Investment demand forecasting model of power grid based on different development paths

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Abstract. Under different economic and social conditions, the development of power grid faces different development foundations, development speeds, development forms, and development goals. The development path and development pattern of the power grid have many commonalities in a certain space-time range, and there are also some natural differences. In terms of analysis of the development path of power grids and the study of the quantification system, which considering the spatial and temporal differences, the research on the spatial-temporal matching of the development path characteristics of the provincial, city, county (district) level units and the prediction of the development pattern is insufficient, and it is impossible to predict the provincial, city, county (district) level. According to the development path characteristics and development forms of provincial, city, and county-level units, this paper establishes a quantitative relationship between grid investment and differential indicators of grid development paths. Based on the analysis of Hunan Province, Changsha, and Changsha County, it is proved that the power grid investment demand prediction models based on different development paths can solve the personalized demand for investment due to differences in power grid development paths, improves the analysis dimension and the level of refinement of investment demand forecasting, and it also provides a reference for forming a scientific investment decision system.

1. Introduction

Electric power supply bears the important mission of ensuring economic and social development. The imbalance and inadequacy of economic and social development are also deeply reflected in the development of the power grid. Under different economic and social conditions, power grid development faces different development foundations, development speeds, development forms, and development goals. The development path and development pattern of the power grid have many commonalities in a certain space-time range, and there are also some natural differences. Therefore, in the process of investment decision-making, this feature can be used to predict the development speed, development form, and development goals of the power grid, so as to obtain the grid investment needs of different development paths that meet its development characteristics.

Regarding the study of the analysis and quantification system of grid development path which considering space-time differences, the current researches are focused on the economic and social
development path, industrial transfer and the law of self-development of the power grid\textsuperscript{[1-8]}. The research on the spatio-temporal matching of unit development path characteristics and the prediction methods of development patterns is insufficient, it is impossible to predict the development path of provincial, city, county (district) level units, and it is difficult to provide a reference for grid investment decisions\textsuperscript{[9]}.

According to the development path characteristics and development forms of provincial, city, and county-level units, this paper establishes a quantitative relationship between grid investment and grid development path difference indicators, and uses a co-integration-error correction model to predict grid investment demand. It can solve the individualized demand for investment due to the differences in the development path of the power grid, improve the analysis dimension of investment demand measurement and the level of refinement of investment decisions, and provide a reference for forming a scientific investment decision system.

Differences in power grids with different development paths

1.1. Definition and structure of grid development path
Starting from the perspectives of development foundation, development goals, development speed, development form and other external socio-economic needs and internal grid development status. The grid development basis refers to the set of index values that characterize the characteristics of the grid at the beginning of the study period; the grid development goal refers to the set of index values that characterize the characteristics of the grid at the end of the study period; The development pattern of the power grid refers to the set of index values that characterize the characteristics of the power grid at each point in time in the study period. That is, the development path of the power grid refers to the change process of the characteristic index set of the power grid from the beginning to the end.

It extracts the power grid development path indicators according to provinces, cities, and counties to drive the different paths of power grid development, and establish an evaluation index system for grid development path differences. As a basis, the investment needs of power grids at all levels are calculated\textsuperscript{[10][11]}.

1.2. Grid investment demand measurement index system for different development paths
The feature set of the development path indicators of the provincial, city, and county (district) three-level power grids are different. This difference is mainly caused by the scale generated by the size of the space, and it affects the stage positioning and development path selection.

1.2.1. Provincial grid investment demand forecast index system
The development and change of the provincial power grid is a reflection of the changes in the development of the provincial economy, and the provincial economy as a whole shows a steady growth characteristic, and the probability of a jump is low. Therefore, the development of the power grid is strong and smooth. Selection of indicator set output indicators. Mainly consider the transmission grid which above 500kv, and inspect the coordinated development of the power grid with the province as the unit.
1.2.2. City grid investment demand forecast index system

The scale of the municipal grid is between the provincial and county levels, and the change process has certain fluctuations, that is, to respond to the smoothness of economic development, and to reflect the step characteristics of grid construction. It mainly consider the distribution network of 110kv and above, consider the coordination of municipal grid and economic development, the level of grid technology and equipment, and grid services and service capabilities.

The development and change of the municipal grid is a reflection of the changes in the development of the municipal economy, it shows the characteristics of step and steady changes between years and spans. For this reason, fine-tuning is needed on the basis of the provincial power grid indicator system, and the indicator system shown in Figure 2.

