Research on the Progress Supervision Technology of Electricity Grid Construction Projects Based on Multi-service Collaboration

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Abstract. With the continuous deepening of external supervision and internal lean management, the quality requirements for investment statistics of power grid enterprises are increasing. However, the scale of investment and the number in power grid projects are large. The traditional management mode is not only heavy workload but also low accuracy. Therefore, it is necessary to strengthen the supervision of the progress of electricity grid construction projects through the coordination of multi-business departments, and check the quality of investment statistics, so as to find suspected problem items in time, to batch positioning the causes of deviation and to improve the lean management level of electricity grid construction projects.

1. Problems in the management of investment statistics
With the gradual deepening of power transmission and distribution prices, the investment of power grid enterprises has been strictly regulated by the outside, and the quality requirements of investment statistics are also increasing. In order to improve the quality of investment statistics, State Grid Jiangsu Electric Power Company actively explored management methods to analyze massive data. However, there are still many problems, which are manifested in the following aspects:

(1) Traditional grid enterprise investment statistics management mode restricts the efficiency of the progress monitoring and analysis of electricity grid construction projects. State Grid Jiangsu Electric Power Company has a large investment scale and a large number of projects. Currently, investment
statistics quality management still relies on provincial and municipal company statisticians to manually screen and troubleshoot abnormal items. This situation severely restricts the monitoring and analysis efficiency of the grid infrastructure projects, which is not conducive to the continuous improvement of the quality of investment statistics and the lean management of the entire investment process.

(2) Extensive management and non-coordination between departments are not conducive to in-depth analysis of business level roots and timely improvement.

(3) Lack of a scientific, effective and quantitative monitoring means to assist investment statistics management and improve the overall investment management level.

2. Construction of dynamic monitoring model for electricity grid construction projects based on multi-service collaboration

In order to solve the above investment statistics management problem, State Grid Jiangsu Power Company actively explored multi-service collaborative progress monitoring technology for 110kV and above electricity grid construction projects. A progress monitoring model for electricity grid construction projects based on multi-service collaboration was established by establishing dynamic monitoring and analysis indicators for electricity grid construction projects. This model is based on a reasonable quantitative relationship between typical engineering theory investment and construction progress, and the cost of accounting. Then determine the reasonable threshold interval of different voltage levels, engineering types and construction properties, to realize the batch supervision and early warning of electricity grid construction projects based on multi-service collaboration. The specific idea is shown in Figure 1:

![Figure 1. Research on the progress supervision technology of electricity grid construction projects based on multi-service collaboration](image)

2.1 Establish a monitoring and analysis index system for the progress of electricity grid construction projects

Establishing a multi-dimensional progress monitoring index system for the whole process of the project according to the dimensions of the project, individual project and four expenses. Verifying the authenticity of the data through a cross-over comparison between the actual indicators of construction, investment, and accounting. The specific indicators and calculation formulas are shown in the following table:
2.2 Analysis of factors affecting multidimensional progress deviation of electricity grid construction projects
Studying the key factors affecting the multi-dimensional progress deviation of electricity grid construction projects, and analyzing the indicator framework that may lead to the deviation of the two indicators at the four cost levels according to the analysis index framework of construction, investment, and accounting actual indicators. Analyzing and summarizing the influencing factors of the identified deviations, and eliminating the influence of non-excludable factors. Factors that will lead to differences between investment completion and engineering costs, such as budgetary balances, untimely settlement of construction, and tax differences, are regarded as objective existences and

