Research on the relevance of the cost of power cable and macroeconomic indicators based on comprehensive cost index calculation

Hanze Wang¹², Xin Ma¹, Kai Huang¹² and Jinping Liu¹²*

¹ School of Economics and Management, North China Electric Power University, Beijing 102206, China
² Beijing Key Laboratory of New Energy and Low-Carbon Development, North China Electric Power University, Beijing, 102206, China
*Corresponding author’s e-mail: hbdlljp@163.com

Abstract. With the rapid development of productivity, the demand for power supply is increasing dramatically. As a safe and reliable way of power transmission, the investment scale of power cable engineering is increasing. This paper innovatively puts forward a calculation method of cable line engineering’s comprehensive cost index, which accurately reflects the variations in cable line engineering’s comprehensive costs with different voltage levels and various construction technologies within a certain period of time. Furthermore, it explores cable line engineering’s comprehensive cost index and the correlation between macroeconomic indicators. The correlation coefficients between research objects are calculated. The research shows that there is a strong correlation between the law of power cable engineering cost hole and macroeconomic index, and the fluctuation of raw material price index also has a profound impact on the cost.

1. Introduction

With the rapid development of the economy and society and the further improvement of power transmission capabilities, the scale of investment in power transmission and transformation projects is expanding, and the power supply level is constantly improving [1]. Compared with traditional overhead lines, the power cable project has the advantages of a smaller area, high power supply stability and being less influenced by natural conditions such as lightning, wind and rain. In recent years, the scale of the power cable projects has been expanding in various types of grid projects. Therefore, a thorough study of the relationship between the power cable cost index and macroeconomic index. Understanding the correlation between macroeconomic fluctuations, power cable costs and exploring the leading driving factors in the process of power cable cost fluctuations that are caused by macroeconomic fluctuations will help to better predict the development trend of project costs and allow for timely adjustments and investments.

The characteristics of power cable engineering include small areas, high transmission stability, and being able to better meet of power cablethe requirements of large-scale urban internal transmissions. The construction of power cables mostly occurs in urban areas and makes great use of the existing preburied pipelines and tunnels in the city. Therefore, most of the civil construction costs are far less than the electrical installation costs, and the equipment purchase costs account for a large proportion of the installation costs [4]. In the power cable construction costs, equipment purchase fees refer to the costs
of acquiring all kinds of equipment that meet the fixed asset standards for the construction project, such as cables, terminal cable joints, intermediate cable joints, grounding boxes, etc. The materials that are required for the above equipment cover conductor materials (such as copper and aluminum), armored layer materials (steel belts), PVC materials, section steel, cable joint metal, etc., which are important statistical indicators of the producer price index (PPI). When the macroeconomy fluctuates under the influence of the market, the costs of cable projects will also fluctuate due to the changes in the prices of raw materials, which is especially obvious in projects with little or no civil construction. This shows that there is a strong correlation between cable project costs, raw material prices and macroeconomic indexes [5].

2. Materials and methods

2.1. Model building steps

This paper mainly studies the relationship between the cost of power cable and macroeconomic changes through the method of Pearson correlation test between the main indicators. Using the principal component analysis to reduce the dimension of the original data, the corresponding principal component data are obtained and substituted for the pauta criterion abnormal data screening model. After eliminating the non-representative special projects, Pearson correlation coefficient among the main indicators is calculated, so as to analyze the correlation between the cost of power cable and macroeconomics. The model building model building mainly includes the following steps:

(1) Determine the indicators that cause the fluctuation of power cable project cost, collect sample engineering data, and clean up the original data.

(2) Principal component analysis (PCA) is used to reduce the dimension of the preliminarily processed sample data, and anomaly project which is far beyond the average level and not representative is eliminated by the pauta criterion anomaly data screening model.

(3) According to the calculation method of project cost index, the power cable project is distinguished according to voltage level, technical scheme, and construction method, and the corresponding investment weight is determined, and the comprehensive cost index of power cable project is calculated.

