Power Grid Construction Project Portfolio Optimization Based on Bi-level programming model

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Abstract: As the main body of power grid operation, county-level power supply enterprises undertake an important mission to guarantee the security of power grid operation and safeguard social power using order. The optimization of grid construction projects has been a key issue of power supply capacity and service level of grid enterprises. According to the actual situation of power grid construction project optimization of county-level power enterprises, on the basis of qualitative analysis of the projects, this paper builds a Bi-level programming model based on quantitative analysis. The upper layer of the model is the target restriction of the optimal portfolio; the lower layer of the model is enterprises’ financial restrictions on the size of the enterprise project portfolio. Finally, using a real example to illustrate operation proceeding and the optimization result of the model. Through qualitative analysis and quantitative analysis, the bi-level programming model improves the accuracy and normative standardization of power grid enterprises projects.

1. Introduction
In Grid Company, power grid construction project takes a high proportion in the total assets, and it always shows the characteristic of capital-intensive and has a long project lifecycle. Therefore, the reasonability and effectiveness of power grid construction project investment can directly impact on the capacity of power supply and the quality of service.

Many scholars studied the optimization problems of the power grid construction project. Literature [1] build the preliminary screening, project optimization and portfolio optimization of the grid investment model. Literature [2-5], introduces the evaluation methods and models of grid projects at home and abroad from the three aspects: economy, reliability and environmental protection, and put forward that the grid project evaluation should consider the link between the projects, opportunity costs of postponing the investment project, the project external benefits and other factors. In literature [6-7], the paper discusses how the grid company makes reasonable fund allocation in different projects as the funds is limited in the market, and expounds the portfolio optimization model under the capital constraints in the market environment. In literature [8], considering the influence of the psychological factors and the risk tendency of the decision-maker in the decision-making process, the prospect theory is introduced into the investment decision of the grid construction project portfolio, then, we choose the weight of index based on differentiation, and use multi-criteria decision analysis method VIKOR to determine the optimal portfolio. However, the county-level power grid construction project has its own characteristics, little research combined the characteristics with quantitative models to optimize the portfolio investment quantitatively and qualitatively. In this paper, the characteristics of county-level grid construction projects are analyzed, and the Bi-level programming mode of
county-level grid company is constructed, and the project is optimized to assist the county-level grid company to select more reasonable project portfolio.

2. Quantitative Analysis
Power grid enterprise power grid construction project investment decision-making has two main contents: the first is determination the scale of investment, the second is the determination of the investment projects.

2.1 the determination of investment scale
The determination of investment scale need comprehensively considering multiple factors, which is mainly manifested in the following three aspects: first, considering the business development of the enterprise to ensure its own financial security scale (cap), and constantly improve profitability scale (lower limit); Second, the scale of investment to meet the needs of the national, local and industry policies and regulations (including lower size limit and scale); Finally, investment scale, also will be affected by other factors such as macro political and economic environment, the power grid investment strategy, the government investment strategy and corporate strategy, the effect of these changes in the external macro environment for the company, is the challenge but also opportunity, the company should be keenly grasping the opportunity and preventing risk. Hence to enhance the control of investment plan, grid company should analyze the inherent law of the influence factors, building the analysis model of power grid construction projects.

2.1.1 Analysis framework of investment scale based on business development
From a business perspective, there are two factors affecting the investment scale, the company’s own development and the requirements of grid company. On the one hand, from the requirements of super company, to meet the grid company's requirement to the Debt Asset ratio, ROE, line loss rate, operating income, controllable expenses and so on. On the other hand, from the company's own development perspective, the first is to ensure its’ own financial security, especially to prevent from the risk of cash flow breakage, then the size of the investment requirements from the target year's profitability and ability to pay the two aspects of comprehensive consider. Profitability mainly has the cost and income decision of the enterprise. Due to the fixed price system, the control ability of the power supply enterprises is weak, mainly through the control of the cost of the enterprise to enhance the profitability of the enterprise. And the ability to pay the enterprise in addition to the higher amount of money, there is a very important part of the financing from their own. Enterprises will be based on the macro environment and the situation of their own enterprises to develop the enterprise's financing strategy.

