Research on multi-dimensional target time series prediction model for power grid infrastructure projects

Jian Zhang¹, Xianing Jin², Yi Song², Weihong Yang³, Mingli Zhang¹, Jing Gao³, Bo Yang¹, Zhanjun Li³ and Yihe Wang³

¹State Grid Corporation of China CO. LTD., Beijing, Beijing, 100000, China
²State Grid Economic and Technological Research Institute CO., LTD., Beijing, Beijing, 100000, China
³State Grid Liaoning Electric Power Co., Ltd. Economic and Technical Research Institute, Liaoning, Shenyang, 110000, China

Corresponding author: Xianing Jin, at Power Economic Research Institute of State Grid Electric Power Company. Tel: (+86)010-66602386; Fax: (+86)010-66602377; E-mail: jessicacau@163.com. Address: B515 State Grid at Future Science Park, ChangPing District, Beijing, China.

Abstract. In order to adapt to the changes in the external power industry environment, prevent external audit supervision risks, and deepen the internal lean management level, we take the investment statistics of power grid infrastructure projects as the entry point, scientifically regulates investment statistics, and focuses on solving the distortion of investment statistics and the problem of the department not cooperating. By constructing the multi-dimensional target timing sequence prediction curve of investment statistics, the paper provides reference for the reported value of investment statistics, improves the authenticity and reliability of investment statistics, and at the same time, deepens the investment statistics management, providing solid support for the lean management and control target of power grid companies.

1. Background
Since the 13th Five-Year Plan, due to the strict regulation of external state-owned assets, the reform of transmission and distribution prices, and the current data distortion in the internal investment management of power grid companies, the lack of coordination between departments and the lack of investment management methods, the grid company has proposed "Proactively adapt to the requirements of reform, accelerate the realization of precision investment, and effectively improve the quality and efficiency of power grid development". In order to achieve this goal, it is urgent to find an effective investment management tool to improve the forward-looking nature of investment management of power grid infrastructure projects, the effectiveness of investment management in the implementation process, and consolidate the investment data base to help the company improve its lean management level.
2. Building a multi-dimensional target time series prediction model for grid infrastructure projects

We take the 110 kV and above power grid infrastructure projects (hereinafter referred to as the power grid infrastructure projects) as the research object, focusing on improving the timeliness, reliability and authenticity of the investment statistics and solving the problem of lack of scientific assessment methods and quantitative guidance objectives for the management and control of investment projects in power grid infrastructure projects. In this regard, with the investment completion data as the core, combined with the project execution data of infrastructure and finance, the joint research of construction, cost and investment is carried out to clarify the logical relationship between the three, and propose a multi-dimensional target time series prediction model, to innovate project process management and control methods to improve project lean management and control. The specific model design framework is shown in Figure 1:

![Figure 1. Schematic diagram of multi-dimensional target time series prediction model framework for power grid infrastructure projects](image)

2.1. Constructing time series forecasting model of physical quantity target of power grid infrastructure project

The time series forecasting model of the physical quantity target of the grid construction project is constructed, that is, the construction schedule target time series curve, that is, the theoretical construction progress curve. The construction progress target timing reflects the construction progress of the project. It is the completion of each part of the project quantity expressed by the percentage of completion. It is an important basis for cost and investment target timing prediction. The specific research ideas are as follows:

1. Using cluster analysis and other methods to study the time rule of different single project construction progress curves of sample projects, and summarize the construction progress characteristics, and provide the basis for the construction of the physical quantity target time series prediction model of subsequent grid infrastructure projects.

2. Combined with the relevant data quality and accessibility, the idea of constructing the theoretical construction progress curve is proposed. Considering the fact that due to the different physical quantity units on site, difficult to measure uniformly, and the difficulty of obtaining data, it is proposed to predict the “project construction progress based on engineering quantity” with “percentage of planned completion based on construction period”, in other words, the single project duration is used to replace the amount of project, and the single project schedule is used to predict the
amount of project progress, so as to build a time series prediction model for the actual amount of power grid infrastructure projects.

(3) According to the milestone plan level (project-single-unit project), the theoretical construction progress of the project is measured from the bottom up.