(4) The Pearson correlation test model is used to calculate the correlation coefficient between the comprehensive cost index and macroeconomic index of power cable project, and then the relationship between the power cable project and macroeconomic fluctuation is analyzed.

2.2. Computation of the comprehensive cost index (CCI)

In the construction of the power grid project cost index, the single index growth rate comparison method is often used to analyze the changing trends of project costs. However, this method has some limitations. First, it is difficult to reflect the differences among various indicators when using a single index for comparative analysis, and it is unable to accurately grasp the overall cost trend of power grid projects [6]. Second, the comparability of the corresponding indicators is poor when the construction schemes and scale of a certain type of project greatly differ in each year. Considering the special structure of the unit cost of a power cable project, this paper puts forward a comprehensive cost index for calculating the power cable project costs. The main basis for the division of the technical schemes is to select the technical conditions with respect to the engineering types (electrical/civil engineering), voltage levels, cable types, cable cross-sectional area, etc. that have great impacts on the costs of power cables and can experience great respective changes. According to the model framework, the formulas for calculating the comprehensive cost index of the power cable project can be obtained as follows:

\[ P = P_{SE} + P_{CC} \]
\[ P_{SE} = \sum a_i \times \sum a_{i,j} \times w_m \]
\[ P_{CC} = \sum a_i \times \sum a_{i,j} \times w_{m+1} \]
Where, $\bar{P}$ is the comprehensive cost index of the power cable project, $\bar{P}_{EI}$ is the comprehensive cost index of the cable installation engineering, $a_i$ is the investment weight of the voltage grade I project of the power cable project, $a_{i,j}$ is the investment weight of the technical scheme J project of the voltage grade I project of the power cable project, $w_m$ is the average annual costs of the technical scheme J project of the voltage grade I project of power cable project, $w_{m-1}$ is the average costs in year $m-1$ of the technical scheme project of type I voltage grade J of the power cable project, $\bar{CC}_{PI}$ is the comprehensive cost index of the civil construction of the power cable project, $b_i$ is the investment weight of the construction scheme project of type I of the power cable project, $b_{i,j}$ is the investment weight of the first type of construction scheme with the Jth type of technical scheme, $v_m$ is the average annual costs of the second type of construction scheme with the Jth type of technical scheme, and $v_{m-1}$ is the average costs in year $m-1$ of the category I construction scheme and the category J technical scheme of the power cable project.

3. Case study

3.1. Indicator screening and quantification

In this paper, 64 power cable projects in a certain area of China from 2012 to 2017 are selected as the object of the empirical calculation. The construction costs of power cables are divided into two parts: electrical installation and civil construction. This paper identifies the influencing factors of the two major cost modules of electrical installation and civil construction, and then summarizes the influencing factors of the overall costs. The identification process is shown in Figure 1.

![Selection Chart of Influencing Factors of Cost](image)

Figure 1. Selection Chart of Influencing Factors of Cost

3.2. Dimension reduction and screening of the sample

To eliminate the influences of the different dimensions and the magnitudes of each index, we retain all the information of the original data as much as possible, and improve the analytical accuracy. Therefore, the original principal component analysis method was improved by means of homogenization. The matrix for further standardization is obtained after a single trend change of the original index data is obtained.

$$z_{ij} = \frac{x_{ij}}{x_j}, \quad i = 1, 2, \cdots, p$$

(4)
Here, \( x = \frac{1}{n} \sum_{j=1}^{n} x_{ij} \). Thus, the homogenizing matrix \( Z = (z_{ij})_{n \times p} \) is obtained, and then the sample covariance matrix of the averaging matrix \( S = (s_{ij})_{p \times p} \) is calculated

\[
S_{ij} = \frac{1}{n-1} \sum_{j=1}^{n} (z_{ij} - z_i)(z_{ij} - z_j)
\]  

(5)

Here, \( z_i = \frac{1}{n} \sum_{j=1}^{n} z_{ij} \).