2.1.2 Analysis of investment scale
Relative to other enterprises, the county-level grid company have their own outstanding features: the first is the "windows server", which means that the county-level power supply enterprises deal directly with residential customers, the Work scope is broader, and the business process is more complicated. Second is "end characteristics", that is, county-level grid company are more focused on demand side management, and dilute the lower management functions. Finally, the "basic characteristics", that is, county-level power supply enterprises to emphasize a wide range of services to the public, local, for the county-level power supply management, the enterprise's own efficiency is only a branch of decision-making, and management decision-making the most important starting point should be Social responsibility. County-level power supply enterprises of the above three characteristics, and further give it a greater sense of social responsibility, mission. This three points directly lead to the enterprise is facing more legal and regulatory environment, shoulder social responsibility is also higher, its investment in addition to meet the national and local governments and other policies and regulations outside the requirements, no doubt also take into account the business where the regional special surroundings. In addition to examining the legal compliance of the corporate budget system and the soundness of the relevant system, the requirements of the external audit for the enterprises are also
taken into account in the process of budget management, with a view to improving the business in a rigid law through a comprehensive and flexible perspective the operating efficiency in the regulatory environment.

Specifically, to meet the policies and regulations of national, local governments and national grid companies and others, for example:

A. the ratio of equity capital is no less than 25%
B. Investment does not exceed 50% of net assets
C. Investment growth is lower than electricity growth
D. Investment growth is lower than revenue growth

2.2 Optimization of investment projects

2.2.1 department optimization

According to the Measures for the Administration of Fixed Assets Investment in Power Grid Enterprises, the fixed assets investment projects are divided into power grid infrastructure projects, special technological transformation projects, small infrastructure projects, fixed assets retail projects, marketing (capital) projects, information construction (capital) Projects, overhead lines transformation project and power facilities removal and reform project and so on. As a grid enterprise, fixed assets investment will have different requirements according to their different contents of the project, the department, as the first window of project evaluation, is more familiar with their own projects, and most have the right to speak, so the departments should carry out the first round of selection and sorting at the department level, namely department selection. In order to facilitate the reporting and management of the fixed assets of the sector.

The department optimization evaluation factors should include at least the following: investment objectives, importance, start conditions, implementation time, etc.[8]

Specifically, the purpose of investment can be divided into several kinds such ensuring the safe and stable operation of power grid, promoting the development of the power grid, seizing the site, path and other resources. Importance can be divided into the company, the national grid, the city government and important users of key projects, and other general projects. The start conditions can be divided into those who have reached the start conditions and who are expected to reach the target year. Has reached the start conditions, in particular, mainly refers to the implementation of the relevant rivers and lakes, railways, subways and other solicitation opinions; access to project EIA approved, pre-trial pre-planning and other relevant requirements; to obtain project approval; access to substations, As well as cut the project planning submissions and other projects. Expected to reach the target year to start the conditions, is completed has signed the investment division agreement, feasibility study, feasibility study report preparation and assessment of the project. Implementation time can be divided into one year, one year to three years, and three years and above.

Finally, the project should be accompanied with the main contents of the relevant project, such as the main transformation project, the main type and number of the equipment, investment agreement, feasibility study, feasibility study report, and preliminary project funding estimates to facilitate the project Screening and management of warehouses.

2.2.2 enterprise optimization

Enterprises and departments consider differently when choice the project, the department is mainly standing on the point of their professional perspective to select and sort projects, and the enterprise is macroscopically handling and screening the project submitted by departments, so that the final implementation of the project can meet the enterprise's strategic objectives and resource levels.

