Research on the Development Input Allocation Model of Power Companies to Integrate Investment Demand and Investment Capacity

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Abstract. Nowadays, the national economy is developing rapidly and the customers' electricity demand is rising year by year. How to optimize the investment scale of electric power enterprises with the available resources and enhance the economy of power grid business and the reasonableness of investment allocation is an urgent problem to be solved. The article uses mathematical programming methods to allocate the total investment capacity of the electric power enterprise company to its corresponding subsidiaries based on the historical data of the electric power enterprise, then constructs a mathematical model for the development input allocation of each subsidiary of the electric power enterprise. The validity of the proposed model is verified by taking five subsidiaries of electric power enterprises as examples, which provides an effective reference for electric power enterprises to make reasonable investment allocation to achieve the purpose of improving quality and increasing efficiency.

Keywords: investment allocation; investment scale; investment capacity

1.Introduction

In recent years, as the trend of globalization continues to advance, China has proposed to build a new power system based on new energy sources with the goal of achieving Peak Carbon Dioxide Emissions and Carbon Neutrality. However, with the structural reform of the energy supply side and the continuous promotion of the power reform system, the development of electric power enterprises is also changing. In this context, electric power enterprises need to accurately grasp their own investment capacity and investment needs, but there are many subordinate companies, and each subsidiary has its own development needs for the company's strategic development. In order to ensure effective and reasonable investment and ensure the smooth development of each subsidiary, the head office needs to make a judgment based on the investment demand and investment capacity of each subsidiary, balance the investment capacity and investment demand of each subsidiary, and allocate the investment amount of the head office in a reasonable and efficient way. Maximizing the total quality and efficiency of the head office of the electric power company under the requirements of electric power reform and strategic goal development is the problem we study.

MSEA 2023, May 26-28, Nanjing, People's Republic of China

DOI 10.4108/eai.26-5-2023.2334228

At present, some scholars, domestic and overseas, are devoted to the research of electric power enterprise investment. The results are remarkable in the direction of measuring the investment capacity of electric power enterprises and optimizing the investment structure of electric power enterprises. Zhang PF[1] established a multi-region grid investment capacity measurement model based on the balance sheet equilibrium relationship, calculated the investment capacity of different regional grids with the limitation of asset-liability ratio, and studied the related problems of grid investment allocation on this basis. Li M[2] By analyzing the relationship between each special input and grid construction-related indexes of historical data, the relationship between the scale of grid infrastructure investment and electricity sales, power supply reliability rate, maximum load, average customer outage time, and the scale of technical improvement special input and depreciated fixed assets are constructed to measure the investment in both grid infrastructure and production technical improvement. Zhao HR[3] The study of the investment capacity of electric power enterprises mainly depends on the operating conditions of the enterprises, the study of grasping the investment capacity of enterprises, the formulation of reasonable investment plans, the quantitative study of the investment capacity of electric power enterprises, the use of financial management, technical and economic theories, the introduction of concepts such as return on investment, operating coefficients, etc., and the construction of a quantitative and demand forecasting model of the investment capacity of electric power enterprises based on co-integration theory and error correction model. Wu[4] comprehensively analyzed the evaluation methods of the implementation benefits of technical standards at home and abroad. Based on the contribution of the standard and the characteristics of the business, the index system of the grid planning, construction, maintenance, and marketing is designed, and the implementation benefits of the technical standards are calculated by numerical analysis. Wei[5] analyzed the investment cost of power transmission infrastructure. Wu[6] combined system dynamics and Bayesian networks to establish a safety investment optimization model for electric power enterprises, which considered the impact of safety investment factors on accidents and determined the factors of safety investment based on sensitivity analysis. Then the optimal security investment strategy is determined through the three-step simulation. Tao[7] evaluated different investment decision algorithms in the literature through a subject-based core long-term model and introduced a new price forecasting method based on optimization modeling. The above scholars mainly focus on the measurement of the investment capacity of electric power enterprises by constructing mathematical models or using simulation, and these methods are worth learning from in the measurement of investment capacity. However, these scholars did not optimize how to allocate investment capacity.