Finally, the covariance matrix can be used for principal component analysis. This method can reflect all the information of the coefficient matrix in the corresponding covariance matrix without changing the correlation coefficients between the indicators.

The corresponding eigenvalues, variance contribution rate and cumulative variance contribution rate of each principal component are obtained by using the SPSS software. To make the original index information that is contained in the principal component more comprehensive and to avoid missing important information, the first seven principal components were selected, and their cumulative contribution rate reached 77.78%. That is, 77.78% of the original index information was synthesized to meet the calculation requirements. Seven principal components are replaced by the original index as a new comprehensive index to replace the Pauta criterion abnormal data screening model. The data bar function diagram before and after the screening is drawn by using the MATLAB software. As seen from Figure 2, data filtering has significantly improved the overall quality of the data.

![Figure 2. Bar function bar chart comparison before and after data filtering](image)

3.3. Correlation test

The electrical installation costs in the power cable engineering comprehensive cost index are much higher than the civil installation costs, accounting for approximately 80% of the total costs. With respect to the electrical installation costs, equipment purchase costs account for a large proportion of the total investment, usually accounting for more than 60% of the total costs, most of which is the purchase costs of cables and cable joints. The prices of the above main equipment are not stable in the market and are greatly affected by macroeconomic fluctuations and raw material prices. In this paper, the CPI and PPI are selected as representative macroeconomic indicators for the calculations.

The utilization rate of copper core cable is very high in power cable engineering. Copper is the main raw material of cables, and its price fluctuation has a significant impact on the total costs of power cable engineering. In addition, as the most important type of nonferrous metal, the price fluctuation range of copper is increasing with the development of its futures and spot markets. Therefore, taking copper as an example to study the driving factors of the macroeconomic fluctuations affecting the construction costs of power cables can accurately reflect the mechanism of the above effect on the closed loop. According to the spot Copper Barycenter Price (CBP) and the corresponding macroeconomic indicators in the past five years, the correlation coefficients are calculated as Table 1.
Table 1. Relevance Analysis of the Comprehensive Cost Index and the Macroeconomic Indexes of Power Cables in Certain Areas.

|       | CCI  | CPI     | PPI      | CBP    |
|-------|------|---------|----------|--------|
| CCI   | 1    | .910*   | .887*    | .889*  |
|       | (0.000) | (0.032) | (0.045)  | (0.044) |
| CPI   | .910*| 1       | .760     | .661   |
|       | (0.032) | (0.000) | (0.136)  | (0.224) |
| PPI   | .887*| .760    | 1        | .923*  |
|       | (0.045) | (0.136) | (0.000)  | (0.025) |
| CBP   | .889*| .661    | .923*    | 1      |
|       | (0.044) | (0.224) | (0.025)  | (0.000) |

*Note: * means that the index is significantly correlated at the 0.05 level (bilateral), and the sig. is in brackets.

From the above chart, it can be seen that the comprehensive cost index of the power cable project is significantly correlated with the CPI and PPI; the correlation coefficients are 0.910 and 0.887, respectively. Furthermore, the correlation coefficient between the comprehensive cost index of the power cable project and the price of copper, its main raw material, is 0.889.

4. Conclusion

The comprehensive cost index calculation model of power cable engineering that is constructed in this paper based on the PASSCHE index method can objectively reflect the general trend of power cable engineering costs, as well as the comprehensive or subitem cost index of power cable engineering with different technical schemes, construction scales and construction natures. Based on the power cable engineering cost data, this paper constructs the power cable engineering cost shock driving factor index system, selects the sample set that can reflect the overall true level, and calculates the correlation coefficients between the power cable engineering comprehensive cost index and the macroeconomic indexes, among which the comprehensive cost index of cable engineering has significant correlations with the CPI and PPI with correlation coefficients of 0.910 and 0.887, respectively. The strong correlation indicates that macroeconomic fluctuations will significantly impact the power cable engineering costs, and the leading driving factor of the effect of macroeconomic fluctuations on power cable engineering costs is the price of raw materials.

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