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Calculation method of multi-regional power grid investment capacity based on debt-to- asset ratio

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Abstract: Under the background of the new reform and regulation of electric power enterprises' operation mode, the study on the investment capacity of an electric power enterprise is becoming increasingly urgent. At the same time, the enterprises are facing problems, e.g., it is difficult to allocate investment considering that electric power systems in different areas have different investment capacities. On this basis, an assessment method for the investment capacity of a multi-area electric power system is proposed based on debt - to - asset ratio. First, the comprehensive benefits are assessed. Then, the allocation coefficients are calculated by combining asset factors and performance factors, according to which the benefits are allocated. Accordingly, the investment capacities of electric power systems in different areas are calculated based on debt - to - asset ratio. Through the analysis of a case study of one city-level electric power enterprise, the investment capacity in the future is forecasted, which can provide reference for the investment plan of the enterprise.

1. Introduction

As a basic facility, power grid construction projects are related to the lifeblood of the national economy and are of great significance in promoting social and economic development. The power grid construction project is different from the general project and has its own particularity. Therefore, it is of great significance for the power grid construction and the sustainable development of the power grid that how the power grid enterprises accurately forecast the power demand and reasonably and effectively plan the power grid under the complex power grid environment, scientifically determine the power grid investment strategy and establish perfect investment decision management methods under the constraint of investment capacity.

Compared with other capital-intensive investment and construction projects, power grid investment has both similarities and unique characteristics. Reasonable investment scale is very important for investors to maintain high economic efficiency and sustainable development level. Investment demand and investment capacity are two sides of a reasonable investment scale, which are accompanied by and full of contradictions. In order to satisfy the planning effect of distribution network and improve the performance of distribution network, there is a certain planning investment demand for distribution network itself. The investment ability reflects the ability of the investor to invest in the actual capital. From the mathematical point of view, it should be an upper limit for the investor to invest in the actual

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capital. Once the upper limit is exceeded, the investor will face the dilemma of unable to recover the cost or insolvency. Obviously, this investment ability mainly depends on the financial condition of the investor.

Under this background, this paper firstly summarizes the research status of investment capacity at home and abroad, and studies the composition of comprehensive benefits of power grid and the method of benefit allocation of multi-area power grid. According to the relationship of the balance sheet, a multi-area power grid investment capacity calculation model based on debt-to-asset ratio is established. Finally, an empirical analysis of a city-level power grid is carried out. The method proposed in this paper is especially suitable for the investment capability analysis of power grid enterprises in many areas under their jurisdiction.

2. Research Status of Investment Capability

The study of investment capacity is of great significance to the determination of the actual reasonable investment scale. However, the current power grid enterprises are project-oriented, first fix the project, then give the funds, and then calculate its impact on enterprise finance in the process of project planning, implementation and operation management. This means that the investors only take investment demand as the actual investment scale orientation, and lack the prediction of investment capacity, and has financial risks. In addition, under the traditional power management system, it is extremely difficult to distribute the benefits of power grid to different regional power grids, and it is impossible to grasp the investment capacity of different regional power grids.

At present, the research on investment capacity mainly focuses on such engineering and technical issues as, risk control and power supply reliability, including cost-benefit analysis, asset portfolio optimization and risk management. And some researches on investment capacity focus on the relationship between national macroeconomic investment, economic aggregate and industrial structure [1]. The research on investment capacity of power grid mainly focuses on the evaluation and analysis of single power project and rural power grid [2-4].

For power grid enterprises, in the traditional sense, there is no evaluation of investment capacity, so there is no index of investment capacity, but the investment benefit or economic evaluation of power grid, which is closely related to investment capacity, has been relatively mature. Traditional financial evaluation indicators include profitability indicators such as internal rate of return, net present value, investment payback period, and solvency indicators such as interest reserve rate, solvency reserve rate, asset-debt ratio, etc. The evaluation of investment benefit has gone through four periods: cost evaluation system, DuPont financial evaluation system, comprehensive evaluation system of return rate and the current evaluation system with financial indicators as the main and non-financial indicators as the supplement. After 1990s, it entered the stage of comprehensive evaluation. Literature [5] presents a financial evaluation framework including project selectivity and uncertainty modeling, Monte Carlo simulation, real option analysis and decision analysis. Literature [6] calculates the capacity of wind energy and solar energy in Semnan City and focuses on the economy of distributed generation access to distribution network. Literature [7] presents a post-evaluation method for investment effect of distribution network and an analysis method for investment rationality of distribution network. In addition, analytic hierarchy process, fuzzy mathematics theory, incremental method and game theory are often used in economic evaluation.

