Research on New Investment Demand Forecast of Power Grid Company After Investment Interface Extension

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Abstract. By extending the investment interface, power grid companies increase investment in business expansion projects, which not only effectively improves market share and customer satisfaction, but also supports economic and social development. However, after the extension of the investment interface, the continuous expansion of the scale of new investment has brought unprecedented challenges to the power grid company. Therefore, it is particularly important to forecast the new investment demand after the extension of the investment interface of the power grid company. In this paper, the principle of support vector machine and grey correlation analysis method are introduced. On this basis, the GRA-SVM model of the new investment demand forecast after investment interface extension of the power grid company is established, and the process and basic steps of building the model are described in detail. Then, the influencing factor system of the new investment demand after investment interface extension of the power grid company is constructed. According to the actual data of the relevant factors of the ZY power grid company from 2011 to 2021, the new investment demand of the ZY power grid company is forecasted by adopting the GRA-SVM model, and the forecast results are analyzed. The research results show that the GRA-SVM model can not only select the important influencing factors independently, but also has good forecast ability, high forecast accuracy and reliable forecast results. This provides a new idea and a new solution for power grid companies to forecast new investment demand after the extension of investment interface.

Keywords: Investment interface extension · new investment demand · grey relational method · support vector machine · GRA-SVM model

1 Introduction

With the deepening of Chinese power grid system reform and the continuing development of new energy, a series of new requirements of power reform, such as the reform of power transmission and distribution price, the liberalization of power distribution business, and

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the change of profit model of power companies, The internal and external environment of China's power grid companies are facing great changes, with increasingly fierce market competition and increasingly diversified customer demands [1]. In order to ensure the sustainable development of power grid companies under the new situation, power grid companies actively change their development ideas, innovate the traditional management mode, take customer demand as the orientation, improve their service mode from the perspective of social development and customer interests, and thus enhance the overall management level and operation capacity of electric power companies [2].

In recent years, Chinese power grid companies have launched the extension of investment interface for promoting industrial expansion projects, which not only expands the power market, increases the electricity sold, but also reduces the burden of customers, solves the "last mile" problem of customers' electricity consumption, improves customer satisfaction and sets up a good social image. At the same time, it has made a positive contribution to regional economic and social development [3]. However, after the extension of the investment interface, the scale of new investment keeps expanding, which brings unprecedented development opportunities to the power grid company, but also puts forward higher requirements for lean management of new investment [4]. Accurate prediction of the new investment of power grid enterprises not only helps to avoid excessive investment and invalid investment, reduce the asset responsibility rate of enterprises, but also helps to improve the precision of investment, improve the efficiency of investment, and promote the healthy and sustainable development of power grid companies.

Many scholars at home and abroad have studied the investment demand of power grid enterprises and proposed some methods for forecasting investment demand [5–8]. Then, after the extension of the investment interface, there is less research on the prediction of new investment by power grid enterprises, and there is almost no new progress. In this paper, the grey correlation analysis method and support vector machine are combined to establish the GRA-SVM model for forecasting new investment demand of the power grid company after investment interface extension. Through the example analysis, the reliability and validity of the model are verified. The model has good reference value and guiding value to the new investment forecast of the power grid company.

2 Overview of Relevant Methods

2.1 Support Vector Machine

In the early 1960s, based on statistical learning theory, Vapnik et al. proposed the Support Vector Machine (SVM), a new machine learning method that can map complex high-dimensional nonlinear problems into linear Spaces and solve high-dimensional nonlinear small sample problems. Meanwhile, SVM has fast convergence speed and strong generalization ability in the optimization process [9]. At present, SVM has developed rapidly and derived a series of improved and extended algorithms, which have been widely used in solving problems such as image recognition, text classification and economic forecasting [10]. The model of SVM can be expressed as:

$$f(x) = \omega \cdot \varphi(x) + b \cdot f(x) \tag{1}$$

where, x is the input feature vector; $f(x)$ is the output value; $\varphi(x)$ is a nonlinear function mapped to a higher-dimensional feature space; ω is the weight vector of the hyperplane; b is the bias vector.

Through the following function [11], support vector machines can solve the optimal solution of nonlinear regression problem.

$$\min_{\omega,b,\xi_i,\xi_*} = \frac{1}{2}\|\omega\|^2 + C\sum_{i=1}^{l}(\xi_{i+}\xi_*) \tag{2}$$

Equation (2) satisfies the constraint condition:

$$s.t.\begin{cases} (\omega \cdot x_i) + b - y_i \le \varepsilon + \xi_i, i = 1, \ldots, l \\ y_i - (\omega \cdot x_i) - b \le \varepsilon + \xi_i^*, i = 1, \ldots, l \\ \xi_i, \xi_i^* \ge 0, i = 1, \ldots, l \end{cases} \tag{3}$$

where, c is the penalty parameter; ε is the insensitive loss; ξ_i, ξ_i^* is the slack variable.

