Principal Component Analysis of Short-term Electric Load Forecast Data Based on Grey Forecast

Su Yinsheng¹, Liu Chunxiao¹, Li Bao¹, Deng Weisi¹, Zhang Peishen²

¹China Southern Grid Power Dispatching Control Center, Guangzhou, Guangdong, 510663, China
²NARI-TECH Nanjing Control Systems Ltd., Nanjing, Jiangsu, 211106, China

Abstract. With the large-scale development of the power industry, new requirements are put forward for the stable operation of the power system. Power system load forecasting refers to the use of historical load data to predict the future load value, which is an important part of energy management system. The short-term load forecasting process is often combined with the basic mechanism of power grid dispatching to achieve the balance of power grid supply and demand, reflecting the highly nonlinear computing ability. Power load forecasting is the premise of power grid real-time control, operation planning and development planning. At present, the grey model model used for power system load forecasting generally has the problems of large calculation amount, no mature theoretical basis for selecting structures and parameters, etc. This paper discusses the application of grey model in short-term power load forecasting, and puts forward a principal component analysis method suitable for ordinary daily power load forecasting data, which improves the accuracy of short-term power load forecasting.

1. Introduction

Power system load forecasting refers to the use of historical load data to predict the load value in the future. It is an important component of energy management system and has become one of the important contents for realizing the modernization of power system management [1]. Today in the 21st century, the power industry is developing on a large scale, which puts forward new requirements for the stable operation of the power system. The function of the power system is to provide reliable and qualified electric energy to all kinds of users as economically as possible so as to meet the requirements of all kinds of users at any time [2]. The process of short-term load forecasting is often combined with the basic mechanism of power grid dispatching to realize the overall balance of power grid supply and demand, reflecting the highly non-linear computing ability, and combining with the application process of self-organizing ability to do a good job in the modeling of short-term load forecasting [3]. The size of the load is an extremely important factor for the planning and design of the power system as well as the operation research. Effectively improving the accuracy of load forecasting is conducive to the economic and safe operation of the power system, and the power system dispatching can be reasonably carried out [4]. Because the theory of multi-dimensional time series prediction is far from mature and the computation is generally very large, many prediction methods proposed by people are aimed at one-dimensional time series [5]. The current gray model for power system load forecasting generally has a large amount of calculations, and there is no mature theoretical basis for the selection of structures and parameters, which brings certain difficulties to the forecasting work that requires accurate results [6].
In order to adapt to the rapid development of power grid technology, prevent and respond to short-term load forecasting of large-scale power systems, various new equipment are put into operation, and new technologies are popularized and used in power dispatching monitoring and substation operations [7]. Grey model (GM) prediction technology has been widely used in power systems, with high short-term prediction accuracy [8]. Control, operation, and planning of power systems all require load forecasting information. Accurate load forecasting is critical to the safety and economic operation of the power system. Power load forecasting is the prerequisite for real-time control, operation planning, and development planning of the power grid [9]. Because the time series corresponding to adjacent points have a strong correlation, this process is simple but ignores a lot of information. Regarding production planning and dispatching applications, the relevant equipment resources should be reasonably allocated in conjunction with the main power distribution process [10]. Grey system theory is a theory that studies the analysis, modeling, prediction, decision and control of grey systems. The model of gray prediction requires less modeling information, convenient operation, and higher accuracy of modeling. In recent years, this theory has been introduced into power system load forecasting and has achieved good results [11]. This article discusses the application of the grey model in the forecast of ordinary daily short-term power loads, and analyzes the main components of short-term power load forecast data.

2. Multivariate Principal Component Analysis Theory

The so-called load forecasting often has a variety of forecasting methods. Through accurate forecasting in the analysis process, the safety analysis of the power system is further realized. Under the environment of continuous reform of the power enterprise market, ensuring the power load demand is the premise of implementing the power system strategy, ensuring the harmonious development of the power enterprise and the national economy is the important guarantee of the power system, and ensuring the optimal allocation of power resources and the reliability of power grid operation are the power supply foundation of the power system. In short-term load forecasting of power system, constrained design optimization needs to be divided into linear programming and nonlinear programming according to the specific characteristics of its constrained objective function or constraint conditions. Since the data of power demand over the years show obvious characteristics and trends, two time series models with completely different modeling principles are used to model and analyze the same power demand sequence [12]. On the one hand, the prediction effects of the two models are compared horizontally; on the other hand, the respective advantages of the two models are brought into play and the prediction results are combined in a weighted average coefficient manner to obtain the final prediction value. In a perfectly competitive market, power generation companies will bid at marginal cost to maximize profits. However, in an imperfect competitive market, the bidding curve of power generation companies with market power may deviate completely from the cost curve, and the market electricity price may be increased by removing part of the electricity quantity or raising the bidding price.

The power plant is the passive executor of the unified dispatching of the system. In the power market, the power generation company has the autonomy of production and operation and becomes the main body of market competition. It will adopt different bidding strategies and realize profit maximization by adjusting the bidding curve. Fig. 1 is a scanning speed modulation architecture of a power prediction model.
If a relatively accurate short-term prediction of power generation can be made, i.e. the short-term prediction error is very small, it will be beneficial for the power system dispatching department to timely adjust the dispatching plan, thus effectively reducing the impact on the power grid, reducing the operating cost of the power system and rotating standby. When the influence of valve point effect is ignored, the total cost of power generation is reduced. It accounts for 4.46% of the total cost. Without considering the consumption cost caused by valve point effect, the scheduling result has a large error. For example, Table 1 shows the optimization results before and after considering the valve point effect.