3. Investment Benefit Distribution of Multi-Area Power Grid

3.1 Comprehensive benefits of power grid

The investment benefit of power grid can be reflected in many aspects, such as power growth, reliability improvement, power quality improvement, loss reduction and so on. This paper calculates the investment benefit by choosing the indicators which can improve obviously after investment and bring greater economic benefits, including electricity sales income, loss reduction income, safety income and environmental protection income. Electricity sales revenue E_1 is closely related to grid

electricity S_u, electricity consumption on the grid S_w, average electricity price on the grid P_u, and average electricity sales price on the grid P_w. The approximate formula is as follows:

$$E_1 = S_w P_w - S_u P_u \quad (1)$$

Loss reduction income E_2 can be calculated by electricity sales income before and after the project, and the calculation formula is as follows:

$$E_2 = (\eta_2 - \eta_1) \mathrm{S_w P_w} \quad (2)$$

In the formula, η_2 is the loss rate before the project is put into operation and η_1 is the loss rate after the project is put into operation.

Safety is an important index to measure the sustained power supply of power grid enterprises. Safety benefit E_3 can be expressed by the reduction of blackout loss before and after the project, and the calculation formula is as follows:

$$E_3 = (\mathrm{T_2 - T_1}) \rho \mathrm{D_a} \quad (3)$$

In the formula, $\mathrm{D_a}$ is the annual average load in the power supply area; $\mathrm{T_2}$ is the average power failure time of the users before the project is put into operation; $\mathrm{T_1}$ is the average power failure time of the users after the project is put into operation; and ρ is the unit power failure loss. The E_3 value may be very small in the actual calculation process, and it needs to be enlarged hundreds of times in some cases to emphasize its influence.

Environmental protection benefits not only include energy saving and emission reduction, but also reduction of coal consumption. Therefore, this paper argues that environmental protection benefits, E_4 includes the benefits of saving coal combustion and emission reduction, and the calculation formula is as follows:

$$E_4 = \Delta S f + \sum_{i-1}^{n} (\mathrm{G_i \Delta S} \lambda) \omega_i \quad (4)$$

In the formula, ΔS is the conventional power generation that can be replaced by new energy access; f is the unit cost of coal combustion; $\mathrm{G_i}$ is emission rate of the nth pollutant [8]; n is the number of pollutants, generally including SO2, NOx , CO, CO2; λ is the coal consumption rate; ω_i is levy standard of environmental protection cost for the nth pollutant.

So far, the comprehensive benefits of power grid can be expressed as follows:

$$E = E_1 + E_2 + E_3 + E_4 \quad (5)$$

3.2 Distribution Coefficient of Power Grid Investment

At present, it has not yet formed a reasonable transmission and distribution pricing mechanism. For power grid enterprises, their comprehensive benefits can be calculated directly from the purchase and sale ends, but it is difficult to calculate the benefits of different voltage levels and different regions. Therefore, this paper first calculates the comprehensive benefits of the power grid, and then distributes the distribution coefficients to all voltage levels and regions. The benefit allocation of power grid depends not only on fixed assets, but also on the performance of power grid. Therefore, the power grid allocation coefficient A [9] proposed in this paper consists of two parts: the basic allocation coefficient F_A and the modified allocation coefficient R_A, namely $A = F_A R_A$.