| Project level | Single project level | Detail level |
|---------------|----------------------|--------------|
| The deviation rate between actual accounting progress and construction progress | The deviation rate between substation project progress and construction progress | The deviation rate between construction project fee recording progress and civil construction progress |
| | | The deviation rate between installation engineering fee accounting progress and equipment installation progress |
| | | The deviation rate between equipment purchase fee accounting progress and equipment installation progress |
| | | The deviation rate between other expense accounting progress and construction progress |
| | The deviation rate between overhead line project crediting progress and construction progress | The deviation rate between installation engineering fee accounting progress and construction progress |
| | | The deviation rate between other expense accounting progress and construction progress |
| | The deviation rate between statistical investment progress and construction progress of substation projects | The deviation rate between construction project cost statistics investment progress and civil construction progress |
| | | The deviation rate between installation engineering fee statistics investment progress and installation engineering fee accounting progress |
| | | The deviation rate between equipment purchase cost statistics investment progress and construction progress |
| | | The deviation rate between other expenses statistics investment progress and construction progress |
| | Statistical progress and construction progress of overhead line engineering | The deviation rate between installation engineering fee statistics investment progress and construction progress |
| | | The deviation rate between other expenses statistics investment progress and construction progress |
| | The deviation rate between substation engineering statistics investment progress and cost accounting progress | The deviation rate between construction project cost statistics investment progress and construction project fee recording progress |
| | | The deviation rate between installation engineering fee statistics investment progress and installation engineering fee accounting progress |
| | | The deviation rate between equipment purchase cost statistics investment progress and equipment purchase fee accounting progress |
| | | The deviation rate between other expenses statistics investment progress and other expense accounting progress |
| | The deviation rate between survey progress and accounting progress of overhead line engineering | The deviation rate between installation engineering fee statistics investment progress and accounting progress |
| | | The deviation rate between other expenses statistics investment progress and other expense accounting progress |
cannot be excluded. Deviations due to the above objective factors are considered as reasonable deviations. The objective deviation between investment completion and project cost is as follows:

1. The impact of unsettled settlement during the construction process: In the actual business, due to the unsuccessful settlement of the construction process of the construction management unit or the lag of the financial documents, the project cost may often lag behind the investment completion statistics, which makes the investment completion progress and the financial accounting progress have objective deviation.

2. Budget surplus effect: Usually the investment is completed on the basis of the project budget, and the project cost is based on the contract and the actual settlement amount. The balance of the settlement compared with the estimate results in an objective deviation between the completion of the investment and the cost of the project.

3. Tax effect: The investment completion reflects the tax-inclusive budget of the project. The cost of the account reflects the actual tax-free price of the project. Taxes will result in an objective deviation between the progress of the investment and the progress of the account.

2.3 Determining the multi-dimensional progress deviation threshold measurement sample screening rules for electricity grid construction projects

In order to ensure that the multi-dimensional progress deviation threshold measurement results meet the business requirements, the sample project screening criteria are clearly measured firstly. Only projects that meet the following sample screening principles can be included in the measurement sample library. The specific sample screening principles are as follows:

1. The project engineering control system, ERP system and planning plan system of each voltage level match well.

2. Key nodes such as milestone plan and construction schedule are in line with the schedule management requirements of electricity grid construction projects.

At the same time, combined with the reasonable construction period standard of the construction department and the construction characteristics of each sub-project, the rationality judgment rules of the project milestone plan and construction schedule are detailed. Take the rules for determining the schedule of civil engineering of equipment installation and construction of substation engineering as an example. The specific judgment rules are as shown in Table 2 below:

### Table 2. Sample project screening rule example

| Milestone node       | Business logic                                                                                                                                 |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| Civil engineering    | Check whether the preparation of the divisional project schedule under the civil engineering stage is reasonable. Judging abnormal conditions: |
|                      | 1) If the initial start of each major branch project is earlier than the start date of the civil engineering milestone period of 90 days / 120 days.  |
|                      | 2) Or the latest completion time of each major segment project exceeds the completion time of the civil construction milestone by 90 days / 120 days.  |
|                      | 3) Or if the initial start time of each major division project is later than the completion time of the civil construction milestone.    |
|                      | Note: (220kV and below: 90 days; 220kV or more: 120 days).                                                                                  |
|                      | 2) Or the start time and completion time of each major division project are exactly the same as the start and completion time of the civil construction milestone. |
|                      | Note: (The main divisional engineering in the civil construction phase refers to: the main control building (joint building); the relay room; the power distribution system construction and structure; the main transformer foundation and structure bracket). |
| Device installation  | Check whether the preparation of the sub-project planning time under the equipment installation stage is reasonable and judge the abnormal conditions: |
|                      | 1) If the earliest start time of each major segment project is less than 90 days / 120 days from the start of the equipment installation milestone phase. |
|                      | 2) The latest completion time of |
2.4 Establishing a multidimensional progress threshold measurement model for electricity grid construction projects

