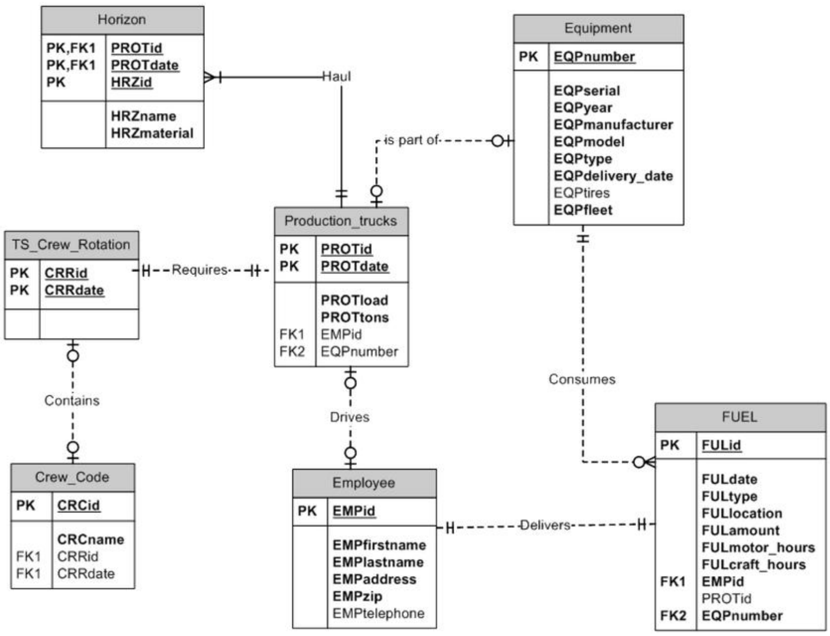

Fig. 10 Database entity-Relationship (E-R) diagram

V. POWER LOAD FORECASTING ALGORITHM BASED ON SUPPORT VECTOR MACHINE

Support vector machine is an optimal classification method under the condition of linear separability [20]. For nonlinear problems, nonlinear transformation should be carried out to linear problems in surface can be obtained from the transformation space. Data set $(u_i, v_i)(i = 1, 2, \cdots, n), u_i \in S^n, v_i \in S$ with n training sample is the input type of input data i. If the obtained function relation is linear function, it is linear regression, represented by $g(u) = \lambda^T u + \varepsilon$, where λ is the weight variable and ε is the deviation. Otherwise it is non-linear regression [21]. In this case, a non-linear mapping $\zeta(u)$ is used to map the data into a high-dimensional feature space, and linear regression is performed in this space, then there is $g(u) = \lambda^T \zeta(u) + \varepsilon$. According to the structural risk function is integrated

$$S = \frac{1}{2} \| \lambda \|^2 + ZS_{cmp}(g) \tag{1}$$

Where, Z is the penalty function parameter, and the model complexity parameter $\| \lambda \|^2$ and empirical risk $S_{cmp}(g)$ are adjusted to improve the generalization performance of the model. Set the experience risk to

$$S_{cmp}(g) = \frac{1}{n} \sum_{i=1}^{n} [v_i - g(u_i)]^2 \tag{2}$$

Then the classification problem of support vector machine in weight λ space can be optimized

$$\min_{\lambda,\varepsilon,\sigma} F(\lambda, \varepsilon, \sigma) = \frac{1}{2} \| \lambda \|^2 + \frac{1}{2} \sum_{i=1}^{n} \varphi_i^2 \tag{3}$$

The restriction specification is: $v_i[\lambda^T \zeta(u_i) + \varepsilon] = 1 - \varphi_i, \delta$ is an adjustable regularization parameter.

Through the Lagrange function, the optimization problem is transformed into the corresponding dual space, then there is

$$R(\lambda, \varepsilon, \varphi, \mu) = F(\lambda, \varepsilon, \sigma) - \sum_{i=1}^{n} \mu_i \{ v_i [\lambda^T \zeta(u_i + \varepsilon) + \varphi_i - 1] \} \tag{4}$$

In the formula, the Lagrange multiplier $\mu_i \in S$, the optimization of the above formula has

$$\begin{cases} \dfrac{\partial R}{\partial \lambda} = 0 \Rightarrow \lambda = \sum_{i=1}^{n} \mu_i v_i \zeta(u_i) \\ \dfrac{\partial R}{\partial \varepsilon} = 0 \Rightarrow \sum_{i=1}^{n} \mu_i v_i = 0 \\ \dfrac{\partial R}{\partial \varphi_i} = 0 \Rightarrow \mu_i = \delta \varphi_i \\ \dfrac{\partial R}{\partial \mu_i} = 0 \Rightarrow v_i[\lambda^T \zeta(u_i) + \varepsilon] + \varphi_i - 1 = 0 \end{cases} \tag{5}$$

Filter the variable λ, φ to obtain the following matrix equation

$$\begin{pmatrix} 0 & -Y \\ Y & XX^T + \delta^{-1} I \end{pmatrix} \begin{pmatrix} \varepsilon \\ \mu \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \end{pmatrix} \tag{6}$$

Where, $Y = (v_1, L\ , v_n)^T; I = [1, L\ , 1]; u_i = [\zeta(u_i)^T v_1, L\ , \zeta(u_n)^T v_n]; \mu = [\mu_1, L\ , \mu_n]$.