| Optimization model                          | Optimization target (thousand yuan) |
|---------------------------------------------|-------------------------------------|
| Ignore valve point effect                   | 174.62                              |
| Considering valve point effect              | 205.37                              |

In an incomplete competitive electricity market, power generation companies can use strategic quotations to maximize profits. The database server is the data layer. It mainly installs large-scale relational database software and stores data, feeds back requests from application servers and performs budget operations. Under the condition of incomplete information, quotation strategies developed based on the estimation of competitors’ costs or quotations generally have certain risks. For example, the power generation capacity that has not been scheduled due to too high an offer or that has been scheduled is obviously less than the expected value, etc. The comprehensive short-term prediction model optimized by the mixed penalty function method is also in line with the urban development. No matter in what area, the hybrid penalty function optimization synthesis model has better fitting precision and short-term prediction precision. Timely maintenance of failed power generation equipment shall be carried out to ensure orderly power supply order and safe operation of the power grid, and an electricity saving mechanism shall be established. Adjust the price of electricity supply timely and appropriately so that the price of electricity changes with the fluctuation of energy price and supply and demand.

3. Grey Difference Forecast Model

3.1 Establishment of Grey Interpolation Model

GM (1, 1) model does not need obvious trend of historical data and requires less historical data, so it has a wide range of application. Short-term power load has obvious periodicity, and the kind of periodicity presents obvious daily periodicity and weekly periodicity. Most of the short-term load forecasting problems are nonlinear programming problems, and the solution is to solve the maximum and minimum values of multivariate nonlinear functions in mathematical functions. Research on new short-term forecasting methods is a key issue for researchers now, and better unconditional constrained
optimization methods are also emerging. The adjustment model is used to separate out the adjusted sequence with the influence factors removed. Finally, the month-on-month growth rate index of power demand is calculated and compared with the year-on-year growth rate index of the original sequence. The trend cycle component can reflect the overall trend change direction of the time series, which is mainly influenced by long-term factors and assumes that the influence will run through the sequence. In the short-term dispatching, due to the randomness and uncontrollable nature of the power, it will cause the increase of the system's rotational reserve capacity and the change of the conventional unit start-up and stop strategy after the power is connected to the network, which may lead to the increase of the operation cost of the power system. The algorithm evolution curve is shown in Fig. 2.

The whole load short-term forecasting system should realize the automation of data processing, meet the short-term forecasting conditions of power demand, and automatically integrate and analyze a large amount of input information. The difference grey prediction model uses the load data of two adjacent days at the same time to form interpolation values, and the difference columns formed at intervals of weeks and in chronological order are used as grey modeling history data columns.

4. Application Effect
In order to continuously promote the steady growth of electricity demand, Shuangcheng Municipal People's Government should actively promote the economic development of the secondary and tertiary industries. This is very beneficial to the increase of electricity consumption of power enterprises. In reality, different decision-makers have different attitudes towards risks, which also determines their different priorities in making decisions. Centralized and unified regulation of the electricity and coal market, strengthening the supervision of coal prices, giving priority to the allocation of new coal resources to large power generation groups. Support the joint venture and merger of power generation enterprises and coal enterprises, and comprehensively supervise the whole process of electricity and coal supply.

Large-scale power cannot be absorbed locally and needs to be transmitted to the load center through the transmission network at a long distance. Under the condition of not considering the electricity operation cost, the expression of the optimization target is:

\[
\theta_i = \frac{a_i p_i}{1 + \sum a_i p_i}
\]

Power balance constraint:

\[
\frac{p}{v} = \frac{1}{v_m a} + \frac{p}{v_m}
\]

In the information sharing strategy, use the formula to update the particle speed:
\[
\ln \frac{c}{c_0} = \frac{1}{RT} \frac{2\gamma M}{\rho R}
\]

System active power balance constraint:

\[
RT \ln \frac{p_2}{p_1} = \frac{2\gamma M}{\rho} \left( \frac{1}{R_2} - \frac{1}{R_1} \right)
\]

In order to meet the load demand and obtain the power generation benefit, the power plant needs to reduce the energy consumption of capturing to increase the net output. At this time, the waste gas emitted by the power plant is continuously absorbed, and the generated rich liquid is sent to the rich liquid storage for storage. The energy consumed by the regeneration tower is reduced to a lower level, and the energy consumption of the electric system is reduced as a whole, and vice versa. In the process of bidding strategy selection by power generation enterprises, any losses and risks incurred will always be borne by the power generation enterprises that have paid the price. Their basic characteristic is that they have the right to make independent decisions and are responsible for the consequences of decisions. It is rather complicated to solve the combined sub-optimal short-term prediction model. Each market in the electricity market, even different regional markets, has different price fluctuation characteristics. In order to achieve satisfactory short-term prediction results, continuous iteration is required.

5. Summary

In this paper, the short-term power load forecasting is discussed by using the grey theory, and a feasible forecasting method is put forward. This method can effectively improve the fitting effect and short-term prediction accuracy of power load short-term prediction. Because load forecasting requires very high historical data, researchers are required to obtain all factors that may affect load characteristics under ideal conditions. The month-on-month growth rate index obtained from the power demand adjustment model is also more sensitive than the year-on-year growth rate index of the unadjusted sequence, and can quickly capture the past and future power demand inflection points. In the environment of electricity market, power generation enterprises will face many uncertain factors in the process of bidding strategy selection. Some unavoidable human factors or objective factors often lead to serious deviation of historical data, thus reducing the accuracy of short-term prediction. Reducing the damaged or lost historical data will help to improve the accuracy of the short-term load forecasting model. In the process of principal component analysis, it is mainly combined with the basic form of grey model to extract some principal components of load data, and then reduce the complexity of the prediction model.

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