The optimal solution can be obtained by introducing Lagrange formula and Karush-Kuhn-Tucker condition and using their duality problem.

$$\begin{gathered} \max_{a,a^*} V\left(\alpha_i, \alpha_i^*\right) = \sum_{i=1}^{l} y_i\left(\alpha_i - \alpha_i^*\right) \\ - \frac{1}{2}\sum_{i,j=1}^{l}\left(\alpha_i - \alpha_i^*\right)\left(\alpha_i - \alpha_j^*\right)K(x_i \cdot x_i) \\ -\varepsilon\sum_{i=1}^{l}\left(\alpha_i - \alpha_i^*\right) \end{gathered} \tag{4}$$

Equation (4) satisfies the constraint condition:

$$s.t.\begin{cases} \sum_{i=1}^{l}\left(\alpha_i^* - \alpha_i\right) = 0 \\ 0 \le \alpha_i, \alpha_i^* \le c, i = 1, \ldots, l \end{cases} \tag{5}$$

where, α_i, α_i^* is the Lagrange multiplier.

The kernel function can be introduced into SVM algorithm to realize high dimensional computation problems. Since the radial function has better forecast accuracy, the radial function is selected as the kernel function:

$$K(x_i, y_i) = exp\left[-\frac{\|x_i - y_i\|^2}{2\sigma^2}\right] \tag{6}$$

When Eq. (4) is satisfied with Eq. (5), by introducing Eq. (1) and Eq. (6), the final regression fitting function of SVM is:

$$f(x) = \sum_{i=1}^{nsv}\left(\alpha_i - \alpha_i^*\right)K\left(x_i, y_j\right) + b \tag{7}$$

Please refer to literature [12] for the basic principles and detailed algorithm steps of the SVM.

2.2 Grey Relational Analysis

Grey Relational Analysis (GRA) is a quantitative description and comparison method for the development and change of a system, which determines the degree of correlation between factors by determining the geometric similarity of reference data columns and several comparison data columns [13]. The application of GRA involves various fields of social sciences and natural sciences, especially in social and economic fields, such as investment income of various sectors of the national economy, analysis of regional economic advantages, industrial structure adjustment, etc., and the application has achieved good results [14]. The calculation process of GRA is as follows.

(1) Determine the analysis sequence. Determine the reference sequence that reflects the characteristics of the system behavior and the comparison sequence that affects the system behavior. The reference sequence can reflect the behavior characteristics of the system. The comparative sequence consists of factors that influence the behavior of the system. Set the reference sequence (also called mother sequence) for $Y = \{Y(k)|k = 1, 2, \ldots, n\}$; ; Set the comparative sequence (also called sub-sequence) for $X_i = \{X_i(k)|k = 1, 2, \ldots, n\}, i = 1, 2, \ldots, m$.

(2) Dimensionless data processing. Due to the data in each column in the system may be diverse in dimension, it is not convenient or difficult to get the correct conclusion during comparison. Therefore, dimensionless data processing is generally required in GRA. In this paper, the mean value method is used for dimensionless processing of the data in each factor column.

$$y_0(k) = \frac{Y(k)}{\frac{1}{n}\sum_{k=1}^{n} Y(k)}, k = 1, 2, \ldots, n \tag{8}$$

$$x_i(k) = \frac{X_i(k)}{\frac{1}{n}\sum_{i=1}^{n} X_i(k)}, k = 1, 2, \ldots, n; i = 1, 2, \ldots, m \tag{9}$$

(3) Grey relational coefficient calculation. Calculate the relational coefficient of $y_0(k)$ and $x_i(k)$ according to the following Equation:

$$\xi_i(k) = \frac{\min_i \min_k |y_0(k) - x_i(k)| + \rho \max_i \max_k |y_0(k) - x_i(k)|}{|y_0(k) - x_i(k)| + \rho \max_i \max_k |y_0(k) - x_i(k)|} \tag{10}$$

where, $\rho \epsilon (0, \infty)$ is the distinguishing coefficient. The smaller the ρ is, the greater the resolution is. Generally, the value interval of ρ is (0, 1), and the specific value depends on the situation. We usually take $\rho = 0.5$.