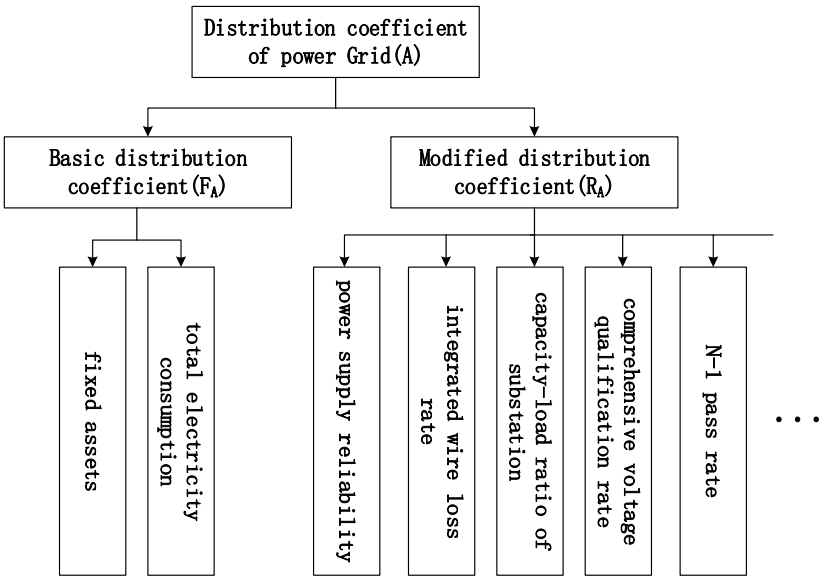


Figure 1. Decomposition of allocation coefficient

The formula for calculating the distribution coefficient of foundation is as follows:

$$F_A = W_1C_1 + W_2C_2 \quad (6)$$

In the formula: W_1 and W_2 are weight coefficients; C_1 is a capital occupancy factor, which is equal to the ratio of fixed assets formed by construction investment of a certain voltage level in a specific year of the evaluation object in a certain area to the total fixed assets of the evaluation object; C_2 is an asset-forming factor, which is equal to the ratio of the total social electricity consumption of the evaluated object to the total social electricity consumption of the evaluated object at a certain voltage level in a certain area. The formula for calculating the modified distribution coefficient is as follows:

$$R_A = \sum_{i=3}^{n} W_i C_i \quad (7)$$

In the formula, W_i is the weight coefficient and C_i is the membership value of various distribution network performance indicators according to their respective membership function. In this paper, five correction factors are adopted, including reliability of power supply, loss rate of integrated wire, load ratio of transformer capacitor, qualified rate of integrated voltage and pass rate of line "N-1", therefore, n = 7. In practical application, different performance indicators can be selected according to the characteristics of power grid and data collection.

The calculation of A can be carried out by using the method of fuzzy mathematics, in which the linear membership function of trapezoidal distribution is used to transform C_i; W_i combines the method of variation coefficient and the method of entropy for combination weighting; and then the "ordinary multiplier and additive operator" is used to determine the F_A and R_A respectively, and finally normalize them. Generally speaking, the sum of A of power grids in different regions with different voltage levels is not equal to 1. Normalization is needed to distribute the benefits of power grids, that is, to distribute the benefits of power grids.

$$A_i^{'} = A_i / \sum_{i=1}^{m} A_i \quad (8)$$

In the formula, m is the number of regions at each voltage level to be allocated.

3.3 Power grid investment benefit distribution

By multiplying the comprehensive benefit calculated in Section 2.1 by the distribution coefficient calculated in section 2.2, the investment benefit value of regional power grids can be obtained, and

then the investment capacity of different regional power grids can be calculated.

4.Investment capacity Calculation of multi-area power grid

4.1 Debt-to-asset ratio constraint

Debt-to-asset ratio is an important indicator to measure the level of corporate debt and the degree of risk. It is the ratio of total debt to total assets, in which total debt refer to the total debt undertaken by the company, including current debt and long-term debt; total assets refer to the total assets owned by the company, including current assets and long-term assets. At present, in order to avoid the impact of over-investment on the sustainable and stable operation of enterprises, power grid companies have defined the overall debt limit of the company, and stipulated the maximum debt ratio of each branch and subsidiary in the investment. Therefore, it is possible to quantify the investment capacity of power grid enterprises under the limitation of asset-debt ratio.

