A Neural Network-Based Model for Predicting Electricity Revenue in the Context of New Energy

Li Wu, Yongjun Chen*, Bo Li, Liangyu Zou

{Yongjun Chen*:chenyongjun@sgec.sgcc.com.c *,Li Wu: zhumeng_nj@163.com,Bo Li:wangyayun_1995@163.com,Liangyu Zou :chenshuang_143@163.com}

State Grid Huitongjincai (Beijing) Information Technology CO., LTD (Beijing ,100089,China)

Abstract. Through big data analysis and modeling research on short-term and long-term electricity bill prediction in the power market, the results show that exponential smoothing method, ARMA model, maximum information entropy model, and "association rule+ARMA" models are suitable for short-term electricity bill prediction; State space models and neural network models are more suitable for long-term electricity bill prediction. By using predictive models, it has a certain guiding role in providing transaction assistance decision-making for the medium to long term electricity market and spot electricity energy market.

Keywords: big data; Electricity fee prediction; Medium and long-term electricity market; Spot market; Assisting decision-making.

1 Introduction

The electricity consumption of the whole society is an important economic indicator in the electricity market, which includes the primary, secondary, and tertiary industries, as well as the daily electricity consumption of urban and rural residents. It reflects the total scale and level of electricity consumption during a certain period and can reflect the overall situation and changes in electricity demand[1]. The prediction of the entire society's electricity consumption is the main content of electricity market analysis and prediction, and its prediction results are directly related to power construction, power grid planning, and the formulation of power marketing strategies. At present, the main methods for predicting electricity consumption include regression, moving average, exponential smoothing, etc. Their common advantages are simplicity and ease of operation, but none of these methods can guarantee satisfactory prediction accuracy. Moreover, the electricity market is a complex nonlinear system, and there are many factors that affect the electricity consumption of the entire society, such as the macroeconomic environment, the development of various industries in the primary, secondary, and tertiary industries, as well as people's electricity consumption methods, which are both qualitative and quantitative. Not only do they find it difficult to establish a definite functional relationship with the predicted target, but the various factors are interrelated and mutually influencing, making it difficult to attempt to use a definite function to represent the relationship between the entire society's electricity consumption and all influencing factors[2]. Therefore, the application effect of conventional prediction methods is not ideal.

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Artificial neural network is a nonlinear system that simulates the structure, characteristics, and functions of the human brain. It has the characteristics of self-organization, adaptability, self-learning, and strong fault tolerance. At the same time, it also has strong input output nonlinear mapping ability and is easy to learn and train. It has a unique function in dealing with variables that affect and constrain each other, and have complex cross effects.

2 Big data analysis models

Prediction of node electricity bills or clearing electricity bills for power generation enterprises. The required data base includes: quantity of suppliers (power generation side), total declared electricity quantity, average price difference, and highest successful declared price difference; The quantity of the demand side (electricity user), the total declared electricity quantity of the demand side, the average declared price difference, and the lowest successful declared price difference; The total transaction volume of the power grid, the marginal transaction declaration price difference of the supply side, the marginal transaction declaration price difference of the demand side, and the unified clearing price[3]. Other basic information also includes the electricity market policy information collected by the system, industrial development market information, weather information sensitive to electricity (temperature, rainfall, etc. the next day and night), power generation capacity information of power generation enterprises (maximum load capacity, maintenance situation), and network tidal current information (power grid congestion, power grid maintenance, etc.). These big data can generally be collected and organized in the form of time series. In addition, relevant information includes national energy strategic planning, electricity environmental protection regulations, electricity development planning, coal industry structural adjustment planning, and electricity development strategic planning. The above major data information constitutes the analytical model for electricity fee prediction. This paper utilizes various big data analysis methods, combined with the above information, to predict and analyze the medium to long term and short term electricity bills in the power market, providing guidance for various power generation enterprises[4].

3 A method for predicting electricity bills based on big data analysis

Different prediction models are used for the medium to long term and short term prediction of electricity bills. This includes but is not limited to: exponential smoothing method, ARMA model, state space, neural networks, and grey theory. The overall idea of electricity cost prediction based on big data analysis is shown in Figure 1.