Specifically, the enterprise needs to sort and screen projects based on the three aspects: the maximum of the project number, the highest operational safety of the grid and the degree of business development. First of all, the scale of investment mainly refers to the financial resources that the enterprise wants to dominate, which is a total number, a hard condition that the final enterprise investment plan needs to meet. The "maximum number of projects" is the goal of the limited resources
in the enterprise level, make full use of all the resources of enterprises to avoid the idle and waste of resources. Second, as a grid enterprise, fixed assets investment need to ensure the safe and stable operation of the power grid, and efforts to enhance the power supply capacity, optimize the grid structure, which is one of the important factors the enterprise level screening sorting need to consider. Finally, we must also take into account the investment projects on the business development needs of the degree of compliance. In face of drastic changes, today’s enterprises need to grasp the projects from the overall level to meet the business strategy, and to seek business development.

3. Bi-Level Optimization Model
3.1 Basic assumptions
In the optimal combination of power grid construction projects, on the one hand the county-level power supply company budget committee put forward a variety of projects to be investment projects, on the other hand for each investment program to evaluate the financial evaluation of the merits of the program, therefore, the power grid construction projects can be regarded as a double-level planning problem, you can build a two-tier planning model. When selecting a project, we should consider the conditions of power grid security, business strategy, financial strategy, investment purpose, start conditions and implementation time. To this end, we should also investigate and forecast the total investment of the project. To establish a model, first make the following basic assumptions:

A. First, in accordance with the county power supply company to meet the power grid security, business strategy and other requirements, the departments have submitted through the first round of hard selection of alternative items.

B. Do not consider the administrative policy works, assuming that all the projects have to be screened, there is no need for the project.

C. Prior to the analysis and combined with the implementation of the conditions of the project section to prepare a number of alternative investment projects, through the optimization model in these alternative investment projects to choose the most reasonable combination of programs to become a project investment program. This idea is also consistent with the general idea of project optimization: the first qualitative re-quantitative, qualitative and quantitative combination of planning concepts and methods.

3.2 Upper layer goal and constraint analysis of Bi-level Optimization Model
3.2.1 Target
We use $X_i$ to indicate the selected situation of project $I$; when $X_i = 0$, it means the project has not been chosen, and when $X_i = 1$, it means the project has been chosen. Target is divided into the following three levels:

Goal I: as far as possible to meet the requirements of the various departments, so does the number of projects in the portfolio:

$$P_1: \max \sum_{i=1}^{n} X_i$$

Target II: the highest safety of the grid operation:

$$P_2: \max \sum_{i=1}^{n} \lambda_i X_i$$

Where $\lambda_i$ is the safety score for the project $i$;

Goal III: make the project portfolio most in line with business development needs

$$P_3: \max \sum_{i=1}^{n} \theta_i X_i$$

Multi-objective programming model has many solving methods, including the constraints method, layered sequence method, the effectiveness of the coefficient method, the evaluation function method. Assuming we use a linear weighting method, the following planning problem can be obtained:

$$\max f(X) = P_1 \cdot \sum_{i=1}^{n} X_i + P_2 \cdot \sum_{i=1}^{n} \lambda_i \cdot X_i + P_3 \cdot \sum_{i=1}^{n} \theta_i \cdot X_i$$

Where: $P_1$, $P_2$ and $P_3$ represent the weight between the equipment failure rate, the conveying capacity, the load growth rate, and the change in the power supply capacity, and $P_1 + P_2 + P_3 = 1$. Since
the upper layer is a multi-objective function, the overall target can be selected according to the purpose and requirements of the project combination.

3.2.2 Analysis of the lower level problem of the bi-level model

The lower level represents the total financial size of the firm's portfolio of investments. With reference to the conventional investment method, it can be assumed that the portfolio selection is based on a total of no more than the investment ceiling. To this end,

A. The amount of investment in each project is generally relatively fixed, so the amount of the project does not change the amount of funds.