4.2 Investment Capacity Calculation Model

Reference [10-11], assuming that the investable assets of a company are zero in the previous year, the following formula of investment capacity is as follows:

$$Y_i = L_i + Z_i + R_i - H_i - J_i \tag{9}$$

In the formula: Y_i is the investment capacity of the year i; L_i is the retained profit of the year i (net profit deducted from the surrendered profits); Z_i is the depreciation of the year i; R_i is the financing amount of the year i; H_i is the repayment amount of the year i; J_i is the current assets of the company in the second year.

The model shows that the maximum investment capacity of power grid enterprises mainly consists of two parts: one is the profit value of the previous year, the other is the fund raised from the society under the threshold of asset-debt ratio. The retained profits, depreciation, repayment and current assets in formula 9 belong to the category of calculating the profit value of an enterprise in the previous year, and the amount of financing is the fund raised from the society for investment in power grids.

1) Retained profits L_i

The formula for calculating retained profits is

$$L_i = E + \sum_{j=1}^{t} O_j - \sum_{j=1}^{v} C_j - LS_i \tag{10}$$

In the formula, E is the comprehensive benefit of regional power grids with different voltage levels, which is calculated by formula (5); O_j is the other operating income except E; C_j is the j-th cost type; LS_i is the profit handed over in the year i, according to relevant regulations, R is 20 % of the profit.

2) Depreciation amount Z_i

On the premise of mastering the investment plan of power grid enterprises, the depreciation amount in the next year is estimated. First of all, we need to analyze the current fixed assets of power grid enterprises, which is to mainly calculate the depreciation amount of the existing fixed assets in the next year, which can be accurately calculated or estimated according to needs. Secondly, the types, quantities and amounts of new fixed assets are expected to be formed in this year, so that the types, quantities and total amount of fixed assets that need depreciation at the end of this year have been determined. The specific calculation method is as follows:

$$Z_i = (J_{Z_{i-1}} - Z_{i-1}) / (15 - i) + A_{zi} / 15 \tag{11}$$

Formula: 15 denotes depreciation period; $J_{Z_{i-1}}$ denotes net fixed assets in year i-1; A_{zi} denotes investment in the year i.

3) Financing amount R_i

The formula for calculating the amount of financing is as follows:

$$R_i = \frac{F_i(Q_{i-1} + L_i) - S_{i-1}}{1 - F_i} + H_i \quad (12)$$

In the formula: F_i is the debt ratio of the year i; Q_{i-1} is the total assets of the year i-1; S_{i-1} is the total debt of the year i-1. Because the calculation includes H_i, it is offset by the sub-term in the investment capacity calculation and therefore no special calculation is required.

4) Retaining Current Assets J_i

Retaining current assets J_i is set according to the company's annual operating expenditure and a fixed proportion, generally set at 5% of the purchase cost of electricity plus 10% of the transmission and distribution costs.

4.3 Investment Capacity Calculation Process

Step 1 By calculating E, other investment income and operation and maintenance costs, the company's operating profit in the year i is calculated, and then the surrendered profit is calculated, and the net profit in the year i can be calculated.

Step 2 To calculate the depreciation of fixed assets, we first calculate the depreciation of the stock assets, deduct the annual depreciation according to the net value of fixed assets of the previous year, and then calculate the depreciation of fixed assets according to the average depreciation of the remaining years (considering that the actual operation of the company is continuous, the depreciation of fixed assets of the research year is calculated according to the depreciation period of 15 years). Secondly, the depreciation of new assets is calculated. In order to simplify the calculation of the original value of assets, we should calculate according to the actual amount of investment.

Step 3 Calculate the maximum amount of financing. The amount of repayment in the subsequent calculation is offset with the amount of repayment in the overall formula, so there is no need to calculate.

Step 4 Calculate the remaining current assets for operation and the maximum investment capacity of the enterprise, and calculate the investment capacity of each year in the forecast stage by iteration.

5. Case Study

Taking a city-level power grid enterprise as an example, the power grid enterprise consists of five districts (B1, B2, B3, B4, B5) with a single voltage level. In 2016, the power consumption of the whole society regulated by the power grid enterprises was 284.36 *108 kW, with an asset-debt ratio of 68%. The average electricity price in this area was 0.43 yuan/(kWh), and the average selling price was 0.79 yuan/(kWh). The unit outage loss was 18 yuan/(kWh). The performance indicators of five municipal districts were shown in Table 1. In 2015, the asset-debt ratio of the grid enterprise is limited to 55%, the depreciation period is set to 15 years, and the residual value ratio is set to 5%.

