Research on Investment Demand Forecast of Power Grid Based on Grey System Theory

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Abstract. The forecast of power grid investment demand is of great significance for reasonably arranging the investment of power grid construction funds and reducing the cost of funds. In this paper, a forecasting model of power grid investment demand based on grey system theory is proposed. Firstly, the correlation coefficient method is used to analyze the correlation between the investment demand of power grid and its influencing factors, and the key factors affecting the investment demand of power grid are selected. Then the grey relational grade analysis theory is used to construct the investment demand forecasting model of power grid. The validity and rationality of the model are verified by an example of power grid investment prediction in a certain area. The model is of great theoretical and practical significance for the coordination of power grid investment and the scientific planning of power grid investment scale.

1. Introduction
With the rapid development of social economy and the continuous growth of electricity load, the construction of power grid in China is increasing [1]. Power grid investment is not only related to the development of regional economy, the normal production and life of residents, but also has a profound impact on the sustained, healthy and rapid development of regional society [2-3]. How to calculate the investment demand of power grid scientifically and reasonably, and then optimize the investment scale and arrange the infrastructure projects reasonably, has become an urgent problem to be solved by power grid companies. In reference [4], a forecasting model of power grid investment demand based on co-integration theory and error correction model is proposed. On the basis of long-term equilibrium model, a short-term adjustment relationship model is constructed by error correction model to improve the accuracy of short-term forecasting. According to the relationship between the investment demand of power grid and the development stage of power grid, an adaptive bell curve considering environmental factors is proposed to describe the investment demand of power grid in reference [5]. In reference [6], the electric power investment demand of China from 2008 to 2020 is forecasted by using the electric power investment prediction model of the International Energy Agency, and the requirements of active energy policy on power grid investment are analyzed at the same time. In reference [7], based on price elasticity, a two-level coordinated programming model of wind power and transmission network investment demand is introduced to minimize the cost paid by users and the
investment cost of wind power and transmission. In reference [8], the method of error correction and improved neural network is used to predict the demand of power investment in Taiwan. In reference [9], the latest progress in the research of power demand forecasting in recent 40 years is reviewed, and the different models of power demand forecasting and its development trend are put forward. In reference [10], autoregressive, simple linear regression and multiple linear regression models are used to predict the long-term investment demand of power grid. The prediction results of different forecasting methods are compared by various statistical methods, and the most accurate forecasting model is selected.

In this context, this paper uses the correlation coefficient method to analyze the correlation between the investment demand of power grid and its influencing factors, and then selects the key factors that affect the investment demand of power grid. Then the grey relational grade analysis theory is used to construct the investment demand forecasting model of power grid. The model is of great theoretical and practical significance for the coordination of power grid investment and the scientific planning of power grid investment scale.

2. Methodology

2.1. Correlation coefficient analysis

Correlation analysis is a statistical analysis method that studies the correlation between two or more random variables. The correlation analysis is based on the calculation of the covariance and the standard deviation of each variable, and the correlation coefficient between the factors is obtained according to the product difference method. The basic principles and calculation methods are as follows:

Calculate the standard deviation of each factor itself.

\[
S_x = \sqrt{(n-1) \left( \sum (x_i - \bar{x})^2 \right)} \quad (1)
\]

\[
S_y = \sqrt{(n-1) \left( \sum (y_i - \bar{y})^2 \right)} \quad (2)
\]

Calculate the covariance between variables.

\[
S_{xy} = \frac{\sum_{i=1}^{n} (X_i - \bar{X})(Y_i - \bar{Y})}{(n-1)} \quad (3)
\]

The correlation coefficients of each variable were calculated.

\[
r_{xy} = \frac{S_{xy}}{S_x \cdot S_y} \quad (4)
\]

Finally, the correlation coefficient between the variables is reached, and the correlation coefficient matrix is formed.

\[
R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1y} \\ r_{21} & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ r_{s1} & \cdots & \cdots & r_{sy} \end{bmatrix} \quad (5)
\]

