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Application of artificial intelligence in electric power dispatching automation system

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Abstract: With the continuous expansion of the scale of the power system, the traditional power dispatching automation system is facing many challenges. In view of the problems of low data processing efficiency and poor load prediction accuracy and low fault diagnosis accuracy in the power dispatching automation system, the application of artificial intelligence technology in the power dispatching automation system is deeply analyzed. By employing a deep learning algorithm to analyze massive amounts of operational data, a load prediction model based on neural networks was constructed. Additionally, fuzzy reasoning and genetic algorithms were utilized to achieve intelligent fault diagnosis. The results indicate that the deep learning-based load prediction model is 15% more accurate than traditional methods. Furthermore, the fuzzy reasoning system can effectively identify over 90% of fault types, and the genetic algorithm can reduce fault location time by 40%. The application of artificial intelligence technology has significantly enhanced the intelligence level of power dispatching automation systems, providing robust support for the stable operation of the power system.

1. Introduction

Electric power dispatching automation system as the core component of electric power system, is of great significance to ensure the safe and stable operation of power grid, in recent years as the power system scale continues to expand, the number of equipment increased dramatically, system operation data grow exponentially, the traditional electric power dispatching automation system in data processing, load forecasting, fault diagnosis face great challenges. Artificial intelligence technology, with its powerful data processing and intelligent decision-making capabilities, plays an increasingly important role in electric power dispatching automation systems. Deep learning algorithms can effectively process vast amounts of data and extract valuable information, while neural network technology enables accurate load forecasting. Fuzzy reasoning and genetic algorithms offer new approaches to intelligent fault diagnosis. Further study of artificial intelligence technology in the application to electric power dispatching automation systems has significant theoretical and practical implications.

2. Current situation of electric power dispatching automation system

2.1 System function and composition

The power dispatching automation system mainly includes multiple functional modules such as remote access and data processing, load prediction and scheduling plan, fault identification and diagnosis. The remote access is mainly responsible for the information collection of various sensor data and relay devices, and the data processing module filters, denoising and calculation analysis of the collected signals. Load forecasting and scheduling plan by modeling analysis of historical data, make specific scheduling planning, complete the power generation and electricity control task, fault identification module based on the equipment operating parameters real-time monitoring and calibration, analyze the operating state is abnormal, and determine the fault type and location, power equipment condition monitoring and fault diagnosis function of equipment operation monitoring and data collection and storage and abnormal identification and fault classification, the system function module with real-time data communication ability, to ensure data sharing and rapid response and unified coordination[1].

2.2 Bottlenecks in technological development

Traditional power dispatching automation system in the practical application process has many technical bottlenecks, data processing, as the power grid scale, the system needs to process the amount of data exponential growth, the traditional data processing efficiency is difficult to meet the requirements of real-time, load forecasting factors such as weather and holidays, traditional statistical model prediction accuracy is limited, unable to adapt to the power load complex characteristics. The traditional fault diagnosis method based on rule generalization has poor adaptability; when faced with new fault modes, its accuracy drops sharply. Online monitoring equipment status data acquisition with low-frequency sampling points makes it difficult to detect potential problems. Imperfect coordination between various system function modules and information sharing mechanisms affect the overall operational efficiency. These technical bottlenecks severely restrict the performance of the power dispatching automation system, necessitating the introduction of new technologies to break through the development bottlenecks.

3. Analysis of the key technologies of artificial intelligence

3.1 Deep learning algorithm

Deep learning algorithm by building multilayer neural network structure, realize the power system of automatic feature extraction and pattern recognition, convolutional neural network is suitable for power system image data processing, can be the equipment appearance defects and infrared thermal imaging for automatic detection and classification, circular neural network is good at processing timing data, can effectively mining power load and voltage and current time series characteristics. A deep confidence network with an unsupervised learning mode processes raw data and performs feature extraction, enhancing the efficiency of subsequent analysis. The attention mechanism, when applied to processing substation monitoring data, can automatically identify key periods and important features. The residual network structure effectively addresses the challenges of deep network training, thereby improving model performance. The deep learning algorithm can be flexibly combined for different application scenarios, building hybrid model architectures that leverage the advantages of various algorithms, significantly enhancing data processing and analysis capabilities[2].

3.2 Intelligent optimization method

Intelligent optimization method plays an important role in electric power dispatching automation system, mainly used in parameter optimization and decision planning, genetic algorithm by simulating the biological evolution process, the selection and cross and variation operation, search the optimal solution in the space for power system complex optimization problem, particle swarm algorithm based on group intelligence theory, has strong global optimal ability, outstanding in the load distribution and scheduling plan. The ant colony algorithm, which utilizes the pheromone mechanism to guide the optimization process, can quickly identify the shortest path for locating substation faults. The simulated annealing algorithm has the capability to find local optimal solutions, making it suitable for setting parameters in power systems. The differential evolution algorithm is characterized by its simplicity and rapid convergence, and it is widely used in power system state estimation. By combining various intelligent algorithms based on actual optimization characteristics, a hybrid optimization strategy can be constructed to overcome the limitations of individual algorithms and enhance the optimization effect.