Firstly, according to Section 2.1, the income of electricity sales of the power grid enterprise in 2014 is 9.268 billion yuan, the income of reducing network loss is 112 million yuan, and the security income is 0.044 billion yuan. Environmental benefits are not included due to lack of data, and the total benefit was 9.584.4 billion yuan.

Table 1. Performance indexes of electric power systems in different areas

region	B1	B2	B3	B4	B5
Fixed assets / billion yuan	59.21	20.53	21.14	39.26	24.56
Electricity consumption of the whole society/(10^3kW·h)	89.09	16.70	29.85	34.96	33.75
Reliability of power supply /%	99.98	99.97	99.97	99.96	99.91
Line loss rate /%	8.23	7.81	6.26	7.55	6.45
Capacity-load ratio	2.11	2.38	2.30	2.68	2.10
Comprehensive Voltage Qualification Rate/%	99.961	99.665	99.927	99.666	99.152
Line "N-1" pass rate	100.00	86.20	78.61	65.95	78.41

Secondly, according to Section 2.2, the membership degree and weight of seven indicators are calculated respectively. When using trapezoidal fuzzy membership function to fit, fixed assets, social

electricity consumption, reliability of power supply, comprehensive voltage qualification rate and line "N - 1" pass rate are positive indicators; Capacity-load ratio is an appropriate index. When using the method of variation coefficient and the method of entropy to combine weighting, the results of W_1 and W_2 are 0.458 3 and 0.541 7, and the results of $W_3 \sim W_7$ are 0.0006, 0.3583, 0.306, 0.0072 and 0.3279. The results of weight can also reflect the impact of each index on investment capacity. By using the method of fuzzy mathematics, the comprehensive distribution coefficients of five districts are obtained: B_1 is 0.4362, B_2 is 0.096, B_3 is 0.1593, B_4 is 0.111, B_5 is 0.1975, and then the comprehensive benefits of five municipal districts are obtained: B_1 is 26.133, B_2 is 5.751, B_3 is 9.544, B_4 is 6.650, B_5 is 11.832.

Then, according to section 3, the retained profits, depreciation, financing and retained current assets of the five municipal districts are calculated in turn. Finally, the final investment capacity of the five municipal districts in 2015 is calculated as shown in table 2.

Table 2. Assessment results of investment capacity of electric power systems in different areas

Region	B1	B2	B3	B4	B5
Financing amount	43.548	9.586	15.908	11.082	19.720
Profit after payment	20.901	4.601	7.635	5.319	9.465
Depreciation amount	3.750	1.300	1.339	2.486	1.556
Investment ability	64.904	14.869	23.779	17.594	29.493

6. Conclusion

From the perspective of power grid enterprises, this paper presents an asset-debt ratio-based multi-regional power grid investment capacity measurement method, and predicts the investment capacity of each region in the coming years as the basis for investment plans of power grid enterprises. The results of case analysis show that the actual investment of power grids in all regions is within the investment capacity, and the calculation method is practical and feasible.

The calculation of investment capacity has a positive guiding role for power grid enterprises. When the investment capacity is greater than the investment demand, power grid enterprises should pay attention to the investment benefit of the power grid, improve the scientific development level of the power grid, carry out in-depth economic evaluation of the long-term planning of the power grid, strengthen input-output and benefit analysis, make the planning lean and refined, grasp the forward-looking of the planning, and avoid duplication of investment and waste of investment. When the investment capacity is less than the investment demand, the first is to arrange the grid structure scientifically, to ensure the coordinated development of transmission and distribution network in the whole province, to ensure that the grid construction meets the needs of various cities; The second is to arrange the annual investment plan scientifically and determine the capital progress reasonably. The annual power grid investment plan should be formulated on the basis of accurately predicting the growth of annual power load, dynamically maintaining the reasonable level of capacity-load ratio of power grid, and avoid the waste of investment caused by excessive capacity-load ratio as far as possible.

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