(4) Grey relational grade calculation. Because the relational coefficient reflects the correlation degree between the comparative sequence and the reference sequence at each moment, its number is more than one, so the information is too scattered to facilitate the overall comparison. Therefore, it is necessary to concentrate all the relational coefficients into a value. Which is to obtain its average value. The average value is expressed as the quantity of correlation between comparative sequence and reference sequence. The relational grade r_i formula is as follows:

$$r_i = \frac{1}{n}\sum_{k=1}^{n} \xi_i(k), k = 1, 2, \ldots, n; i = 1, 2, \ldots, m \tag{11}$$

(5) Grey relational grade sorting. The correlation sequence is formed by arranging the relational grade of m comparative sequences to the same reference sequence in order of magnitude, which reflects the “pros and cons” relation of each sub-sequence for reference sequence. If $r_1 < r_2$, it indicates that the reference sequence Y is more closely related to the comparison sequence X_2.

3 GRA-SVM Model for Forecasting New Investment Demand of Power Grid Company

3.1 Basic Principles of Building the GRA-SVM Model

There are many factors affecting the new investment demand of power grid companies, such as regional GDP, total industrial output value, new transmission line length, new reporting capacity, etc. These factors contribute differently to the new investment demand. As a result, if all the factors are input as variables in support vector machines, the complexity of the calculation will obviously increase, the performance of the system will be crippled, the time of calculation will significantly skyrocket and the accuracy of the calculation will be affected. Grey relational analysis method provides a solution to such problem.

Grey relational analysis is a method that of measures the correlation between factors. It’s possible to reduce the attribute indexes of information expression through the grey relational analysis method, removing the factors that have a low impact on the new investment demand of power grid companies, reducing the input variables of the support vector machine and the complexity and training time. That is, the grey relational analysis method is primarily adopted to delete the influencing factors of the new investment demand, then the simplified factors are used as the input variables of the support vector machine. Afterwards the support vector machine will learn further. The principle of this method is that although the grey relational analysis method starts from the correlation of the data and find the correlation between the factors, it owns no advantages in forecast, while support vector machine experts in learning, reasoning and classification. What’s more, support vector machine excels in finding rules from a large amount of data, extracting information and has a good dynamic forecast function. Therefore, the two methods are organically combined, enhancing the ability of support vector machine to deal with unstructured, non-linear complex problems.

3.2 Basic Algorithm of the GRA-SVM Model

Combining the grey relational analysis and support vector machine, the GRA-SVM model of the power grid company’s new investment demand forecast is established, and the basic algorithm of the model is given as follows:

Step 1: Preliminarily determine the influencing factors of the new investment demand of the power grid company, take these factors as independent variables; At the same time, the new investment of the power grid company is taken as the dependent variable.

Step 2: Collect the data of the new investment of the power grid company and form a reference series; Accordingly, data that affects the factors of demand for new investment are collected to form a comparative sequence.

Step 3: Using the grey relational analysis method to calculate the correlation between the influencing factors of the new investment demand of the power grid company and the new investment, delete the influencing factors with low correlation.

Step 4: Take the remaining influencing factors as input variables for support vector machine; simultaneously, the new investment is used as the output variable of support vector machine.

Step 5: Select the kernel function of SVM and determine the parameters of the kernel function; Then, the SVM algorithm is used to map the training samples to a high-dimensional space to form a stable SVM model.

Step 6: Use a stable SVM model to forecast the new investment needs of the power grid company.

4 Case Study

Based on the GRA-SVM model forecasting the new investment demand after the extension of the investment interface of ZY Power Grid Company in western China.

4.1 Construct a Factor Index System

According to domestic and foreign literature related to the new investment of power grid companies [15–18], after sorting out and summarizing, we can initially form a list of influencing factors for the new investment demand of power grid companies. Then, through the questionnaire survey method, several rounds of anonymous consultation and feedback were conducted on the opinions of experts in the power industry, in line with the principles of systematisms, comprehensiveness and scientific, the factors affecting the new investment demand of power grid companies were selected. What's more the index system of influencing factors of the investment interface of power grid companies was constructed. The factor index system includes two first-level indexes and 23 s-level indexes, as shown in Table 1.

4.2 Use the GRA Method to Delete Factor Indexes

We start with collecting the index data of ZY Power Grid Company's new investment and influencing factors from 2011 to 2021. Since the data dimensions of each factor index are different, the data of these factor indexes need to be processed in a dimensionless manner using formula (9). At the same time, the use of formula (8) to the data of new investments is dimensionless processing. After the process, the correlation degree r_{ij} of these factor indexes with new investments is calculated separately using the GRA method.

