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A review of load forecasting technology based on artificial intelligence

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Abstract. Driven by the "dual carbon" goals and the construction of new-type power systems, the importance of power load forecasting technology has become increasingly prominent. Accurate power load forecasting can not only ensure the safe and stable operation of the power system, but also promote the efficient use of clean energy and reduce carbon emissions. Traditional power load forecasting methods have become insufficient in dealing with the complexity and nonlinear growth of power systems, and the development of artificial intelligence technology has brought new possibilities for power load forecasting. Power load forecasting methods based on machine learning and deep learning have gradually become a hot topic of research due to their powerful nonlinear mapping capabilities and advantages in processing big data. These methods not only perform well in short-term forecasting, but also show potential in medium- and long-term forecasting. This paper discusses the application of different artificial intelligence technologies in power load forecasting by sorting out the development status of related technologies, and provides a reference direction for future research.

Keywords: load forecasting, artificial intelligence, machine learning, deep learning.

1. Introduction

With the realization of the "dual carbon" goals and the construction of the new-type power system, the power system continues to develop and improve, and the importance of load forecasting has become increasingly prominent [1].Load forecasting is an important process in the power industry, which is characterized by uncertainty, continuity, complexity, and timeliness. With the increasing complexity of the power system and the large-scale access of new energy, traditional load forecasting methods have obvious shortcomings in dealing with nonlinear relationships, responding to emergencies, adapting to the volatility of new energy, using big data, multi-factor interaction, and seasonal processing.

Traditional load forecasting methods include least squares method, linear and multiple regression analysis, exponential smoothing method, grey prediction model, trend analysis method, time series analysis method and other methods [2]. In the early days, the structure of the power system was relatively simple, and there were fewer factors affecting the load. Traditional models based on analytical technology could predict the load relatively quickly and accurately. With the rapid development of society and changes in economic structure, the nonlinearity and uncertainty in load make load forecasting more and more difficult. Traditional forecasting methods cannot predict the results well, and it is necessary to optimize and improve the forecasting methods based on actual conditions.

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Currently, artificial intelligence prediction methods based on machine learning such as decision trees, vector machines, and random forests and deep learning based on neural networks and transformer models have greatly improved the accuracy of large-scale data processing and prediction [3].

This paper will summarize the advantages and disadvantages of the currently common artificial intelligence-based load forecasting, sort out and analyze the existing achievements of load forecasting and the prospects for future development.

2. Artificial Intelligence Based Prediction Methods

2.1. Machine Learning

Machine learning performs well in dealing with nonlinear problems in load forecasting because of its powerful nonlinear mapping capabilities. Common machine learning methods include support vector machines, decision trees, random forests, etc.

1) Support vector machine performs classification or regression by finding the best hyperplane. When the data is linearly separable, support vector machine classifies by finding a linear hyperplane that separates different categories of data; when the data is not linearly separable, support vector machine maps the data to a higher dimensional space using a kernel function so that it is linearly separable in the space. However, in practical applications, the data may contain noise and outliers, which makes the assumption of complete linear separability invalid. Therefore, soft margin support vector machine came into being, which allows some data points to be on the wrong side of the decision boundary, thereby balancing accuracy and interval. support vector machine performs well in high-order space and is suitable for processing complex data. It can handle linear and nonlinear problems through different sum functions. However, for large-scale data sets, training support vector machine can be very time-consuming, especially when the data dimension is high. support vector machine is suitable for ultra-short-term, short-term, medium-term, and long-term load forecasting. Reference [4] proposes a new algorithm based on multi-kernel learning and weighted support vector machine to predict load. In addition, support vector machine can also be optimized by least squares support vector machine, seagull optimization algorithm, sparrow search algorithm, etc.

2) Decision tree is a supervised learning algorithm for classification and regression. It makes decisions on data through a tree structure to form a decision model. The tree consists of a root node, internal nodes, leaf nodes, and branches, where each internal node splits the data based on a condition of the feature, and the leaf node provides the final Fey label or regression. Decision trees are insensitive to the scale of features, can evaluate the importance of features, and help with feature selection; but they are prone to overfitting the training data, especially when the depth of the tree is large. Decision tree learning algorithms are suitable for short-term and long-term load forecasting. Overfitting can be prevented by pre-pruning and post-pruning operations, and the performance of load forecasting can be improved by reducing the interference of data, reducing the data size, and improving the algorithm. The prediction performance of the decision tree learning algorithm can also be improved by using a decision tree algorithm based on the Person correlation coefficient [5].

