Information Operation and Maintenance Optimization Strategy for Power Industry Based on Artificial Intelligence

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Abstract: In this study, an AI-based information operation and maintenance management system for the power industry was designed to improve the efficiency and reliability of information operation and maintenance in the power industry. The system mainly includes multiple layers, such as data acquisition layer, data processing and analysis layer, decision support layer, execution and control layer, user interface and reporting layer, etc. In this system, it uses integrated smart sensors and technologies such as RTUs and PMUs to collect high-quality real-time data. In addition, it also uses big data platforms and machine learning algorithms to carry out data processing and analysis, and at the same time, optimizes power generation dispatch and grid load management. Based on the multiple strategies provided by the system, fault isolation and system recovery operations can be automatically controlled, improving the overall response speed and accuracy of the power grid. With this system, the equipment failure rate can be greatly reduced, and the power resource allocation can be optimized, and at the same time, the power operation and maintenance efficiency can be improved.

1 INTRODUCTION

With the advancement of technology, especially the development of artificial intelligence and big data technology, the power industry is ushering in a huge change in the way of operation and maintenance (Biro and Jakovac. 2022). In other words, traditional power system O&M relies too much on manual monitoring and regular maintenance, resulting in inefficiency and inability to handle complex and emergency situations (Fang and Qin , et al. 2024). Based on this, this study is based on the design of a set of information operation and maintenance management system for the power industry, to demonstrate a powerful operation and maintenance management optimization strategy, and to use artificial intelligence technology to achieve real-time data collection and analysis (Hunter and Albert, et al. 2024), intelligent decision support, and automatic controlIn this way, the efficiency and reliability of the system operation in the power industry can be greatly improved, and the current power supply and its system information operation and maintenance management will maintain a high level of security (Jakubik and Vössing, et al. 2024).

2 RESEARCH METHODS

2.1 Theoretical Analysis

In the early stage of the design of this system, this paper determines the basic framework and functional requirements of the system based on the specific analysis of relevant theories, literatures and prior technologies.

2.2 Data Analysis Method

In this study, in the data processing and analysis layer of the system, the researchers carried out in-depth analysis of the collected power system data based on the effective use of data analysis methods, so as to propose specific optimization strategies and effectively predict faults (Kieseberg and Tjoa, et al. 2024).

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2.3 Empirical Research Method

In this paper, the important power system operation data is collected through the deployment of the system in related systems, and the effectiveness and practicability of the system design are verified (Mercado and Mercado. 2022).

2.4 Simulation Method

In this paper, the simulation method is used to carry out specific research and test a variety of power dispatching and fault response strategies when studying the decision-making level, so as to ensure the scientific and effective strategies of the strategies.

2.5 Algorithm Testing Method

In this study, for the execution and control layer, the researchers deliberately develop and test algorithms that can be applied to the automation control, so as to ensure the execution accuracy and response speed of the system.

3 RESEARCH PROCESS

3.1 Overview of the Design of Each Layer

The design of this power industry information operation and maintenance management system needs to involve many different dimensions, and at the same time, it needs to include a multi-layer structure. Based on this, the following article will elaborate on these specific designs:

First, the **data acquisition layer**. At this layer, smart sensors and smart meters need to be deployed, while also collecting data such as load and generation, voltage, line load and frequency (Müller, 2022). At the same time, it is necessary to be able to collect high-quality and real-time grid operation data based on the two units of RTU and PUMU; Second, the **data processing and analysis layer** (Spring and Faulconbridge, et al. 2022). At this layer, a big data platform is needed to complete the integration, storage and collection of data, so as to maintain the integrity and security of its data. In addition, it is also necessary to process and analyze data based on machine learning algorithms, including load forecasting and fault detection, equipment maintenance demand forecasting, etc. Third, the **decision support layer** (Thaler and Williams, et al. 2024). At this layer, the system generates specific optimization recommendations and decision-making plans based on the analysis results, including power generation dispatching, grid load management, fault response, and other aspects. At the same time, it will also use the expert system and rule engine to provide people with decision-making support in fault handling, emergency response, etc.; Fourth, the **execution and control layer**. At this level, the goal of establishing an interface with the grid automation system will be achieved, such as the use of SCADA systems to implement optimized generation and distribution plans (Yan and Yan, 2022). At the same time, this layer will also automatically control fault isolation and realize system recovery operations, thereby reducing manual intervention and improving response speed and accuracy. Fifth, the **user interface and reporting layer**. At this layer, a user-friendly interface is provided where operators can monitor system status and view alerts and decision support information. At the same time, it also generates regular and demand-driven reports so that management can get the decision-making they need.