According to the above research ideas, the time series prediction model of the physical quantity target of the grid infrastructure project is constructed. The specific modelling ideas are as follows:

The actual physical quantity target progress of the power transmission and transformation project = \( \sum \) the progress of the physical quantity target of each unit of the substation transformation project \* the weight of each unit project + \( \sum \) the cumulative progress of the physical quantity of each unit of the line unit project \* the weight of each unit project;

Among them, the monthly construction of the physical quantity target of the unit project = the cumulative construction period of the unit project per month / the total construction period of the unit project.

Taking the single substation engineering as an example, the physical quantity target time series prediction model is as follows:

Table 1. Example of time series prediction model for physical quantity target of substation engineering

| Serial number | Schedule name                  | Plan type              | Planned start time | Planned completion time | Planned duration (days) | Infrastructure management system weight | Normalized weight | October 2015 | November 2015 | … | total |
|---------------|--------------------------------|------------------------|--------------------|-------------------------|-------------------------|------------------------------------------|------------------|--------------|--------------|-----|-------|
| 1             | Civil engineering              | Milestone plan         | 2015/10/30         | 2016/6/30               | 245                     | 40.00%                                   | 40.00%           | 0.40%        | 6.10%        |     |       |
| 2             | Main control building project | Unit engineering       | 2015/10/30         | 2016/4/30               | 184                     | 22.00%                                   | 30.00%           | 1.10%        | 16.30%       |     |       |
| 3             | Main transformer foundation and structure bracket | Unit engineering       | 2016/4/29         | 2016/8/30               | 124                     | 8.00%                                   | 11.10%           | 0.00%        | 0.00%        |     |       |
| 4             | Outdoor distribution equipment structure project | Unit engineering       | 2016/2/29         | 2016/5/28               | 90                      | 22.00%                                   | 30.00%           | 0.00%        | 0.00%        |     |       |
| 5             | ……                              |                        |                    |                         |                         |                                         |                  |             |              |     |       |
| 6             | Electrical engineering        | Milestone plan         | 2016/7/1           | 2016/9/30               | 92                      | 40.00%                                   | 40.00%           | 0.00%        | 0.00%        |     |       |
| 7             | Main transformer system equipment installation project | Unit engineering       | 2016/7/1           | 2016/11/1               | 124                     | 15.00%                                   | 16.30%           | 0.00%        | 0.00%        |     |       |
| 8             | Main control and DC equipment installation project | Unit engineering       | 2016/7/30         | 2016/8/26               | 28                      | 12.00%                                   | 13.00%           | 0.00%        | 0.00%        |     |       |
| 9             | Power distribution unit installation project | Unit engineering       | 2016/8/7           | 2016/9/30               | 55                      | 30.00%                                   | 32.60%           | 0.00%        | 0.00%        |     |       |
| 10            | ……                              |                        |                    |                         |                         |                                         |                  |             |              |     |       |
| 11            | Debugging                      | Unit engineering       | 2016/10/1          | 2016/12/30              | 91                      | 20.00%                                   | 20.00%           | 0.00%        | 0.00%        |     |       |
| 12            | Integrated automation system debugging | Unit engineering       | 2016/10/1         | 2016/10/31              | 31                      |                                         |                  |             |              |     |       |
| 13            | ……                              |                        |                    |                         |                         |                                         |                  |             |              |     |       |

Monthly progress of physical quantity target of substation project  0.16% 2.40%
Target progress of cumulative physical quantity of substation projects  0.16% 2.56%
Actual progress of cumulative physical quantity of substation projects  0.00% 0.00%
2.2. Construction of cost target time series prediction model for power grid infrastructure projects

The time series prediction model of power grid infrastructure project cost objective is constructed, which is the time series curve of the progress target of the account entry, namely the theoretical progress curve of the account entry.