4. Intelligent data processing technology

4.1 Data preprocessing method

In view of the problems of noise interference, outlier value and missing value existing in the data collection of the power dispatching automation system, the intelligent data preprocessing method is adopted to improve the data quality. Multi-scale analysis based on wavelet transform through the decomposition of reconstruction mechanism, decompose the signal into different frequency band components effectively filter high frequency noise in voltage and current signal, while retaining effective information integrity, median filter algorithm using the sliding window processing mutation data, has a good smooth effect on the spike interference in the monitoring data, based on the depth of the encoder, the characteristic decoder compression data reduction data, improve data reliability through the reconstruction error.

To address the issue of missing data in time series, we construct a long short-term memory (LSTM) network model. This model utilizes historical data to fill in missing values, ensuring data continuity. We design an adaptive normalization method based on the characteristics of the data distribution, which dynamically adjusts the normalization parameters according to the properties of different data types. This multi-level data preprocessing process includes data cleaning, anomaly detection, missing value imputation, and feature normalization, forming a comprehensive data purification chain. This establishes a reliable database for subsequent analysis, enhancing the efficiency and accuracy of data processing.

4.2 Feature extraction technology

Feature extraction technology provides a key basis for intelligent analysis and decision-making by mining the deep features of power system data. The principal component analysis method is used to construct a feature space mapping for dimensionality reduction of high-dimensional data. It effectively reduces data redundancy through the decomposition of the most representative principal components. Frequency domain analysis transforms the data into the frequency domain space, extracting the base frequency characteristics and harmonics of the power signal to fully reflect the system's dynamic characteristics. Empirical mode decomposition technology employs an iterative screening approach to adaptively decompose non-stationary signals, obtaining intrinsic mode functions that reveal the intrinsic characteristics of the signal[3].

The characteristics of timing data from the regressive sliding average model, along with the extraction of data trends through autocorrelation analysis, reflect load changes in the periodic prediction model. The model automatically learns and abstracts data, obtaining significant distinguishing features. It employs a multidimensional feature extraction framework that includes time domain, frequency domain, and statistical characteristics analysis methods. This approach describes the system state using waveform features, spectral characteristics, and statistical moments. It also runs features through a screening and feature importance evaluation mechanism to select the most valuable features combination, thereby improving the efficiency of feature extraction.

4.3 Data fusion strategy

Data fusion strategy comprehensive utilization of multi-source heterogeneous data implementation information complementary and deep mining, based on the Bayesian reasoning framework of probability fusion method, can effectively handle sensor data uncertainty, improve the reliability of fusion results, using the theory of evidence to build multi-level fusion model, combined with expert experience knowledge, improve fusion decision-making accuracy. The soft computing fusion method, based on the theory of fuzzy sets, is capable of handling data ambiguity and incompleteness, and adapting to complex conditions. The deep learning-based fusion architecture learns end-to-end, discovering multi-source data association characteristics and improving fusion efficiency. It designs distributed data fusion algorithms according to real-time requirements, using parallel computing to accelerate processing. An adaptive fusion mechanism is built, dynamically adjusting the fusion strategy based on data characteristics to optimize the fusion effect. Through the design of multi-level fusion schemes, it fully explores the value of data, providing strong support for system decision-making as shown in Figure 1.

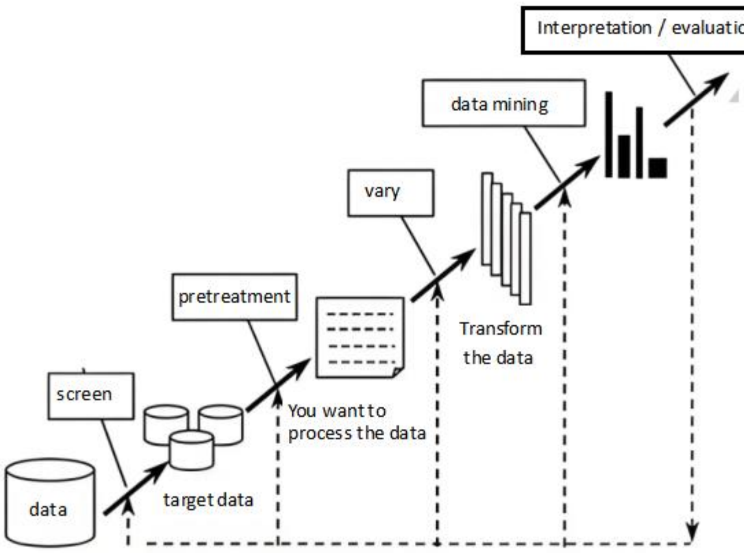

Figure 1: Data processing process

5. Research on intelligent load forecasting

5.1 Prediction model construction

Deep neural network in the power load prediction showed strong nonlinear fitting ability, using multilayer sensor build basic prediction model, input layer contains meteorological elements such as historical load data and temperature and humidity, hidden layer using multilayer structure extract deep features, output layer predict future load value, loop neural network through the introduction of memory unit, capture load sequence long-term dependence, improve the timing prediction accuracy. The attention mechanism automatically assigns weights based on data correlation, highlighting important features. The residual connection structure effectively addresses the problem of gradient vanishing in deep networks, ensuring the stability of training. By integrating a learning strategy, the weighted fusion of predictions from multiple base models reduces the limitations of individual models. To address the challenges of holiday load prediction, a dual-branch network structure is built to model the characteristics of both working days and holidays, thereby enhancing prediction adaptability.