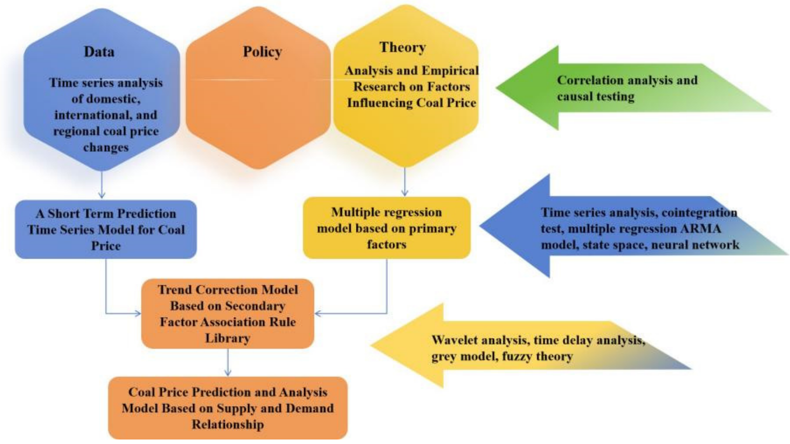

Fig. 1. Roadmap for Research on Medium to Long Term and Day Ahead Node Electricity Prices and Weighted Average Price Forecasting of the Whole Network

3.1 Short term prediction methods

Real time, daily electricity bill prediction. The real-time bidding strategy for the spot market of power generation enterprises plays a crucial role. If enterprises have accurate real-time electricity fee prediction data, it can effectively improve their profitability in the electricity market. Short term electricity cost prediction for enterprises, including hourly electricity prices quoted in advance and average prices across the entire network. Based on the functional characteristics of different mathematical models, after research, exponential smoothing method, ARMA model, maximum information entropy model, and a combination of association rules and ARMA model were used for electricity bill prediction. The following are the characteristics of each model[5].

(1) Exponential smoothing method

Exponential smoothing is a very important and commonly used time series prediction method. Its basic idea is to obtain the "smoothing value" of the data by performing relevant operations on the original data. Then calculate and construct a prediction model to further predict future values. For time series data that is not sensitive to seasonal fluctuations and is not significantly affected by seasonal trend changes, the exponential smoothing method is generally used to fit and predict the data mathematically. Exponential smoothing is a simple mathematical method that predicts trends and is difficult to achieve accurate quantitative predictions. It can be used as a preliminary analysis tool for data.

(2) ARMA model

The ARMA model (Auto Recursive and Moving Average Mode1) is also an important method for studying time series data. Composed of autoregressive model (AR) and moving average model (MA). The main idea is to establish an accurate fitting method for the model based on the information of past time points (historical information) in the time series, fit the data, and predict the future values of important parameters. The application steps are as follows:

1) Data preparation and preprocessing. The prerequisite of this model is that the time series of the predicted object or parameter is a stationary random sequence with zero mean. However, in general, with the accumulation of time, a large amount of data always has upward or downward fluctuations, which constitutes a non-stationary time series. For this phenomenon, expenditure should be established in the model[6]. Perform stationarity testing on the time series of parameters, that is, perform data preprocessing on non-stationary time series through zero mean and differential stationarization operations.

2) Determine the autocorrelation coefficient and partial autocorrelation coefficient of the parameters.

3) Model fitting and prediction. This article uses various modeling methods such as Eviews, SPSS, Maflab, and tests the predictive performance of the model.

(3) Maximum Information Entropy Principle

When predicting prices based on past experience, many data are difficult to obtain directly and are offline. In the absence of some data, the maximum information entropy principle can be used for modeling and analysis.