Sample items of different voltage levels and engineering types are selected as the measurement targets of the threshold based on the sample item screening criteria. Construction of dynamic monitoring model for the whole process of electricity grid construction projects based on multi-service coordination with different voltage levels, construction properties and engineering types. The measurement can be divided into the following steps:

1) Calculate the construction, investment, and record progress value of key milestones of each sample project. Calculate the progress value by substituting the balance rate into the accounting progress.

2) Construction settlement in actual business usually lags 1-3 months from the progress of construction, considering the impact of this factor. In accordance with the time requirements for settlement of different voltage grades in the general system of the State Grid, the three service-related costs of construction, installation and other expenses are recorded as lags behind the calculation of the cost of progress in February or March.
(3) The maximum, minimum, median and mean values of the engineering theoretical deviation index values of the single project and milestones are counted, and the maximum and minimum values are taken as the standard reference values of the individual engineering deviation thresholds.

(4) For the sample items selected according to the rules, the deviation thresholds of different milestone stages are measured by voltage level and single item type, and the deviation index values of each sample item are summarized.

(5) Excluding the outliers in the summary results of the theoretical deviation index values for each sample and each milestone according to the 3σ criterion.

(6) For the sample index value after the outlier is removed, set the expected standard coverage probability according to the “mean±a*standard deviation” method. Calculate the range of the upper and lower limits of each deviation index value separately. According to the needs of its own business, the threshold standard selection method is set, and the result is used as the first threshold standard of the deviation index value.

(7) Select projects for preliminary verification and analysis. According to the preliminary verification results, correct the threshold criteria that obviously do not meet the actual business, and obtain the final threshold standard.

2.5 Establishing multi-dimensional progress deviation early warning model for electricity grid construction projects

The deviation warning model sets the supervision logic from the “detail level-single item level-project level” to supervise the detailed layer, single item level and project level progress. The specific logic is as follows:

(1) According to the measured detailed layer and single-layer progress deviation threshold standard, the dynamic supervision of the detailed layer and the single item layer is realized. First, judge the milestone stage corresponding to the current month of the individual project. Secondly, compare the actual indicator value of the current month with the corresponding milestone stage progress deviation threshold standard and display the monitoring result with traffic lights. The specific results are divided into two types: normal within the standard range of the threshold (displaying a green light), and an early warning exceeding the threshold standard interval (displaying a red light).

(2) Supervise the progress deviation of the project layer according to the supervision result of the single-layer progress deviation. The single-level progress deviation supervision result is scored according to the principle of “1 point for early warning (red light) and 0 point for normal (green light)”. Then, the weighted average of the main individual project score results is based on the estimated weight of the individual items, and the project level indicator score is obtained. According to the established project level schedule deviation supervision rules (such as: project level indicator score less than or equal to 0.5 shows normal, green light display, greater than 0.5 display warning, red light display), to achieve supervision of the project level.

3. Empirical analysis

Carrying out an empirical analysis on the investment, construction and accounting progress indicators of a new 110 kV substation project. Compare the indicator value with the threshold value and analyze whether the warning situation is reasonable to verify the correctness of the model. The substation project started in March 2018 and was put into operation in August 2019. The early warning results of the progress deviation of the project in December 2018 (the third month of the civil construction phase) are as follows:
Table 3. Early warning results of progress deviation in civil construction stage of a substation project in December 2018