3) Random forest consists of multiple decision trees, each of which is constructed by random sampling and feature selection of a data set. It is an ensemble learning algorithm that improves overall performance by combining the predictions of multiple models and is used for classification and regression tasks. The random forest learning algorithm reduces the overfitting of a single tree by integrating multiple decision trees, has good generalization ability, can handle large-scale data sets, and has high training and prediction efficiency; but compared to a single decision tree, the random forest model is more complex, requires predictions for each tree, has poor interpretability, and may take a long time to predict. This method is suitable for short-term, medium-term, and long-term load forecasting. Reference [6] proposes combining a weighted adaptive neuro-fuzzy inference system with a random forest to improve the load forecasting performance of the random forest learning algorithm.

Compared with traditional prediction methods, machine learning load forecasting methods have greatly improved the prediction accuracy of nonlinear data, and can train more efficient models with smaller datasets; however, machine learning methods are usually unable to capture the complex nonlinear relationships and advanced feature interactions in the data. Under complex feature relationships, machine learning algorithms cannot provide sufficiently accurate prediction results.

2.2. Deep Learning

The deep learning method is a machine learning method that uses a neural network as a parameter structure for optimization. Its adaptive learning characteristics are very helpful for fitting data features and forecasting power load. The deep learning prediction method is a machine learning method that uses a neural network as a parameter structure for optimization. A neural network is a computational model that simulates the biological nervous system. It consists of a large number of artificial neurons that transmit and process information through connections. By simulating the computational process of the biological nervous system, the neural network achieves powerful data processing and pattern recognition capabilities [7]. At present, the neural networks widely used in load forecasting include convolutional neural networks and Transformer models.

1) Convolutional Neural Network (CNN) is a deep learning model that processes data with a grid-like topological structure and automatically extracts features from the data through convolution operations. The structure of CNN is input layer, convolution layer, pooling layer, fully connected layer and output layer. The input data of CNN is usually a multi-dimensional vector. The convolution layer generates a feature map through convolution operations. After that, a nonlinear transformation is performed by applying an activation function to enhance the expressive power of the model. The pooling layer reduces the size of the feature map to reduce computational complexity and prevent overfitting, while retaining important features. The fully connected layer flattens the feature map output by the pooling layer into a one-dimensional vector. Finally, the output layer uses a suitable activation function to generate the final result according to the task type (classification or regression). CNN can automatically learn features in the data. Its convolution layer uses local connections and shared weights to more effectively utilize the spatial structure of the data. The convolution kernel operates on the input data and shares weights, reducing the number of parameters and the amount of calculation of the model. CNN is suitable for short-term load forecasting. CNN is often combined with long short-term memory (LSTM) to build prediction models that capture the spatial and temporal dependencies in load data. Compared with independent CNN and LSTM, its accuracy in short-term load forecasting is significantly improved [8,9].

2) Transformer model is a deep learning model for processing sequence data. Transformer model uses self-attention mechanism to capture the dependencies between positions in the sequence, instead of relying on traditional recurrent neural network (RNN) or convolutional neural network (CNN). Transformer model consists of encoder and decoder, and each encoder and decoder layer contains self-attention mechanism, feedforward neural network, layer normalization, and residual connection. The function of encoder is to convert the input sequence into a fixed-length representation, while the function of decoder is to convert the output of encoder into the output of target sequence. Transformer model is suitable for short-term, medium-term and long-term load forecasting, and can effectively mine the medium-term and long-term dependencies of power load data. Reference [10] proposes a new load forecasting model based on fast Fourier transform Transformer model. This model redefines load forecasting as a time series problem, enabling it to extract the periodic characteristics of electricity consumption from data, which can further improve the accuracy and efficiency of load forecasting.

3. Conclusion

In general, with the increasing complexity of the power system and the widespread access to new energy sources, traditional power load forecasting methods can no longer meet current needs. Power load forecasting methods based on artificial intelligence, especially machine learning and deep learning, have demonstrated strong forecasting capabilities and broad application prospects. In the future, with the improvement of big data technology, computing power and further optimization of algorithms, power load forecasting will be more accurate and intelligent, providing solid technical support for the safe and stable operation of the power system and the realization of the "dual carbon" goals. This trend also means that power load forecasting technology will play an increasingly important role in future power systems.

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