3.2 Data Acquisition Layer

There are many technologies that need to be used in the data collection layer, and their key technologies and applications include:

First, smart sensors and smart meters. First, smart **sensors**. Smart sensors are installed on power equipment, including transformers and generators, so that the system can monitor the specific operating status of the equipment, including temperature and vibration, voltage, current, etc. Generally speaking, it has a certain data preprocessing ability, which can carry out preliminary analysis and screening and compress data before data transmission, so as to reduce the communication load and improve the data transmission efficiency. Secondly, smart **meters**. Smart meters will be installed at the consumer end to record the user's electricity consumption, and can support remote meter reading and real-time data transmission. The technical characteristics of smart meters are that they can not only measure power consumption, but also provide data such as load curves and voltage quality, and support remote control functions, such as remotely turning power on and off； Second, RTU. RTUs are an important part of power automation systems, as they capture data from all field devices and transmit them directly to the central control room. The technical characteristics of RTUs are that they usually have strong real-time data processing capabilities, can process signals transmitted from various sensors, and have control functions, such as switch control; Thirdly, the PMU. A PMU is a device that can provide high-precision measurements, providing the system with data such as voltage, current, frequency, and phase of the grid operation, and it is synchronized with high temporal accuracy. The technical characteristics of PMU are that its data can reflect the dynamic state of the entire grid in real time, and it can be said to be an important tool in modern grid management, especially when it can be applied to highly dynamic and interconnected power systems.

There are a number of different key elements in the data processing and analytics layer, including:

First, the effective application of big data platforms. Data integration and storage can be completed first. For the integration function, the big data platform will carry out specific analysis of data from different devices or units, such as data from smart sensors and smart meters, RTUs, PMUs, etc., and provide them with a unified view. This includes the fusion of data in different formats and structures, based on which data consistency and integrity can be maintained. At the same time, in terms of storage, it adopts more efficient and reliable data storage solutions, such as Hadoop distributed file system or cloud storage services, so that massive data can be stored and accessed effectively and quickly. In addition, these technologies guarantee redundant storage of data, so that it can be recovered in the event of a hardware failure. As for data security, **specifically,** it will use strict data encryption technology to protect data in storage and in transit from unauthorized access. In terms of access control, its performance is strict, and fine-grained data access control is adopted, so that only authorized users can access the sensitive information in it, based on this, to prevent data leakage; Second, the application of machine learning algorithms in it. As far as load forecasting is concerned. To select a model first. Time series forecasting models such as ARIMA and seasonal ARIMA, or LSTM neural networks, can be used to predict grid load trends. Then, optimize the goal. In this regard, power companies can optimize power generation and distribution plans through more accurate and reliable load forecasting, and reduce energy waste, which can greatly improve energy efficiency. In addition, for fault detection. For example, pattern recognition. It can detect abnormal behaviors and potential faults in the power system through classification algorithms and anomaly detection technologies, such as deep learning-based autoencoders, random forests, and support vector machines (SVMs). In addition, real-time monitoring. It can complete real-time data stream processing, quickly identify the abnormalities in the system, shorten the fault response time, and at the same time, reduce the impact of the fault. Third, equipment **maintenance demand forecasting**. In this regard, the design of this layer is to predict the possible maintenance needs of equipment through the application of machine learning models, such as regression analysis and decision trees, and neural networks, with the support of historical maintenance data and real-time operating data. In terms of maintenance optimization, this predictive maintenance will enable companies to better develop effective maintenance strategies that will reduce unplanned equipment downtime and reduce maintenance costs.

3.3 Decision Support Layer

At the decision support level, the main technologies or contents include:

First, the expert system. Its definition and function are mainly reflected in the fact that, as an effective computer program that simulates the decision-making process of human experts, the expert system contains a huge amount of domain-specific knowledge and reasoning rules. Expert systems can help non-experts make complex decisions by leveraging the knowledge and experience of integrated power industry experts in the power system. Its application advantage is that in the process of power grid operation and maintenance, the expert system can effectively analyze the overall stability of the power system, assess the potential risks for it, and provide more comprehensive fault prevention suggestions. Second, the rules engine. For example, definitions and functions. A rules engine is a reliable system that can execute user-defined rules, and it is mainly used in complex automated decision-making processes. Rules can be built on the basis of logical expressions, and when certain conditions are met, actions can be triggered. For example, in terms of applications. The rule engine can automatically identify the fault indication information obtained from the data analysis layer in the fault response, and at the same time, based on the preset O&M rules, quickly decide whether to cut off a certain power supply line or use a reroute strategy to avoid power supply interruption.