| Detail indicator level                                                                 | Index value | Early warning result | Threshold interval |
|----------------------------------------------------------------------------------------|-------------|----------------------|--------------------|
| The deviation rate between construction project fee recording progress and civil construction progress | -26.70%     | -48%                 | 0%                 |
| The deviation rate between installation engineering fee accounting progress and equipment installation progress | 59.30%      | 0%                   | 0%                 |
| The deviation rate between equipment purchase fee accounting progress and equipment installation progress | 0.00%       | -1%                  | 20%                |
| The deviation rate between other expense accounting progress and construction progress  | 35.10%      | 13%                  | 37%                |
| The deviation rate between construction project cost statistics investment progress and civil construction progress | 5.10%       | -8%                  | 13%                |
| The deviation rate between installation engineering fee statistics investment progress and equipment installation progress | 0.00%       | -9%                  | 1%                 |
| The deviation rate between equipment purchase cost statistics investment progress and construction progress | 97.90%      | -4%                  | 5%                 |
| The deviation rate between other expenses statistics investment progress and construction progress | 24.40%      | 20%                  | 48%                |
| The deviation rate between construction project cost statistics investment progress and construction project fee recording progress | 31.80%      | 19%                  | 45%                |
| The deviation rate between installation engineering fee statistics investment progress and installation engineering fee accounting progress | -59.30%     | 0%                   | 5%                 |
| The deviation rate between equipment purchase cost statistics investment progress and equipment purchase fee accounting progress | 97.90%      | 1%                   | 8%                 |
| The deviation rate between other expenses statistics investment progress and other expense accounting progress | -10.60%     | 9%                   | 16%                |

According to the above warning results of the progress deviation of the substation project, the indicator of red light display is analyzed emphatically. The analysis process is as follows:

In December 2018, the deviation rate between installation engineering fee accounting progress and equipment installation progress is 59.30%, and the model threshold interval is (0%, 0%), with a red light warning. As the current civil construction phase, the installation phase has not started. The equipment installation progress is 0, the installation fee is also recorded as 0, and the model threshold interval (0%, 0%) is reasonable. The deviation rate between installation engineering fee accounting progress and equipment installation progress is 59.3%, which deviates from the threshold range and the warning is reasonable.

In December 2018, the deviation rate between equipment purchase cost statistics investment progress and construction progress is 97.9%. The model threshold interval is (4%, 5%), with a red light warning. As the current stage of civil construction, the reported investment in equipment purchases should be consistent with the equipment installation schedule. Under normal circumstances, the deviation rate should be around 0 and the model threshold interval (4%, 5%) is reasonable. The deviation rate between equipment purchase cost statistics investment progress and construction progress is 97.9%, which deviates from the threshold range and is reasonable for early warning.

In December 2018, the deviation rate between other expenses statistics investment progress and other expense accounting progress is -10.6%, and the model threshold interval is (9%, 16%), with a
red light warning. As the cost is affected by settlement, taxes, etc., the cost accounting progress should be smaller than the investment progress. The model threshold interval (9%, 16%) is reasonable. The deviation rate between other expenses statistics investment progress and other expense accounting progress is -10.6%, which obviously deviates from the threshold range, and the warning is reasonable.

Through the above verification analysis, the model early warning is consistent with the actual business situation, the threshold interval is reasonable, and the model can timely reflect the progress of the power grid infrastructure project, find problems in time, batch positioning the causes of deviation and improve the lean management level of power grid infrastructure projects.

4. Conclusion
This paper mainly explores how to coordinate with the professional departments of construction, finance and development to realize the dynamic supervision and management of the progress deviation of 110kV and above electricity grid construction projects, so as to find and solve problems quickly, and then improve the quality of investment statistics. The progress monitoring of electricity grid construction projects is based on the multi-dimensional progress monitoring index system of the whole process of the project, the key factors affecting the multi-dimensional progress deviation of the electricity grid construction projects, and the construction process of the electricity grid construction projects based on multi-service coordination with different voltage levels, construction properties and engineering types. The deviation dynamic monitoring model realizes the dynamic supervision system from the level of “detail level-single item level-project level”.

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