1.2.3. County grid investment demand forecast index system

County-level power grids are small in scale and have large fluctuations in power grid development. The annual coupling between economic and grid development is weak. The power grid development law has a strong policy impact, and it also needs to meet the needs of local economic development. The main consideration is the rural distribution network. The development and change of the county-level power grid is a reflection of changes in the development of the city-level economy, it must cover the local economic development plan for a period of time To this end, adjustments need to be made on the basis of the municipal grid index system, and the index system shown in Figure 3 is established.
2. Forecast model of investment demand for power grid with different development paths

2.1. Model approach
Grid investment will be affected by various factors, and the main impact indicators and their proportions of grid investment at the three levels of provinces, cities, and counties are quite different. Provincial power grids mainly consider 500kv and above transmission grids, which mainly involve the coordination of different voltage levels and the power generation and power balance between various provincial power grids; municipal grids mainly consider 110kv and above power distribution networks, mainly involving municipal The coordination relationship between the power grid and economic development; county-level power grids are mainly concerned with rural distribution networks. The indicators involved are researched from two aspects of socio-economic and power grid development. Including GDP, per capita disposable income, per capita electricity consumption, power supply reliability rate, comprehensive voltage qualification rate and proportion of intelligent substations, etc. Based on past experience, except for the macro policies factors that cannot be quantified, the remaining quantifiable factors are non-stationary. Based on this feature, this paper uses the co-integration-error correction model to predict the investment demand of the power grid.

The significance of the co-integration relationship is that although the variables have their own long-term fluctuation laws, they are co-integration, there must be a long-term stable proportional relationship between them. This meaning is also the basis of the model. The advantage of the error correction model is that when the equation is estimated, because the equation contains multi-order lag terms, multi-collinearity often occurs between the variables, which affects the estimation accuracy, and the variables after the difference are almost orthogonal, which avoids multiple Linear.

2.2. Establishment of Forecast Model for Investment Demand of Power Grid
Grid investment and its influencing factors are usually non-stationary variables, but there is a long-term co-integration relationship between non-stationary variables of the same order. Therefore, this paper first uses the ADF test to verify the same-order single-integrity of grid investment and its influencing factor variables; then uses co-integration tests to find the co-integration relationship between them, finds the co-integration vector, and establishes long-term equilibrium Relationship model; Finally, an error correction model is constructed based on the co-integration relationship, and a short-term adjustment relationship model between the grid investment and its influencing factors is derived. The establishment of the model is based on the statistical data of the three-level power grids of Hunan Province, Changsha, and Changsha County from 2003 to 2018, with the help of econometric analysis software EViews.

The process of grid investment demand prediction model based on co-integration-error correction is as follows:
Variable selection

Data preprocessing

Stationarity test, put forward single integer variables of different orders

Co-integration test for the remaining variables, and remove variables with insignificant co-integration coefficients

Co-integration test of the remaining variables is continued until a co-integration equation with significant coefficients is obtained

Establish error correction model based on co-integration equation

Derive a short-term regulatory relationship model

Building an error correction model

Figure 4. Grid investment demand forecasting model flow chart

1) According to the provincial, city and county three-level power grids, different index systems are selected from the two aspects of socio-economic and grid development.

2) When using E-views for ADF test, if the ADF statistic is less than the critical value, the tested variable is stable and the index is retained; otherwise, it is not stable and the index eliminated;

3) Use E-views to perform the Johansen co-integration test, solve the co-integration vector, and obtain the long-term equilibrium equation between the grid investment demand and the index system;

4) On the basis of estimating the co-integration relationship, the short-term adjustment relationship model of the investment demand of the power grid can be determined through the estimation error correction model;

5) Select the 1st to 2nd order lag variables (the lag interval is consistent with the Johansen co-integration test) and the error correction term, and then gradually remove the non-significant variables, and finally get the error correction model;

3. Example analysis

3.1. Investment Demand Forecast Model of Hunan Power Grid
Figure 5. Time series of indicators

It can be seen from Figure 5 that the indicators in the selected indicator system show a clear upward trend and show unstable characteristics, so the ADF test type of each variable level term should include intercept terms and trend terms; urbanization Rate, per capita power consumption, power supply reliability, and smart substation share have no obvious time trend, and become relatively stable compared to the original sequence, with the characteristics of white noise, so the ADF test type of the first order difference term should include the intercept term It does not include trend terms. The ADF test results in Table 1 show that the horizontal time series of each variable are non-stationary. But after the first order difference, except for lnGDP, lnADC, lnRP, each variable can form a stable time series.