As for the research on the development investment allocation model of electric power enterprises, Ma CH[8] applied the goal programming method and established the goal planning model for the allocation of scientific and technological funds of power grid companies by considering the constraints of the total amount of funds, the number of projects and the total amount of classified funds invested in the scientific and technological projects. Wang C[9] considered the single-objective allocation result with the maximum NPV and the multi-objective allocation result with the maximum NPV and minimum outage loss under the conditions of historical factors and reliability constraints, and used the improved particle swarm optimization algorithm to optimize the allocation of distribution network investment in 13 cities in a province in 2014. Chen X[10] Taking Foshan Power Supply Bureau as an example, the prediction and allocation model of power grid investment in local and municipal bureaus is studied, introducing enterprise operation performance and service capability assessment as constraints, using

regression theory to study the relationship between investment amount and comprehensive evaluation value and establishing an investment scale prediction model. Then the indexes reflecting the investment efficiency of main and distribution networks are selected to build the index system, and the coefficient of variation method is used to determine the index weights of the selected index system, which is combined with the investment scale prediction formula to form the investment allocation model. Yi QH[11], by analyzing the current situation of the power grid and fully considering the load growth, the load carrying capacity of the current grid, and the economic benefits of investment to analyze the distribution network investment decision problem, then proposed four methods are: allocation by rigid demand of distribution network, allocation by equal yield method, allocation by relevant power and comprehensive allocation. Zhu YJ[12] Firstly, the preliminary allocation scheme of investment scale in each region is measured by certain methods, and the development capacity assessment method is established to make a comprehensive assessment of the future development of each region's economy before optimizing and adjusting the preliminary investment allocation scheme to arrive at the final investment allocation. Chi[13] builds an investment capacity measurement model to adapt to the electric power system reform through comprehensive plan balance optimization and used a combination of qualitative and quantitative methods to build an investment allocation model to make the effective and reasonable investment structure of each profession within the investment capacity.

According to the above research literature, it can be seen that most of the research on grid enterprises in China is focused on measuring the investment capacity of enterprises, and the allocation strategies considered by scholars are mostly single-stage investment allocation strategies, a few scholars choose to use simulation to study the input allocation problem, and some scholars provide optimized strategies for coordinating grid investment capacity with investment demand. At present, a small number of scholars, domestic and overseas, are consider the relationship between the allocated investment amount and relevant indicators based on historical data and form investment allocation schemes by fitting historical data or setting weights. However, these methods are to allocate the amount to maximize investment capacity without considering the quality and efficiency of the company. The allocation of investment capacity of the head office is to meet the investment needs of the subsidiaries, combined with their capacity to allocate investment, not only to optimize the effectiveness of the subsidiaries but also to maximize the overall quality and efficiency of the head office, to achieve the goals of the power grid enterprises in the face of power reform and internal strategic requirements of the enterprise. This paper uses mathematical programming methods to allocate the total investment capacity of the grid business to its corresponding subsidiaries to maximize the overall quality and efficiency of the grid company, and thus gives a mathematical model of the development input allocation for each subsidiary of the grid business.

2.Construction of investment allocation model for the development of investment demand and investment capacity

2.1 Problem description

For the problem of allocating investment capacity to maximize the comprehensive quality and efficiency of electric power enterprises, a development input allocation model that integrates

investment demand and investment capacity is constructed, taking into account the investment capacity of the head office of electric power enterprises and the investment capacity and investment demand of their subsidiaries. The investment scale, demand, and capacity of the electric power enterprise are known; the investment demand control coefficient and investment capacity control coefficient of the electric power enterprise, the electric power enterprise's quality and efficiency measurement indexes and the index weights are known. To study how the electric power enterprise allocates the investment capacity of the head office to its subsidiaries so that the efficiency of each subsidiary can meet its investment demand and achieve optimal efficiency, and the head office achieves the goal of improving quality and increasing efficiency, the following mathematical model is established.