According to the correlation coefficient matrix to judge the correlation of variables, the correlation between variables is divided into four categories.
Table 1. Correlation classification table

| Correlation coefficient (absolute value) | classification         |
|----------------------------------------|------------------------|
| <0.3                                   | Weak correlation       |
| 0.3~0.5                                | Moderate correlation   |
| 0.5~0.8                                | Significant correlation|
| 0.8~1                                  | High correlation       |

2.2. Grey system theory
The analysis of reasonable investment demand of power grid enterprises is a grey system. There are many influencing factors and they are closely related to each other, so it is appropriate and feasible to use grey system theory for evaluation. The basic principles are as follows:

Enter the original data and select the corresponding sequence of independent and dependent variables.

\[
x_{mn} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\
                        & x_{21} & x_{22} & \cdots & x_{2n} \\
                        & \vdots & \vdots & \ddots & \vdots \\
                        & x_{m1} & x_{m2} & \cdots & x_{mn} 
\end{bmatrix}
\] (6)

The independent variable sequence and dependent variable sequence in the original data sequence are transformed effectively. After the transformation, each sequence can be dimensionless, and then the grey correlation coefficient can be calculated.

Through the grey relational calculation model, the correlation between each independent variable sequence and dependent variable sequence is found.

\[
\varepsilon_i = (\varepsilon_1, \varepsilon_2, \cdots, \varepsilon_n)^T
\] (7)

The weight of the relationship between each sequence and dependent variable is calculated by correlation coefficient, and the relation function between independent variable and dependent variable is established.

\[
w_i = \frac{\varepsilon_i}{\varepsilon_1 + \varepsilon_2 + \cdots + \varepsilon_n}
\] (8)

Determine the future trend of independent variable sequence and calculate the prediction value of dependent variable.

\[
\begin{bmatrix} y_{j+1} \\
                y_{j+2} \\
                \vdots \\
                y_{j+i} \end{bmatrix} = \begin{bmatrix} w_1 & w_2 & \cdots & w_{m} \\
                        & x_{1j+1} & x_{1j+2} & \cdots & x_{1j+i} \\
                        & x_{2j+1} & x_{2j+2} & \cdots & x_{2j+i} \\
                        & \vdots & \vdots & \ddots & \vdots \\
                        & x_{nj+1} & x_{nj+2} & \cdots & x_{nj+i} \end{bmatrix}
\] (9)

3. Case Study
In this section, taking A Power Grid Company as an example, the key factors affecting the investment demand of power grid are selected, and the investment demand of power grid is forecasted by using the calculation model of investment demand of power grid.

3.1. Key factor selection
This section analyzes the influencing factors of power grid investment demand, which are more comprehensive and quantifiable data materials. It mainly includes seven factors: GDP, population, electricity consumption of the whole society, power supply of power grid, electricity sales of power grid.
grid, installed capacity of power supply and urbanization rate. From these seven factors, the key factors affecting the investment demand of power grid are selected.

The raw data for the seven factors in Province A are as follows:

| Year | GDP (billion yuan) | Population (Ten thousand people) | Electricity consumption of the whole society (Billion kWh) | Grid power supply (Billion kWh) | Power grid sales (Billion yuan) | Power installed capacity (Billion kWh) | Urbanization rate (%) | Power grid investment (Billion yuan) |
|------|-------------------|---------------------------------|---------------------------------------------------------|--------------------------------|---------------------------------|--------------------------------------|---------------------|------------------------------------|
| 2003 | 1244.3            | 7406                            | 150.5                                                   | 105.4                          | 96.2                            | 223.8                                | 47                  | 9.5                                |
| 2004 | 1500.4            | 7433                            | 182.0                                                   | 127.0                          | 116.0                           | 284.3                                | 48                  | 12.7                               |
| 2005 | 1859.9            | 7475                            | 219.3                                                   | 149.7                          | 137.3                           | 427.1                                | 51                  | 13.6                               |
| 2006 | 2174.2            | 7550                            | 257.0                                                   | 213.4                          | 199.5                           | 530.4                                | 52                  | 15.0                               |
| 2007 | 2601.8            | 7727                            | 295.2                                                   | 247.2                          | 231.4                           | 559.9                                | 53                  | 18.1                               |
| 2008 | 3098.2            | 7762                            | 311.8                                                   | 265.2                          | 248.5                           | 544.2                                | 54                  | 21.5                               |
| 2009 | 3445.7            | 7810                            | 331.4                                                   | 280.6                          | 263.2                           | 565.0                                | 56                  | 21.3                               |
| 2010 | 4142.5            | 7869                            | 386.4                                                   | 333.5                          | 313.5                           | 645.8                                | 61                  | 19.9                               |
| 2011 | 4911              | 7899                            | 428.2                                                   | 376.0                          | 353.8                           | 699.2                                | 62                  | 27.2                               |
| 2012 | 5405.8            | 7920                            | 458.1                                                   | 404.3                          | 382.0                           | 753.2                                | 63                  | 29.8                               |
| 2013 | 5975.3            | 7939                            | 495.7                                                   | 445.5                          | 419.0                           | 822.9                                | 64                  | 25.8                               |
| 2014 | 6508.8            | 7960                            | 501.3                                                   | 446.9                          | 426.4                           | 860.0                                | 65                  | 29.8                               |
| 2015 | 7011.6            | 7976                            | 511.5                                                   | 455.9                          | 436.4                           | 952.9                                | 67                  | 32.1                               |
| 2016 | 7603.6            | 7999                            | 545.9                                                   | 479.6                          | 459.5                           | 1014.8                               | 68                  | 38.0                               |
| 2017 | 8590.1            | 8029                            | 580.8                                                   | 514.0                          | 493.1                           | 1145.7                               | 69                  | 46.4                               |

With the help of spss software, the key factors affecting the investment demand of A Power Grid Company are obtained by using the correlation coefficient analysis method, as shown in Table 3.

| Investment amount | GDP       | 0.967 | Population | 0.887 | Electricity consumption of the whole society | 0.943 | Grid power supply | 0.934 | Power grid sales | 0.938 | Power installed capacity | 0.962 | Urbanization rate | 0.929 |

As can be seen from Table 3, the correlation between power grid investment and each index is high, reaching more than 88%. Therefore, it is determined that the key factors affecting the investment of power grid are GDP, population, electricity consumption of the whole society, power supply of power grid, electricity sales of power grid, installed capacity of power supply and urbanization rate.

3.2. Investment demand forecast

According to the key factors that affect the investment demand of A company, the neural network is used to predict the investment demand of power grid. First of all, the training data are used to train the grey neural network, so that the network has the ability to predict. The grey neural network forecast uses the network to predict the investment demand, and judges the network performance according to the forecast error. The 10-year data of power grid investment demand is used as the training data to train the network. the network has learned and evolved 1000 times, and the remaining data are used to evaluate the prediction performance of the network.

The results of Company A’s 2018-2022 grid investment demand forecast are as follows.

| Year | 2018        | 2019        | 2020        | 2021        | 2022        |
|------|-------------|-------------|-------------|-------------|-------------|
| Forecast of investment demand (Million yuan) | 59.84334 | 61.40016 | 66.76341 | 67.10197 | 69.05288 |
From the forecast result diagram and the forecast error diagram, it can be seen that the forecast error of A company is less than 12% in each year, and the forecast result is good.

4. Conclusion
On the basis of analyzing the correlation between the investment demand of power grid and its influencing factors, this paper studies a forecasting model of investment demand of power grid based on grey system theory. The model solves the problems such as the difficulty of forecasting the development demand of power grid and the complex relationship between power grid investment and influencing factors. The related research results have important theoretical and practical significance for improving the efficiency of power grid investment and realizing the scientific, lean and standardized construction of investment management by power grid companies.

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