The cost target sequence is a process in which the estimated amount is the total control and the value is continuously confirmed according to the progress of the project construction. On the basis of the national grid accounting method, based on the approved budget estimates, the effects of tax and project final settlements are eliminated, and a method for constructing a cost target time series prediction model is proposed. The specific research ideas are as follows:

1) Staged first: Establish the correspondence between the recording time of the cost of the WBS element (4 items of expenses) and the milestone planning node. According to the estimated budget and milestone plan, the corresponding relationship between the project WBS elements and the milestone plan was set for the single project included in the power transmission and transformation project of different voltage levels, and the corresponding plan start and end time of the project WBS elements was determined to form the parameter standard predicted by the model.

2) Sub-monthly: Study the value confirmation law of WBS elements between the corresponding milestone stages. Based on the WBS element of the sample project, the distribution rules are determined according to the cost characteristics, and the characteristics of the WBS element are summarized.

According to the rules of (1) and (2), the monthly decomposition rules for the construction period, the installation cost, the equipment purchase fee and other expenses are set separately. The specific rules are as follows:

The construction project fee corresponds to the “civil construction” stage in the construction schedule, and is periodically decomposed according to the percentage of completion of each month of the civil construction phase;

The installation engineering fee corresponds to the “Electrical Engineering” and “Commissioning” phases in the construction schedule, and is periodically decomposed according to the percentage of completion of the electrical engineering and commissioning phase progress;

The equipment purchase fee is determined by the “planned arrival time”, which usually occurs before the installation project begins. The “planned arrival time” can be determined according to the situation of the project:

Other expenses consider the actual time interval of the business, and determine the cost of the WBS element of the project according to the method of monthly average allocation or one-time full allocation. For example, during the construction period, the interest will be distributed on a monthly basis between the time of commencement of the project and the time when the project is put into production. The construction site requisition and cleaning fees will be fully distributed at the time of project start-up; the pre-project work fee will be fully distributed at the site of the survey and design bidding completion.

3) According to the above-defined rules, combined with the estimated cost (excluding tax) value of each expense, the detailed budget estimate is decomposed into each month of the project life cycle, and the cost target time series prediction curve is drawn. According to the “project - single project - WBS element” architecture, the reverse recursion is set to form the overall cost forecasting curve of the project.

According to the above research ideas, the cost target time series prediction model of grid construction projects is constructed. The specific modeling ideas are as follows:
2.3. Constructing time series forecasting curve model of investment objective of power grid infrastructure project based on conduction effect

Construct a time series forecasting model of the investment objective of the grid infrastructure project based on the conduction effect, that is, the investment schedule target time series curve, in other word, the theoretical investment progress curve.

The investment target timing reflects the proportion of the estimated budget for the investment in fixed assets of the project. Based on the fixed assets investment quota of the National Bureau of Statistics, the WBS element is used as the forecasting unit, considering its relationship with the construction progress, the investment target time series forecasting model construction method is proposed, and the model building framework analog cost time series forecasting model is proposed. But there are two differences: (1) Time characteristics of WBS elements in investment: starting at the start of the project and ending at the project; (2) The investment timing curve forecast is based on the estimated (tax-included) value, which is different from the cost curve's estimate (excluding tax, excluding balance).

Considering the difference between cost and investment target timing, the time series forecasting model of investment target of power grid infrastructure project is constructed.

Based on a comprehensive consideration of the relationship between investment and construction progress and cost, through the above model algorithm design, the whole process control time series curve of 9 grid infrastructure projects including physical quantity target progress, cost target progress, investment target progress, actual physical quantity progress, actual cost progress, actual investment progress, cumulative release investment plan and cumulative budget release is constructed. These curves supplement and improve the construction of investment statistics monitoring system, give full play to the supervision role of investment statistics, and further improve the lean management level of power grid infrastructure projects.

3. Empirical analysis

Select the data of a 110kV voltage grade power grid infrastructure project and carry out model validation analysis. The specific case analysis is as follows:

(1) Project overview

A certain 110kV power grid infrastructure project is selected. The project has a line length of 4km, a substation capacity of 100,000kva, and a total initial investment of 42.19 million. It can be seen from the following figure that there is a large trend between the three actual curves and the target timing curve.
Figure 3. Example of three-rate analysis curve of a 110kV power grid infrastructure project

Note: The green line indicates the physical quantity target timing curve, red indicates the investment timing curve, and blue indicates the cost timing curve.