B. The purpose of each project is different, there is no overlapping items. Therefore, whether or not each project is selected does not directly affect whether other items are selected.

It can be seen that, for a priority level under the combination of the choice of the project portfolio can be considered as follows: First, the most in line with the safety of the grid, the most suitable for the development of enterprise strategy for the combination of the premise that the utility of the biggest factors. At the same time, in the actual optimization, due to the limited total investment will make some projects have to exclude the combination.

In the above analysis, we can use the total investment (M) upper limit allocation method, and we can think that the project portfolio is selected as follows: project 1≤M → Project 1+ Project 2≤M→ ... → Project 1 + ... +project N≤M: Then In the same priority level under the first utility of the highest combination, only in a combination of the total investment limit to consider the suboptimal portfolio. Figure 1 shows the logic diagram of the total investment limit allocation method.

Figure 1 Logic diagram of the total investment limit allocation method

3.2.3 Select the project and combined

One of the key issues in model solving is the determination of the combined project. The steps are as follows:

(1) Select any item from the first item to the second item to the Nth project.
(2) the total amount of investment required for the N projects to be summed.
(3) the amount of investment required is less than the investment ceiling, return to the first step; greater than the amount of investment will be the last selected project excluded after the project portfolio.

The lower model reflects the constraint:

\[ \sum_{i=1}^{N} \beta_i \cdot X_i \leq \rho; \]
\( \beta_i \) is the investment volume of each project, and \( \rho \) is the investment limit of the company.

3 Example Based on the NY county electricity grid construction project portfolio optimization

Here is the basic information for the projects of NY county power supply company:

| NO | Detail | Start date | Investment budget | Type | Source | \( \lambda_i \) | \( \theta_i \) |
|----|--------|------------|-------------------|------|--------|-------------|-------------|
| 1  | Huafeng Town 10 kV line construction project | 2014-1-1 | 465.80 | infrastructure | The development planning department | 0.3 | 0.6 |
| 2  | Air conditioning purchase of Tai'an Ningyang company | 2013-5-1 | 2.50 | purchase | The development planning department | 0.5 | 0.2 |
| 3  | Building construction projects | 2013-9-1 | 460.00 | mini infrastructure | The development planning department | 0.3 | 0.9 |
| 4  | Smart meter | 2014-1-1 | 25.00 | marketing investment | Marketing department | 0.4 | 0.5 |
| 5  | Maintain project of electric energy meter of Tai'an Ningyang company in 2013 | 2013-9-1 | 25.00 | overhaul project | Maintenance department | 0.2 | 0.8 |

As \( \rho = 950 \), set \( P_1 = 0.7 \), \( P_2 = 0.2 \), \( P_3 = 0.1 \), (using expert scoring method or synthetical evaluation method) The multi-objective programming problem is transformed into single objective problem. In above foundation data, we can get:

\[
\max f(X) = 0.82X_1 + 0.82X_2 + 0.85X_3 + 0.83X_4 + 0.82X_5 \\
465.8X_1 + 2.5X_2 + 460X_3 + 25X_4 + 25X_5 \leq 950
\]

Using method of exhaustion, we can learn that the second, third, forth and fifth project can be the best investment. Portfolio. And, \( \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 = 2.50 + 460.00 + 25.00 + 25.00 = 512.50 < 950 \)

4. Conclusion

The number of projects with the largest portfolio of investment, the highest operational safety of the grid, the project portfolio is best suited to the business development needs for the optimization objectives, and consider the financial size of the project portfolio of the total investment limit, the establishment of the power grid construction project portfolio Double layer optimization model. The optimization model is in the form of two layers: the upper layer is the multi-objective optimization function, and the lower layer is the total limit allocation model. The model describes the optimization
of the portfolio of grid investment projects.

Using the built-up two-tier model to screen for possible grid construction projects in reality to obtain a reasonable portfolio solution. The model provided the theoretical basis for the optimization of the investment portfolio of the grid construction project.

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