5.2 Parameter optimization method

Model parameter optimization is very important to improve the prediction performance. The parameter optimization method based on genetic algorithm encodes the network weight into chromosomes, and searches the optimal parameter combination through evolutionary operation. The particle swarm algorithm uses the population intelligence characteristics to accelerate the convergence speed in the parameter space in parallel. The differential evolution algorithm employs a simple and efficient variation strategy to avoid local optima. The grid search method is used to explore the parameter space, and although computation can yield the global optimal solution, the Bayesian optimization algorithm guides the search direction by constructing an agent model that balances exploration and exploitation. An adaptive learning rate adjustment strategy dynamically updates parameters according to the training process, improving optimization efficiency. The multiple objective optimization method considers both prediction accuracy and computational complexity to obtain a set of Pareto optimal solutions[4].

5.3 Precision evaluation system

A comprehensive accuracy evaluation system is constructed to quantify the performance of the prediction model from multiple dimensions, the root mean square error reflects the deviation degree between the predicted value and the actual value, the average absolute percentage error evaluates the relative prediction accuracy, and the coefficient of determination measures the goodness of fit. Time assessment method respectively statistical peak and trough prediction error, identify the model in different periods, seasonal assessment system considering seasonal factors, test the ability of adaptation to seasonal characteristics, extreme condition assessment focus on high temperature and cold extreme weather, stability assessment through multiple prediction experiment, analyze the model output fluctuations, interpretable assessment using characteristic importance analysis, reveal the key factors affecting the prediction results. (see Table 1)

Table 1: Performance of different prediction models

Predicted model type	Mean relative error of (%)	Computation time (s)	Applicable scene
Deep neural network	2.35	45	Large-scale grid
Recurrent neural network	2.81	38	Short-term forecast
Attention network	2.42	52	Complex working conditions
Residual network	2.56	41	Long-run forecast
Integrated model	2.15	63	Comprehensive prediction

6. Intelligent implementation of fault diagnosis

6.1 Design of the diagnostic model

Failure diagnosis model based on deep learning through multi-layer feature extraction of power equipment abnormal state accurate identification, convolutional neural network equipment vibration signal time frequency domain feature learning, extract fault features from the original waveform, multi-scale residual network using jump connection structure, fusion of different level feature information, improve the fault pattern recognition ability, transfer learning method using pre-training model knowledge, quickly build a diagnostic model in small sample scenarios. Model the relationship between neural networks and equipment topology, analyze the fault propagation paths, and realize fault source location. The attention mechanism automatically captures the key time windows, extracts important features of the fault stages, and designs a hierarchical diagnostic structure. It includes fault type and severity, and integrates the reasoning mechanism of the knowledge map with expert experience into the diagnostic process to improve diagnostic interpretation. From data collection and feature extraction to fault identification, a complete diagnostic framework is established.

6.2 Real-time monitoring technology

The real-time monitoring technology of electric power equipment finds the potential faults in time through the online data collection and analysis. The layout of a distributed sensor network in transformers and circuit breakers, key equipment nodes, enables comprehensive collection of operating parameters such as current and temperature. Edge computing nodes, equipped with integrated data processing modules, perform data filtering and feature extraction as basic computing tasks. The flow computing framework utilizes a micro-batch mode to continuously analyze real-time data streams and dynamically update equipment status assessment results. A sliding window algorithm with a fixed time span captures the latest data segment's real-time features to detect status trends[5].

The sequence modeling method based on the recurrent neural network construction predicts the evolution trajectory through the long and short-term memory unit to find the abnormal signs in advance. An online clustering algorithm with an improved density-based clustering method is used for real-time classification of equipment operation modes. It identifies abnormal conditions and employs an incremental learning strategy with an experience forgetting mechanism. The monitoring model parameters are dynamically updated based on new data, enhancing the model's adaptability. The algorithm features a parallel computing architecture to increase data processing speed, meeting real-time requirements. Additionally, an adaptive sampling strategy adjusts the sampling frequency according to equipment status, achieving a balance between monitoring accuracy and computing resource consumption.

7. Conclusion

Remarkable achievements have been made in the application of artificial intelligence technology in power dispatching automation system. A deep learning algorithm efficiently processes massive datasets, enhancing the accuracy of load prediction through a neural network model. Fuzzy reasoning and genetic algorithms accelerate fault diagnosis. By constructing an intelligent data processing platform, an accurate load prediction model is established, and a real-time fault diagnosis system is developed. This significantly improves the intelligent power dispatching automation system. Future research will focus on further optimizing algorithm performance, enhancing model adaptability, and improving the real-time capabilities of the system. These technical innovations will provide strong support for enhancing the operational efficiency and reliability of the power grid.

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