The significance of information entropy. In 1948, C E. Shannon proposed the concept of "information entropy", which solves the problem of quantifying information. In abstract terms, information entropy can be seen as the probability of the occurrence of a specific information, and its mathematical meaning is to characterize the uncertainty of the information source.As shown in equation (1):

$$H(x) = \mathrm{E}[I(x_i)] = \mathrm{E}\{\log[1/p(x_i)]\} = -\sum p(x_i)\log[p(x_i)], (i = 1,2,\cdots,n) \tag{1}$$

In the formula: P (xi) is the probability of taking the i-th symbol from the information source; H (x) is the information entropy of the information source.

1) Mathematical principle of model: To make accurate predictions about the distribution of data with only a portion of information, the following conditions should be met: ① compliance with constraint conditions; ② Take the probability distribution with the maximum entropy value. This is an unbiased choice made in a mathematical sense.

Using the above principle, using information entropy as the uncertainty benchmark for this parameter, it is determined that under the relevant constraint conditions (satisfying the real

The maximum estimated distribution of this parameter can be obtained by taking the case with the highest probability and eliminating human factors, under the condition of random distribution under the international situation. This can be used to predict important parameters. This principle has been successfully predicted in some short-term load forecasting, and currently, based on existing implementation plans and the prediction mechanism of electricity prices, the maximum information entropy principle can be used to predict node electricity prices.

3.2 Medium and Long Term Prediction Methods

Medium - and long-term electricity cost prediction can provide effective data support for medium - and long-term auxiliary decision-making in electricity. This paper uses state space models and neural network models for medium to long-term prediction of related electricity bills. It is worth noting that neural network models can also predict short-term electricity bills.

(1) State space model

The state space model, also known as the dynamic time domain model, is a mathematical model with implicit time as the independent variable. At present, the form of electricity in China, the demand for electricity in the electricity market, the marginal cost on the generation side, and the load output situation will not undergo frequent and significant changes due to the large size of the national economy. In the case of relatively stable coal prices, the marginal power generation cost on the power generation side can remain relatively stable. But if these three variables, or one or two of them, undergo significant changes, such as high coal prices from the beginning of 2021 to the present, reaching historical highs and maintaining such long-term highs, it has had a huge impact on the marginal cost of power generation[7]. Furthermore, the impact of the epidemic and the international market has led to significant fluctuations in electricity supply in some months; In this case, using a state space model can better characterize the changes in node electricity bills. By predicting long-term coal prices and economic conditions, the state space model can be used to obtain the predicted trend of long-term electricity bills, which can provide medium to long-term market transaction support for enterprises.

(2) Neural network model

Due to the fact that there are many factors that affect the node electricity bills in the electricity market, not all of them are time series parameters. Therefore, when a large number of parameters in the influencing factors exhibit strong coupling characteristics or nonlinear temporal characteristics, neural networks can be used for modeling and analysis. This model does not require the calculation of statistical characteristics of parameters. In theory, neural networks can be applied to the modeling, prediction and analysis of any nonlinear time series parameter. At present, other modeling tools such as fuzzy mathematics and neural networks are commonly used in the academic and engineering fields to predict thermal analysis of non temporal parameters. According to the author's research, wavelet neural networks based on wavelet analysis have good function approximation ability and generalization performance, and can be applied to the prediction of electricity bills.

3.3 Prediction range and accuracy analysis of the prediction model

The comparative analysis of the advantages and disadvantages of each model method is shown in Table 1.

Table 1. Comparison of Electricity Price Forecasting Models

Prediction model	Advantage	Shortcoming
Exponential smoothing method	The smaller the smoothing coefficient, the stronger the smoothing effect	Slow response to changes in actual data
ARMA	Regression+moving average, high short-term prediction accuracy	Suitable for short-term forecasting
State space model	Widely applicable; Internal	High modeling accuracy

	description method	requirements
Neural network	Possess self-learning and adaptive abilities; Fast calculation speed	Dependent data
Maximum information entropy	Mastering some information can make predictions	The model algorithm is relatively complex; Short term prediction
Association Rules+ARMA	Increase association rule correction for high prediction accuracy	Suitable for short-term forecasting

Specifically, short-term electricity bill forecasting, including hourly electricity bill issues, has a certain relationship between electricity bill fluctuations and time periods[8]. For different electricity bill trends during peak and valley periods, time series prediction models such as ARMA model, state space, and neural network modeling can be used for modeling. For medium to long-term electricity bill prediction, due to the long time cycle and uncertain influencing factors, electricity bill fluctuations may be significant. State space models and neural network models are used for prediction. The corresponding relationship between the model algorithm and prediction accuracy is shown in Table 2, taking into account the applicability of each model and the characteristics of different electricity tariff indicators.