2.2 Mathematical model

Parameter Description:

i: Subsidiaries of electric power companies, i = 1, 2, 3, 4, 5.

x_i: The scale of investment in electric power companies in 2021.

x_{ele}: Total investment capacity of power companies in 2021.

l_i: The scale of investment in electric power enterprises.

p_i: Investment capacity of power companies.

r_i: Investment needs of power companies.

k: quality and effectiveness measures, k = 1, 2, 3.

w_k: The weighting of indicators for quality and effectiveness measurement.

q_{ik}: Quality and efficiency of power companies.

m_i: Maximum size of investments by electric utility companies for the period 2016-2020.

w_r: Investment demand control factor.

w_m: Investment scale control factor.

Take the power company the current investment amount of the subsidiary multiplied by The quality effect generated by the investment amount of each subsidiary as the total quality effect of the subsidiary in the current period to maximize the absolute quality and efficiency of the current period of each subsidiary, the development input allocation model of the electric power enterprise that integrates investment demand, and investment capacity is established as follows.

$$\mathrm{Max} \sum_{i=1}^{5} \frac{\sum_k w_k \cdot q_{ik}}{l_i} \cdot x_i \tag{1}$$

Constraints:

$$\sum_i x_i \leq x_{ele}; \tag{2}$$

$$x_i \leq p_i \quad i = 1, \ldots, 5; \tag{3}$$

$$x_i \geq r_i \cdot w_r \quad i = 1, \ldots, 5; \tag{4}$$

$$x_i \leq m_i \cdot w_m \quad i = 1, \ldots, 5; \tag{5}$$

$$\left|\frac{x_i}{l_i} - \frac{\sum_i x_i}{\sum_i l_i}\right| \le d_1 \qquad i = 1, \ldots, 5; \tag{6}$$

$$\left|\frac{x_i - l_i}{l_i}\right| \le d_2 \qquad i = 1, \ldots, 5; \tag{7}$$

In the model, equation (1) is the objective function, the model optimization objective is to maximize the sum of the integrated quality efficiency of the five subsidiaries of the power company in 2021. The quality efficiency of each subsidiary is the investment amount of the subsidiary in the current year multiplied by the integrated quality efficiency value created per unit investment of the previous year. Equation (2) means that the sum of the investment amount of the five subsidiaries in 2021 shall not be higher than the total investment scale of the power enterprise in 2021. Equation (3) means that the investment amount of each subsidiary in that year shall not exceed its investment capacity. Equation (4) means that the investment amount of each subsidiary shall not be lower than the investment demand of the subsidiary itself. Equation (5) means that the investment amount of each subsidiary for the year shall not be significantly higher than the highest level of the investment scale of that subsidiary within five years. Equation (6) means that the difference between the amount of investment allocated to each subsidiary and the year-on-year rate of change of the total investment scale of the five subsidiaries should not be too large, equation (7) indicates that the difference between the amount of investment allocated to each local company and its investment scale in the previous period should not be too large.

3.Example analysis

The mathematical model constructed in section 2.2 was solved using lingo software, and the values of the parameters in the model are shown in Table 1 to Table 5.

Table 1: The scale of investment in electric power enterprises in 2016-2020

	l_i/ million				
	2016	2017	2018	2019	2020
l_1	1872717	1998508	1769675	1164449	936046
l_2	833703	560443	907221	1223389	1044922
l_3	4257047	5361236	4415406	3108897	2470763
l_4	814660	1051803	1353444	1236800	1112644
l_5	3081260	2657332	3183350	3070919	2346480

Table 2: Investment capacity and investment demand in 2021

p_i / million		r_i/ million	
p_1	1227134	r_1	1200000
p_2	1188578	r_2	1000000
p_3	3247902	r_3	3500000
p_4	1245211	r_4	1100000
p_5	3077326	r_5	3000000

Table 3: Investment demand control factor and Investment scale control factor

Investment demand control factor		Investment scale control factor	
w_r	0.7	w_m	0.9

Table 4: Maximum size of investments by electric utility companies for the period 2016-2020

m_i / million	
m_1	1998508
m_2	1223389
m_3	5361236
m_4	1353444
m_5	3183350

Table 5: Total investment capacity of power companies in 2021

x_{ele} / million	
x_{ele}	7910855

Each subsidiary has annual investment demand for its rapid development. Because each subsidiary has different development strategy requirements and matches with the head office to a different extent, the actual investment scale and investment demand differ. Hence, it is necessary to introduce the investment scale control factor and investment demand control factor to constrain the investment amount of the enterprise not to exceed the maximum investment scale in the past five years multiplied by the investment scale control factor and not to be lower than The current year's investment demand multiplied by the investment demand control factor. The investment scale of the grid business should not fluctuate too much each year, so the difference between the ringgit of the investment amount allocated to the five subsidiaries of the grid business and the ringgit of the full investment scale of the grid business in the current year should not exceed the threshold, and the rate of change of its investment scale in the previous year should not exceed the threshold.