When the correlation degree between a certain factor index X_{ij} and the new investment of the power grid company is $r_{ij} < 0.5$, it indicates that the influence of the factor index on the new investment of the power grid company is very low, as a result the factor index is deleted. According to this deletion principle, combined with the calculation results of the correlation between factor indexes and new investment, 10 factor indexes are deleted, namely: disposable income of residents per capita (X_{14}), investment in fixed assets (X_{15}),

Table 1. The index system of influencing factors of new investment demand

Influencing factor (first-level index)	Factor index (second-level index)
External factor	Regional GDP (X_{11}) Employees in the region (X_{12}) Number of households (X_{13}) Disposable income of residents per capita (X_{14}) Investment in fixed assets (X_{15}) Total retail sales of consumer goods (X_{16}) Total industrial output value (X_{17}) Total output value of Construction Industry (X_{18}) Added value of primary industry (X_{19}) Added value of secondary industry (X_{110}) Added value of tertiary industry (X_{111}) Added value of wholesale and retail trade (X_{112}) Social electricity consumption (X_{113}) Maximum load on the whole society (X_{114})
Internal factor	Newly added 10kV and above transmission line length (X_{21}) Newly added length of low voltage transmission line (X_{22}) Newly added installed capacity of 10kV and above (X_{23}) Newly added low-voltage installation capacity (X_{24}) Electricity price (X_{25}) Power supply load of unit grid asset (X_{26}) Grid capacity-to-load ratio (X_{27}) Grid security (X_{28}) Comprehensive line loss rate (X_{29})

total output value of the construction industry (X_{18}), added value of primary industry (X_{19}), added value of secondary industry (X_{110}), added value of tertiary industry (X_{111}), Added value of wholesale and retail trade (X_{112}), electricity price (X_{25}), grid security (X_{28}), comprehensive line loss rate (X_{29}).

4.3 Use SVM to Build a Forecast Model

Using the GRA method, the main factor indexes affecting the new investment of ZY Power Grid Company were selected, namely: regional GDP (X_{11}), employees in the region (X_{12}), number of households (X_{13}), total retail sales of consumer goods (X_{16}), total industrial output value (X_{17}), social electricity consumption (X_{113}), and maximum load on the whole society (X_{114}); Newly added 10kV and above transmission line length (X_{21}), newly added length of low voltage transmission line (X_{22}), Newly added installed capacity of 10kV and above (X_{23}), newly added low-voltage installation capacity (X_{24}), power supply load of unit grid asset (X_{26}), grid capacity-to-load ratio (X_{27}).

The data of the above factors and indexes of ZY Power Grid Company from 2011 to 2018 is used as the input data of SVM, and the data of the new investment amount

Table 2. Forecast results and error analysis

Year	Actual value of new investment (ten thousand yuan)	Forecasted value of new investment (ten thousand yuan)	Absolute error (ten thousand yuan)	Relative error (%)
2018	80.25	79.51	−0.74	−0.92%
2019	86.96	85.27	−1.69	−1.94%
2020	87.73	86.19	−1.54	−1.76%
2021	85.92	85.63	−0.29	−0.34%

of ZY Power Grid Company from 2011 to 2018 is used as the output data of SVM, and the SVM algorithm in SPSS software is used to obtain a stable SVM model. Using this model, ZY Power Grid Company's new investment demand from 2019 to 2021 is forecasted after the fact to test the effectiveness of the above model. The actual and forecast values of ZY Power Grid Company's new investment from 2019 to 2021 are shown in Table 2.

It can be seen from Table 2 that the absolute values of the relative error of forecasted values according to the GRA-SVM model are between 0.34% and 1.94%, and the absolute values of the absolute error of forecasted values are between 2900 and 16900 yuan. The forecast accuracy is quite high. In this model, the selection of independent variables reduces the influence of the modeler's subjective factors to a greater extent, avoids the noise interference of redundant data, and makes the model closer to the situation of the real system. As a result, it has better predictive reliability. Therefore, the GRA-SVM model can be used as a forecast model for the new investment demand of ZY power grid company.

5 Conclusion

At present, forecasting the new investment demand after the extension of the investment interface of power grid companies is a hot but difficult issue in the field of power grid research. Based on the principle of support vector machine and the grey relational analysis method, this paper establishes the GRA-SVM model for extending the forecast of new investment demand in the investment interface of power grid companies, and the results show that:

(1) When adopting the GRA-SVM model to forecast new investments, it is mainly through screening independent variables and selecting factors that have important impacts on new investments, thus avoiding the influence of subjective factors.
(2) As a method in machine learning, SVM can solve some nonlinearity, uncertainty, small sample and other problems, and has good applicability in the forecast of investment demand of power grid companies.
(3) The GRA-SVM model established by using the support vector machine principle and the grey relational analysis method has high forecast accuracy and reliable forecast

results, which provides a new scientific method for the forecast of new investment demand after the extension of the investment interface of power grid companies.

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