Table 2. Comparison of application scope and accuracy of electricity price forecasting model

Prediction model	Prediction cycle	Theoretical accuracy/%	Transaction type	
			Medium and Long Term Transactions	Trading in the spot market before the day
Exponential smoothing method	short-term	>90		√
ARMA	short-term	>95		√
State space model	Medium to Long Term	>90	√	√
Neural network	Short term+medium to long term	>95	√	√
Maximum information entropy	short-term	>95		√
Association Rules+ARMA	short-term	>98		√

4 Experiments

In order to verify the practical value of the basis neural network designed in this article for predicting the electricity market's daily electricity bill revenue, this article conducts experimental verification on the above method. The experimental results are presented in the form of a comparison between the traditional electricity market day ahead electricity revenue prediction method and the electricity market day ahead electricity revenue prediction method based on long short-term neural networks designed in this paper. The specific experimental process and results are shown below[9].

4.1 Experimental process

This article takes recent changes in electricity revenue as the main experimental object. There are significant fluctuations in electricity revenue at 6:00, 12:00, 18:00, and 24:00 within a day. After using the prediction method designed in this article, the relative prediction error is shown in Figure 2.

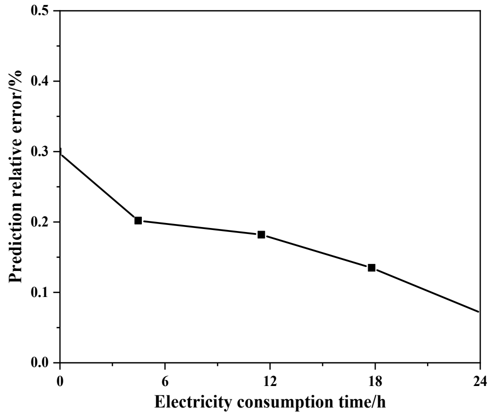

Figure 2. Prediction relative error

Analyzing Figure 2, it can be seen that there are 24 data points for daily electricity revenue, and the electricity revenue shows a significant trend of change at 6:00, 12:00, 18:00, and 24:00. Therefore, this article analyzes the relative prediction errors at 6:00, 12:00, 18:00, and 24:00. As can be seen from Figure 2, when the power consumption does not change, the prediction relative error is about 0. 30%, when the power consumption time is 6:00, the forecast relative error is about 0. 20%, the electricity consumption time is at 12:00, and the relative prediction error is 0.17%, the electricity consumption time is at 18:00, and the relative prediction error is 0.14%, the electricity consumption time is at 24:00, and the relative prediction error is 0.07%. Therefore, the prediction error of the electricity market's daily electricity bill revenue prediction method designed in this article is relatively small, which can effectively meet the ever-changing electricity bill revenue market demand[10].

5 Conclusion

Research has shown that exponential smoothing method, ARMA model, maximum information entropy model, and "association rule+ARMA" models are more suitable for short-term electricity bill prediction; State space models and neural network models are more suitable for long-term electricity bill prediction. Through multiple factor analysis and multi-level validation of various models, node electricity bills are predicted and applied to the medium to long term electricity market and energy market. The results show that: ① the core of medium to long term auxiliary decision-making lies in the effective prediction of node electricity bills. The holding strategy mainly includes: in the future, node electricity bills are expected to rise while holding fewer positions; Future node electricity bills are bearish, increasing positions; ② The strategy for holding positions in the electricity market is: recently, the predicted value of spot electricity bills is high (with a high probability), increasing the amount of spot clearance electricity and reducing short-term contract electricity; Recently, the predicted value of spot electricity bills is low, increasing the contract electricity base and reducing the amount of spot cleared electricity.

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