Matching Algorithms between Investment Projects and Grid Weak Links

Lixia Liu¹, Chao Ma², Dong Zhang¹, Na Li¹, Fei Xiao³*, Jie Yang⁴, and Yutong Ye⁴

¹ State Grid Tianjin Electric Power Economic&Technology Research Institute, Tianjin, 300171, China
² State Grid Tianjin Electric Power Company, Tianjin, 300010, China
³ Swan College, Central South University of Forestry and Technology, Changsha, Hunan, 410000, China
⁴ School of Economics and Management, North China Electric Power University, Beijing, 102206, China

*331658326@qq.com

Abstract. This paper analyzes the weak links of the power grid from the perspectives of grid operation and future investment management of power grids. Based on the research theory, the matching algorithm of investment project and weak link of power grid is constructed based on 0-1 planning and empirical analysis is carried out. This paper construct a model based on constraints such as the maximum objective value of the net present value rate and the investment ratio, calculate and analyze the case, get the investment results, and optimize the resource allocation.

1. Introduction
With the development of the economy, the growth of the load and the gradual implementation of the national networking project, the scale of China's power grid is expanding. The expansion of the power grid, the complexity of the power grid structure, and the application of various new transmission technologies make the dispatching operation of the power system more complicated. In the operation of the power grid, there are weak links in line construction management, natural disasters and economic benefits[1]. In addition, with the reform of transmission and distribution prices, the effective assets of the grid are crucial to the efficiency of the grid.

2. Establishment of Matching Algorithms for Investment Projects and Grid Weak Links
Establishing investment project and grid weak link matching algorithm from objective function and constraint condition, the algorithm is solved using the lingo software.

2.1. Objective function of weak link matching algorithm for different types of investment projects and power grids
The project to solve the weak link investment in the grid operation is defined as a Class A project, and the project to solve the weak investment in the future investment management of the power grid is defined as a Class B project. The use of general linear programming does not solve the fixed cost
problem and it requires 0-1 planning. In order to determine whether a project is adopted or eliminated, an optimization variable 0-1 vector $X$ can be defined\cite{3}.

$$X = [x_1, x_2, ..., x_n]$$  \hspace{1cm} (1)

Where, $X_i$ represents the selection of the $i$-th item, $X_i$ is a variable, only takes 0 or 1, when 0 is taken, the item is not selected, 1 is selected to indicate the item; $n$ is the total number of alternative items.

(1) The investment function and the grid operation weak link matching algorithm objective function

The weak link in the operation of the power grid is a problem in the current power grid. In order to measure the power transmission and distribution capacity of the investment, and pay attention to economic benefits, the maximum value of power supply reliability and the maximum value of net present value are selected as the objective function\cite{4-5}.

The reliability of power supply refers to the actual value of the reliability of the power supply after the project is completed and put into production, compared with the realization of the target rod of the same kind, and the actual effect of measuring the reliability of the power supply of the power grid. The calculation formula is

$$RPS_{\text{real}} = (1 - \frac{TT_a - TT_x}{T_t}) \times 100\%$$  \hspace{1cm} (2)

Where, $RPS_{\text{real}}$ is reliability for power supply, $TT_a$ is user average power outage time, $TT_x$ is user average power outage time, $T_t$ is statistical period time.

The net present value formula is

$$NPVR = \frac{NPV}{I_p} \times 100\%$$  \hspace{1cm} (3)

Where, $NPVR$ is the rate of net present value, $NPV$ is net present value, $I_p$ is project original investment present value.

Therefore, in order to make the selected project match the weak link of the grid operation as a whole, the power supply reliability rate and the net present value rate of the selected project are maximized, and the construction objective function is as shown in equations (4) and (5).

$$\max RPS_{\text{real}} = \sum_{i=1}^{n} (RPS_{\text{reali}} \times x_i)$$  \hspace{1cm} (4)

$$\max NPVR = \sum_{i=1}^{n} (NPVR_i \times x_i)$$  \hspace{1cm} (5)

Where, $RPS_{\text{reali}}$, $NPVR_i$ is project decision value, $RPS_{\text{reali}}$ is power supply reliability rate of the $i$-th project, $NPVR_i$ is the net present value of the $i$-th project, $n$ is the total number of items included in the project.