The function ζ and a kernel function $L(u_i,u_j)=\zeta(u_i)^T\zeta(u_j)$, if $\psi = XX^T$, then There are

$$\psi_{kl} = v_k v_l / \zeta(u_k)^T \zeta(u_l) = v_k v_l L(u_k,u_l) \tag{7}$$

The classification decision function of LS-SVM is

$$v(u) = \text{sgn}\left[\sum_{i=1}^{n} \mu_i v_i L(u_i,u) + \varepsilon\right] \tag{8}$$

In the formula, μ_i, ε is obtained by formula (6), which can be obtained according to functional analysis, and the function conforming to Mercer's theorem specification is kernel function $L(u_i,v_i)$.

VI. CHECK THE SYSTEM

It can be seen from the procedure of load forecasting method shown in Figure 11 that when the load forecasting of power system is carried out, the training data for load forecasting must be selected first, and then the relevant load forecasting data must be pre-processed, which also includes the load history value, holiday information, meteorological information and seasonal information of various regional networks [22]. The data preprocessing mainly includes deletion repair, noise removal, abnormal data correction and so on. After pre-processing the data, it is restricted, the values of each parameter are set, and it is trained according to the needs of the model. The load forecasting method of power system is established by collecting the data of 4 seasons every 20 minutes. In each quarter, 5,000 samples will be selected in the first 20 working days of the first month and tested in the last 5 working days of each month. After the model is trained, the predicted result data is obtained.

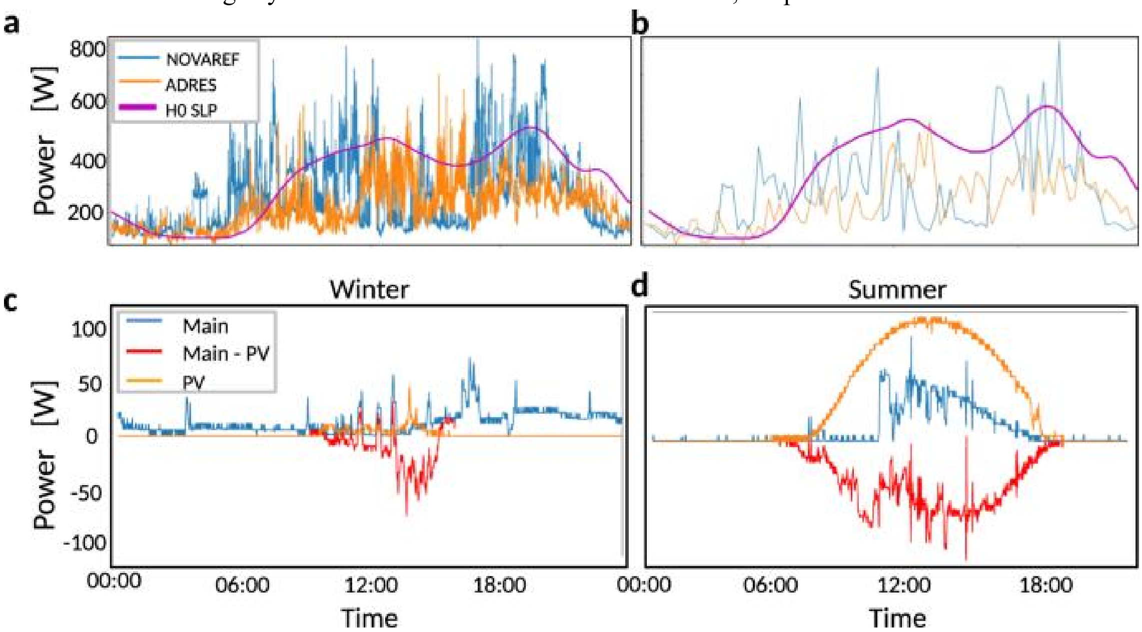

Fig. 11 Load forecasting result curve

It can be seen from the SVR prediction results shown in Figure 11 that the support vector regression algorithm can effectively predict the power grid load. Figure 12 shows the implementation interface of regional power load forecasting.