3.4 Execution and Control Layer

There are many aspects that need to be included in the design of the execution and control layer, and the following are the relevant points:

First, system integration and automation control. In terms of system integration, it is necessary to perform integration with the control level, SCADA, and other automation systems (e.g. EMS and DMS systems). At the same time, APIs and special protocols are used to achieve effective communication with the above systems, and real-time monitoring and control of the power grid. In terms of automated control, automation technologies such as rapid circuit breakers and reconfiguration technologies can be used to isolate faults and restore systems. These include quickly isolating the affected area when a fault is detected, and automatically reconfiguring the network when the fault is resolved, so that normal power can be restored as quickly as possible. Second, dynamic scheduling and optimization. It works by adapting power generation and distribution strategies based on real-time data analysis and load forecasting. Through the effective use of dynamic scheduling software and optimization algorithms, it can automatically adjust its power generation and distribution network configuration, so as to better respond to real-time demand changes and market dynamics. The benefits that can be demonstrated are that such a dynamic dispatching department can effectively optimize the cost-effectiveness and energy efficiency of the power grid, so that its power supply has a certain stability and economy; Third, enhance responsiveness and accuracy. The execution and control layer mainly chooses more advanced and reliable control algorithms and machine learning technology, which not only ensures that it can automatically perform routine operations, but also ensures that it can learn and adapt to the actual operating environment of the power grid, so as to reduce human operation errors and improve operation accuracy. In terms of response optimization, the automation system has a strong ability to respond quickly, which is significantly higher than the traditional manual operation, especially in some emergency situations, it can respond quickly to ensure that the system loss and impact are greatly reduced.

3.5 User Interface Design

In terms of user interface design, the contents that need to be involved are: first, the **operation interface**. Functionality for the user interface. Designers need to design a user-friendly interface that allows operators to easily implement real-time monitoring of power system status, such as monitoring its real-time power flow, equipment status, system load, etc. At the same time, it is necessary to ensure the interactivity of the operation interface. For example, it supports friendly interactive operation, can set alarm thresholds, adjust load distribution, and respond to fault handling at the same time, so that O&M personnel can respond quickly. Second, visualization tools. In this regard, in the process of designing the user interface, the designer should be able to ensure that there are charts, dashboards, GIS and other parts in it, so as to display key data such as grid load maps, historical data trends, and prediction results, so that operation and maintenance personnel can have an intuitive understanding of the operation status of the system. At the same time, the interface should be able to ensure that the data can be updated in real time, and provide the latest status and alarm information of the system for the operation and maintenance personnel, so that the operation and maintenance personnel can respond to potential changes or failures in a timely manner. Third, the report generation function. At the user level, it should be able to provide regular reporting functions, such as system operation summary, equipment operation and maintenance records, energy efficiency analysis, fault logs, etc. The availability of these reports allows management to monitor the performance and operational efficiency of the system in a comprehensive manner. In addition, it is necessary to allow users to set the report generation cycle as daily, weekly, or monthly, so that management can customize it freely.

4 STUDY RESULTS

Through the detailed research in this paper, the strategies for information operation and maintenance optimization in the power industry based on artificial intelligence can be derived, which include:

First, enhance data-driven, predictive maintenance. In this study, the researchers used machine learning algorithms in the data processing and analysis layers to analyze the device's historical operating data and real-time performance data to predict possible equipment failures and maintenance needs. This predictive maintenance strategy can reduce unplanned downtime of equipment to a certain extent, and make the equipment service as long as possible, thereby reducing the operation and maintenance costs of the power industry. Second, effective dynamic load management and adaptive control. From this study, it can be seen that based on the close collaboration between the decision support layer and the executive and control layers of the system, effective dynamic load management can be achieved (mainly through real-time data). Through the application of advanced control algorithms, people can ensure the automatic adjustment of power generation and distribution strategies based on the real-time load and energy demand of the grid. Third, enhance the intelligence of the decision support system and its automatic response ability. The focus of this strategy is that it can learn historical data and operation results based on the development and integration of decision support systems with a high level of intelligence, so as to automatically propose better and intelligent processing strategies and response measures.

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