(2) Investment project and grid future investment management weak link matching algorithm objective function

As the weak link of future investment management of power grid is in order to adapt to the future problems of power transmission and distribution price reform, and the focus of power transmission and price reform is on electricity price regulation, how to make investment more favorable to the formation of effective assets is an important goal of power grid investment. In order to measure the development capability of the grid on the basis of ensuring the reliability of the grid operation, the investment focus is selected, and the maximum net present value ratio and the maximum effective asset formation are used as the objective function\cite{6}. Among them, the maximum objective value function of the net present value rate is shown in the above formula (5).

According to the "Provincial Power Transmission and Distribution Price Pricing Method (Trial)", the effective assets of the grid's accrued income are composed of three parts. The calculation formula is
Where, $E_a$ is effective assets that can accrue income, $N_{\text{vfa}}$ is net value of fixed assets, $N_{\text{ia}}$ is net intangible assets, $W_{\text{oc}}$ is working capital. The objective function is

$$\max E_a = \sum_{i=1}^{n} (E_{ai} \times x_i) \quad (7)$$

Where, $E_a$ is project decision value, $E_{ai}$ is effective assets of the $i$-th item that can be accrued, $n$ is the total number of items included in the project.

### 2.2. Constraints of investment project and grid weak link matching algorithm

For the investment projects that match the weak link of the power grid, the constraints mainly include the total investment constraint, the investment allocation ratio constraint, and the relationship between the projects.

1. **Total investment constraints**
   
   The total investment constraint can be expressed as
   
   $$s.t. \sum_{i=1}^{n} (c_i \times x_i) \leq T \quad (8)$$
   
   Where, $C_i$ indicates the planned investment amount of the $i$-th project, $T$ represents the total investment in the grid this year.

2. **Investment allocation ratio constraint**
   
   For A and B projects classified by investment decision attributes, the investment allocation ratio constraint can be expressed as
   
   $$\sum_{j=1}^{P} (c_{pj} \times x_{pj}) \leq T_p \quad (9)$$
   
   Where, $C_{pj}$ represents the planned investment amount of the $j$-th project under the P-type project, $P_n$ represents the total number of projects in the P-type project, $T_P$ represents the total investment of the P-type project, and $P$ is equal to A or B.

3. **Association relationship constraints between projects**
   
   1) Dependent projects. If there is project $k$ and project $l$, and the occurrence of project $k$ must be established in the case where project $l$ occurs, the constraint equation can be expressed as
   
   $$x_k - x_l \leq 0 \quad (10)$$

   2) Strictly complementary constraints. If project $m$ and project $n$, both projects must be at the same time or not at the same time, the constraint equation can be expressed as
   
   $$x_m - x_n = 0 \quad (11)$$

### 3. Empirical Analysis of Matching Algorithms for Investment Projects and Grid Weak Links

In this section, based on the model constructed in the previous section, an empirical analysis of the weak link investment project of a certain region in 2019 is conducted. The grid in this region has high power supply reliability and the ability to maintain the transmission and distribution price level. Therefore, the weak link investment projects only use the net present value rate as the decision value.

1. **Investment project basic data**
Table 1 Basic data table of investment projects for weak links in power grids

| Item category | Item Number | Initial investment amount (ten thousand yuan) | Net present value (ten thousand yuan) | The rate of net present value (%) |
|---------------|-------------|-----------------------------------------------|---------------------------------------|----------------------------------|
| A             | 1           | 233                                           | 300                                   | 1.29                             |
|               | 2           | 500                                           | 612                                   | 1.22                             |
|               | 3           | 120                                           | 150                                   | 1.25                             |
|               | 4           | 148                                           | 220                                   | 1.49                             |
|               | 5           | 320                                           | 420                                   | 1.31                             |
|               | 6           | 300                                           | 325                                   | 1.08                             |
|               | 7           | 195                                           | 220                                   | 1.13                             |
|               | 8           | 280                                           | 311                                   | 1.11                             |
|               | 9           | 450                                           | 721                                   | 1.60                             |
|               | 10          | 311                                           | 419                                   | 1.35                             |
|               | 11          | 326                                           | 453                                   | 1.39                             |
|               | 12          | 140                                           | 215                                   | 1.54                             |
|               | 13          | 160                                           | 301                                   | 1.88                             |
|               | 14          | 211                                           | 357                                   | 1.69                             |
|               | 15          | 223                                           | 335                                   | 1.50                             |
|               | 16          | 411                                           | 523                                   | 1.27                             |
|               | 17          | 350                                           | 369                                   | 1.05                             |
|               | 18          | 265                                           | 305                                   | 1.15                             |
|               | 19          | 228                                           | 245                                   | 1.07                             |
|               | 20          | 110                                           | 254                                   | 2.31                             |