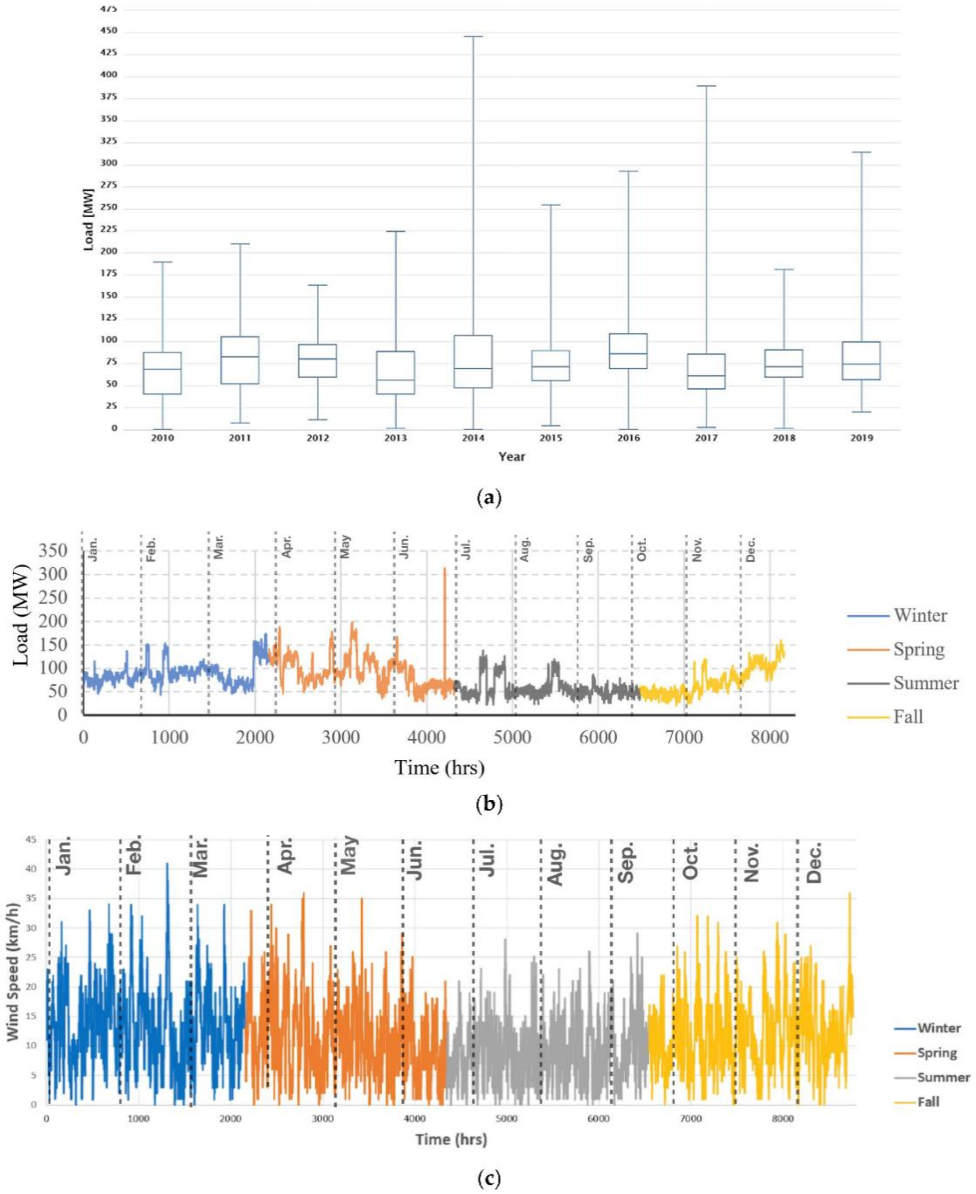

Fig. 12 Regional power load forecasting interface

VII. Conclusion

In this study, we introduce a new method based on ASP. It can automatically split individual business workflows. This coordination promotes a unified approach to business process management and form data processing. In order to improve the intelligence of the system in operation, maintenance and repair tasks, we propose a method using support vector regression (SVR). The integration of SVR helps to improve the system's capabilities towards more informed decision making and more efficient task execution. In order to ensure that the function and performance of the system meet the design specifications, a comprehensive test is carried out. The functional evaluation was performed using the Selenium software suite, which is known for its ability to simulate user interaction and verify the responsiveness of the system to various inputs and scenarios. This allows us to measure system scalability, stability and resource utilization in demanding operating environments. By using these advanced test methods, we aim to provide a power equipment maintenance management system that not only simplifies business processes and data management, but is also adaptable, reliable and intelligent, ultimately helping to improve the efficiency and sustainability of power system operations.

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