Cointegration is only possible for single-order integer sequences of the same order, so lnGDP, lnADC, lnRP is first removed before the cointegration test. It can be seen from Figure 5 that some variables are basically coincident. In order to avoid multicollinearity, some variables can be eliminated. So the variables entering the model are: lnCLR, lnUR, lnPDI

By E-views software, using Johansen test method, the co-integration vector is [1,-0.553,0.563,-480.723,2209.876]

Long-term equilibrium equation:

\[ \ln JV = -2209.876 + 0.553\ln CLR - 0.563\ln UR + 480.723\ln PDI \]  \hspace{1cm} (1)
Table 1. Test results of ADF

| Test variable | ADF     | P      | 1%      | 5%      | 10%     |
|---------------|---------|--------|---------|---------|---------|
| ln GDP        | -2.497530 | 0.3267 | -4.323979 | -3.556823 | -3.228734 |
| ln PDI        | 4.455365  | 1      | -4.004425 | -3.093896 | -2.690439 |
| ln PHC        | 0.504589  | 0.9988 | -4.323979 | -3.586423 | -3.215830 |
| ln RP         | -0.205858 | 0.9121 | -4.200056 | -3.175352 | -2.728985 |
| ln UR         | -5.578394 | 0.0001 | -3.699871 | -2.978763 | -2.627420 |
| ln CLR        | 0.083752  | 0.9988 | -4.323979 | -3.580623 | -3.223340 |
| ln PSC        | 0.504889  | 0.9988 | -4.323979 | -3.586423 | -3.215830 |
| ln ADC        | 0.482116  | 0.9777 | -4.125290 | -3.147720 | -2.713751 |
| ln ASAI       | 0.416454  | 0.0197 | -4.125290 | -3.147720 | -2.713751 |
| ln CVQR       | -2.753948 | 0.0784 | -3.625671 | -2.958283 | -2.628860 |
| ln PIS        | -5.058555 | 0.0004 | -3.697625 | -2.756863 | -2.647330 |
| ln PNEI       | -4.244010 | 0.0027 | -3.526387 | -2.976263 | -2.685420 |

Based on the estimated co-integration relationship, the short-term adjustment relationship model of the investment demand of the power grid can be determined through the estimation error correction model.

Error correction equation:

$$\Delta \ln I^V_t = -0.29\Delta \ln CLR_t + 4.819\Delta \ln UR_t + 285.454\Delta \ln PDI_t - 0.056 \\
-0.669(\ln IV_{t-1} + 2209.876 - 0.553\ln CLR_{t-1} + 0.563\ln UR_{t-1} - 480.723\ln PDI_{t-1})$$

(2)

Figure 6. Analysis of the investment demand forecasting model of Hunan Province
3.2. Changsha Power Grid Investment Demand Forecasting Model

The same steps as in 4.1 can be obtained. The variables entering the model are: \( \ln CVQR, \ln PIS, \ln PDI \)

The long-term equilibrium relationship between Changsha’s investment demand and its indicator system is:

\[
\ln IV = 28.15 - 1.534 \ln PDI + 5.934 \ln CVQR - 8.464 \ln PIS
\]  

(3)

Error correction equation:

\[
\Delta \ln IV = 35.75 - 0.174 \Delta \ln PDI_r + 4.299 \Delta \ln CVQR_r - 4.447 \Delta \ln PIS_r - 0.5454(\ln IV_{r-1} + 54.58 + 126.3 \ln PDI_{r-1} - 52.6 \ln CVQR_{r-1} - 15.55 \ln PIS_{r-1})
\]  

(4)

Figure 7. Analysis of the investment demand forecasting model of Changsha

3.3. Changsha County Power Grid Investment Demand Forecasting Model

The same steps as in 4.1 can be obtained, the variables entering the model are: \( \ln PHEC, \ln PDI \)

The long-term equilibrium relationship between the investment demand of Changsha County power grid and its index system is:

\[
\ln IV = -4.633 + 1.612 \ln PHEC - 15.2 \ln PDI
\]  

(5)

Error correction equation:

\[
\Delta \ln IV_r = 1.57 \Delta \ln PHEC_r - 0.233(\ln IV_{r-1} + 4.633 - 1.612 \ln PHEC_{r-1} + 12.7 \ln PDI_{r-1})
\]  

(6)

Figure 8. Analysis of the investment demand forecasting model of Changsha County

4. Conclusion

The paper aims at the development path characteristics and development forms of provincial, city, and county-level units, in order to solve the individualized investment needs of the development path differences of the power grid and improve the analysis dimension of investment demand measurement. The provincial, city and county three levels of grid investment differentiation index system has been
established. The co-integration-error correction model is used to solve the quantitative relationship between the investment demand of the power grid and the index system. The analysis results from examples show that the model has achieved excellent performance in the grid-level investment demand forecasting at the provincial, municipal, or county levels. The forecasting results have high accuracy and small fluctuations, and improve the precision of investment decisions level, providing a reference for the formation of a scientific investment decision system.

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