(2) Matching algorithm between investment project and grid weak link

The total investment in the region in 2019 is 50 million yuan, and the net present value rate is selected as the decision value. According to the model established in the previous article, the objective function of the investment project is

$$\max NPVR = \sum_{i=1}^{20} (NPVR_i \times X_i)$$  \hspace{1cm} (12)

Where i=1, 2, ..., 20

According to the previous algorithm constraint model, the constraints of the investment project are shown in Table 2.

Table 2 Different categories of project constraints

| Total investment (ten thousand yuan) | Item category | Investment distribution ratio | The maximum investment amount (ten thousand yuan) | Association constraint |
|--------------------------------------|---------------|--------------------------------|---------------------------------------------------|------------------------|
| 5000                                 | A             | 35%                            | 1750                                              | x7-x9=0               |
|                                      | B             | 65%                            | 3250                                              | x14-x17\leq0          |

(3) Calculation results of investment project and grid weak link matching algorithm

After the objective function and the constraint condition are established, the model is solved by Lingo, and the calculation result is shown in Fig. 1.
Figure 1. Calculation results of investment project and grid weak link matching algorithm.

The calculation results of the investment project based on Lingo software and the weak link matching algorithm of the power grid are shown in the following table.

| Measuring content          | Calculation result |
|---------------------------|--------------------|
| Item category A           | 1, 3, 4, 7, 8, 9, 10 |
| Project decision value    | 24.07              |
| Total investment (ten thousand yuan) | 4161             |
| Balance of investment (ten thousand yuan) | 839               |

It can be seen from the above results that after the completion of the investment, the project decision value is 24.07. Due to the constraints of the entire investment project, the balance of the investment after the completion of the investment is 8.39 million yuan, so the second option is selected for the unselected project. Optimization results are shown in Figure 2.
It can be seen from the results of the above figure that the second preferred result is that the items 2 and 5 can be invested, so the results after combining the two calculations are shown in Table 4.

Table 4 Final calculation results of the matching algorithm between investment project and grid weak link

| project category | Investment result | Planned investment allocation ratio | Plan Investment amount (tenthousand yuan) | Actual investment amount (tenthousand yuan) | Actual investment distribution ratio | Investment balance (tenthousand yuan) |
|------------------|-------------------|------------------------------------|-------------------------------------------|--------------------------------------------|-------------------------------------|--------------------------------------|
| A                | 1,2,....,5, 7,8,....10 | 35%                                | 1750                                      | 2557                                       | 51.14%                              | 19                                   |
| B                | 11,12,....20       | 65%                                | 3250                                      | 2424                                       | 48.48%                              |                                      |

4. Conclusion

From the above results, it can be known that when the project investment is completed, all projects except project 6 are invested when the constraint and objective function are satisfied. This investment maximizes the net present value of the entire project, with a balance of only 190,000 yuan, which achieves the optimal allocation of resources while solving the weak link of the power grid.

Acknowledgments

This work is funded by State Grid Tianjin Electric Power Company under project no.KJ19-1-21

References

[1] Huang D, Huang T, Han L, et al. Research on the technology of tracking & analyzing the weak links base on condition assessment of power grid[C]// International Conference on Power System Technology. 2014.
[2] Blackmore P, Leeprechanon N. Improving network reliability through effective asset management[C]// Innovative Smart Grid Technologies-Asia. 2016.
[3] Wei C, Zhang L. Global optimality conditions for quadratic 0-1 optimization problems[J]. Journal of Global Optimization, 2010, 46(2):191-206.
[4] Guoqing L I, Sun W, Zhang Y. Study on power supply reliability of distribution network including distributed generation[J]. Heilongjiang Electric Power, 2012.
[5] Liu J, Zhang J, Da Z. Effect of Distributed Generation on Power Supply Reliability of Distribution Network[J]. Zhongzhou Coal, 2016.
[6] Garcia R C, Contreras J, Correia P F, et al. Transmission assets investment timing using net present value curves[J]. Energy Policy, 2010, 38(1):598-605.