(2) Curve analysis
Analysis of the reasons:
(1) By analysing the investment completion data, the project reported a large amount of construction, installation, equipment and other expenses in July 2017.

Table 2. Investment completion data

| time         | Composition by investment total | building | installation | device | other |
|--------------|---------------------------------|----------|--------------|--------|-------|
| September 2016| 98                              | 0        | 0            | 0      | 98    |
| April 2017   | 277                             | 52       | 0            | 0      | 225   |
| July 2017    | 2923                            | 571      | 683          | 1039   | 630   |
| Estimated value | 4029                            | 506      | 1614         | 1063   | 845   |

(2) By inquiring about financial accounting data, it was learned that from August 2016 to the end of the year, many installation fees and equipment fees were recorded.

Table 3. Financial accounting data

| time      | Project monthly cost |
|-----------|----------------------|
|           | Construction fee | Installation fee | equipment fee | other fee | total |
| July 2016 | 0                  | 2                | 6             | 70        | 78    |
| August 2016| 0              | 732              | 0             | 0         | 732   |
| September 2016| 0          | 137             | 32            | 45        | 215   |
| October 2016 | 0             | 0               | 2             | 2         | 4     |
| November 2016| 0             | 152             | 608           | 0         | 760   |
| December 2016| 0             | 106             | 0             | 10        | 116   |
(3) Penetrating the inquiries and infrastructure construction control progress report, and after on-site verification, it was found that the investment plan adjustment resulted in insufficient funds and the impact of winter shutdown. The project started in May 2017 after 9 months of delay. And the electrical engineering installation and line engineering tower started in September. Based on the above analysis, the investment progress is basically in line with the construction progress, and the cost accounting progress is significantly ahead of the actual construction progress.

| time      | Actual cumulative construction progress |
|-----------|----------------------------------------|
|           | Substation engineering | Line engineering | Total project |
| May 2017  | 1.95%                     | 0.00%            | 1.12%         |
| June 2017 | 6.95%                     | 0.00%            | 3.97%         |
| July 2017 | 11.95%                    | 15.00%           | 13.26%        |
| August 2017 | 21.95%                   | 35.00%           | 27.54%        |
| September 2017 | 45.41%       | 50.00%           | 47.38%        |
| October 2017 | 53.41%                 | 50.00%           | 51.95%        |

(4) Reasons for analysing costs ahead of time:
Looking up the reasons for the advance entry of costs, it was found that the cumulative amount of actual costs in 2016 (1905) was exactly equal to the annual budget issued value (19.05 million yuan). After verification, this project is to complete the annual budget assessment target, the cost is recorded in advance.

4. Conclusion
This paper takes the 110kV and above power grid infrastructure projects as the research object, and focuses on the solution of the quantitative control objectives of the investment process of 110kV and above power grid infrastructure projects. It constructs multidimensional (physical quantity, cost, investment) target time series forecasting model by studying the relationship between construction, finance, investment and other parties, realizes the scientific formulation of the quantitative objectives of the investment process, improves the coordination level of development, finance, construction, materials and other multi-sectors, and innovates the investment statistics monitoring means of the grid infrastructure projects, completes the scientific and standardized investment, and improves the quality of investment statistics of power grid infrastructure projects while significantly improving the efficiency and efficiency of investment statistics management.

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References
[1] Li C.X. (2018) Thinking about the statistics of fixed assets investment. J. Economist, 3.
[2] Li L, Wu Z.Q. (2015) Some thoughts on doing a good job in the statistics of fixed assets investment. J. Statistics and Management, 2.
[3] Tan L.J. (2011) Statistical management analysis of fixed assets investment. J. Inner Mongolia Workers Magazine, 5.
[4] Shi N.N. (2013) Optimizing and Suggestions on Statistical Method of Investment in Power Grid Construction. J. Modern Property (Previous Periodicals), 3.
[5] Gao W, Yang J.Y. (2018) Zhang Q.L etc. Research on investment statistics reporting based on the upper limit of cumulative investment completion of key nodes. J. Economic Research Guide, 8.

[6] Zheng L. (2011) Power grid construction project investment optimization management method and application [J]. Electric Power Construction, 1.