The most important indicators of the quality and efficiency of the power company are electricity sales, line loss rate and newly installed power generation capacity, which account for 0.4, 0.2 and 0.4, respectively. Thus the comprehensive quality and efficiency of the five subsidiaries of the power company are calculated. Finally, the results of the development input allocation model constructed according to the Lingo solution to coordinate investment demand and investment capacity are subsidiary one investment scale of 840000 million, subsidiary two investment scale of 700000 million, subsidiary three investment scale of 3247902 million, subsidiary four investment scale of 770000 million, and subsidiary five investment scale of 2352953 million in 2021. According to constraint (6) and constraint (7), it can be concluded that the year-on-year rate of change of the investment amount allotted to the five power companies' subsidiaries concerning the total investment scale of power companies is within the acceptable range. The investment scale in 2021 decreases relative to 2020 but is within the year-on-year growth.

4.Discussion of results

According to the results of the solution, it can be seen that in 2021, the investment scale of the five subsidiaries of electric power enterprises has decreased except for subsidiary three and

subsidiary 5. Firstly, affected by the epidemic, the enterprise's capital turnover is affected and being forced to give up the business will lead to a decline in the income of the electric power enterprises. At the same time, the state takes measures to reduce or waive the electricity tariff to alleviate some enterprises' electricity consumption problems, so the turnover is one of the reasons that directly affects the scale of investment. Second, according to historical data can also be seen that the whole society's electricity consumption has also declined, and it is known that domestic residential electricity consumption has been in the state of rising. Still, due to the second half of 2021 power restrictions, residential electricity consumption has been reduced, which is also the cause of the decline in the scale of investment. Third, the power reform to achieve clean, safe, efficient and sustainable development of electricity, power investment is more inclined to technical reform and other aspects of the work, for large infrastructure investment reduced. When the investment scale has declined, more need to consider how to allocate investment to make the grid business development quality and efficiency.

5.Conclusion

Investment in electric power enterprises is a multi-attribute and multi-decision work, and many factors must be considered. In this paper, we take the historical data of five subsidiaries of electric power enterprises as the basis for calculation, select the main indicators that affect the quality and efficiency of electric power enterprises, and construct the investment capacity allocation model based on the historical data of electric power enterprises to maximize the quality and efficiency of electric power enterprises in the current year. The calculation example shows that the model can make the investment capacity allocation of electric power enterprises to meet the needs of each subsidiary while optimizing the overall quality and efficiency of the head office, better realize the scientific and refined management of development inputs, achieve the total balance and optimization of core resources and needs, and implement the strategic objectives and development plans of enterprises. As the reform of electric power enterprises advances, the allocation of investment in the grid business is even more critical, not only to enable better development of subsidiaries but also to optimize the grid business's overall integrated quality and efficiency. Our model aims to solve the problem of allocating the investment capacity to maximize the overall quality and efficiency of the grid business. Still, this study is not deep enough to analyze the mechanism between the investment capacity and the overall quality and efficiency of the electric power enterprise. At present, we only simply think that each subsidiary's investment scale, output quality, and efficiency are on the same path. Still, the operating conditions of each enterprise are different, and further analysis of the mechanism is needed, which is also a possible future. It is also a direction that we can focus on in the future.

Acknowledgments

The authors particularly grateful for the support from members of STATE GRID HEBEI INFORMATION & TELECOMMUNICATION BRANCH. Project fund: Key Technologies for Development Investment and Operation Quality Improvement of the Sgcc's "One Body and Four Wings" under the New Situation (1400-202157361A-0-0-00).

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