Research on Substation Comprehensive Investment Demand Evaluation Model under the Background of Electricity Reform

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Abstract: Based on the background of electricity transmission and distribution price reform, this paper focuses on the substation assets, through the influence analysis of reform policies to the power grid company operation and management, aimed at the high quality development of the company and power grid, to establish the substation comprehensive investment demand evaluation index system, specify the index calculation methods and evaluation principles, construct the substation comprehensive investment demand evaluation model, collect the actual data of a power grid company’s substations, measure and calculate, and put forward the substation investment and construction advice according to the results of the measurement, to assist the company for investment decision making.

1. Introduction
The electricity transmission and distribution price reform changes the profit model of power grid enterprises, and the investment scale related to the power grid will directly affect the approval level of the regulatory authority to the company's permitted income. The regulatory authority’s investment restraint mechanism makes the investment benefit of power grid related project and the operation efficiency of invested assets becoming the key that whether the permitted revenue can be recovered in full. Besides, SGCC proposes the "three types and two networks, world first class" strategic objective and "quality reform, efficiency reform, kinetic energy reform" strategic way of 2019, to require each unit paying attention to the efficiency of corporate investment benefit, strive to promote the development of high quality of the company and power grid, and promote the company strategic target realization.

The company faces the conflict of overall quality improvement and efficiency promotion of power grid and regional development imbalance, and also faces the conflict of external regulation getting stricter and the company's management needing to be promoted. Substation as the important asset equipment for power transmission and distribution function realization plays a critical role in the whole power grid; at present, the company’s investment of transformer substation construction still adopts the traditional planning idea, which is closely related to the economic benefits of substation and regional development level, but lack of quantitative means of comprehensive investment demand level, and not optimizing the investment strategy according to the electricity transmission and distribution price reform policy.

In this paper, based on the electricity reform policy and the analysis of the company development strategy, combined with the company’s current transformer substation construction investment focus, it analyzes the substation investment motivation, to establish the substation comprehensive investment demand evaluation index system respectively from the operation efficiency, safety and reliability, economic benefits and regional economy, etc., construct the model of comprehensive investment
demand evaluation, and collect data to carry out the calculation, and finally put forward the investment advice through the analysis of the measuring result.

2. Analysis of Substation Investment Motivation

Since the document “Several Opinions on Further Deepening the Reform of Electric Power System of State Council of Central Committee of Communist Party of China” (ZF [2015] No. 9) released in March 2015, the electric power system reform has brought unprecedented impact to the power grid enterprises, and also caused the heated debate and conflict of interests. This paper analyzes the influence of electric power system reform on power grid operation, the influence of electric power system reform on power grid operation strategy, and the influence of electric power system reform on power grid investment strategy, to provide the direction and basis for the selection of substation comprehensive investment demand evaluation index.

2.1. Influence of electricity reform policy on power grid operation

The traditional management of power grid operation mode is mainly based on the power grid safe and stable operation and reliable supply of electricity. At present, the dispatching institutions could actively arrange the startup combination of generator set on the second day, the output curve of generator set, spare capacity, power transmission and transformation equipment maintenance and power outages, to optimize the operation mode on the premise of meeting the security constraints. Along with the advancement of electric power system, the output of generator set, startup combination, trend method, spare capacity, and other elements related to the power grid security will be determined by the market, which increases the complexity of the operation arrangement, squeezes the flexibility of operation arrangement, objectively causes the control reduction of dispatching institutions to the power grid operation, and increases the difficulty to ensure the safety of power grid. At the same time, along with the continuous expansion of trade size, the trade contract solidifies more grid regulated resources, so the normal power grid operation constraint increases, and thus affecting the ability of power grid operation control. The principle of electric power dispatching institution when arranging the operation mode shall gradually shift to ensure the safe and stable operation of power grid, reliable electricity supply and effective implementation of trading plan. This requires that the power grid shall give full consideration to the current operation status of the power grid (maximum load rate, average load rate and substation main transformer standby condition, etc.), regional economic development level (electric quality growth rate, GDP level, population growth, etc.), user contract transaction quantity (such as the planned trading contract electric quantity) in the investment and construction of power grid.

2.2. Influence of electricity reform policy on company operation

Electricity sales reform is one of the important contents of new electricity reform, whose scheme proposes the electricity sale, increment distribution business shall be open, the trading platform shall be relatively independent, and the power grid enterprise profit model shall be reformed, which will profoundly affect the current electric power market pattern. After the electricity sales marketization reform, it will allow 6 types of enterprises becoming the subject of new electricity sales, including existing independent electricity distribution and sales enterprises, high and new industrial park and economic development zone, social capital invested, distributed energy users or micro network system, public service industry and energy-saving service companies and power generation companies. At present, the national registered electricity sales companies increase year by year, which will be the powerful competitor in the field of electricity sales of the power grid company, and the electric power industry exclusive monopoly will be broken. Market competition is conducive to improve the enterprise development level and service ability, but the power grid companies facing the competition from market will become more and more fierce. This requires that the company investment should give full consideration to increase the market share and improve the service quality.
2.3. Influence of electricity reform policy on investment management

The power grid investment plan of traditional companies is mainly based on the power grid plan, and the power grid plan is mainly based on the power planning and regional economic development needs, which emphasizes the overall development and safe operation of the power grid, and the analysis of project economic benefits is slightly insufficient.

After the electricity reform, all provincial companies check and ratify the electricity transmission and distribution price based on the "permitted cost plus reasonable profits" mode according to the asset scale of different voltage levels, whose core is to approve the price on the basis of reasonable cost and reasonable return, which will control the key parameters of power grid enterprise such as the effective assets, depreciation rate, operational maintenance rate and capital fund yield. It shall plan the power grid investment in accordance with the forecasting of government department authority, conforming to the electric power planning, and check and ratify in the principle of fixed assets investment growth matching with the planned electricity growth, load growth, and power supply reliability; the assets has nothing to do with the transmission and distribution and the unreasonable assets will be strictly reduced, while the transmission and distribution assets increased at the regulating cycle and electricity growth, load growth, and power supply reliability improvement deviation parts, depreciation cost related to electricity transmission and distribution assets, and operational maintenance cost can be temporarily not included in the electricity transmission and distribution price of the regulating cycle. This requires the power grid investment strictly according with the power planning, he power grid planning shall give full consideration to the investment and electricity growth, load growth, and power supply reliability growth.

3. Substation Comprehensive Investment Demand Evaluation Index

According to the influence analysis results of electricity reform to the company power grid operation, company operation and investment management, combined with the state grid economic interaction analysis key index, power grid enterprise assets management benchmarking index system, power grid development diagnosis and analysis index system, evaluation index system of effective asset input and output of power grid enterprises, company electricity distribution network planning and comprehensive evaluation index system, state grid corporation unified statistical index system specifications, etc., it shall establish the substation comprehensive investment demand evaluation from the eight aspects of the expected economic benefits from the station construction, expected power grid benefits, expected social benefits, related station running efficiency, safety and reliability, quality of power supply, power supply capacity and economic benefit, to specify the index meaning and the index calculation formula, and the index weight is determined by Delphi method (subjective weighting method) according to the tightness between the evaluation index and the target, to lay the foundation for the evaluation and analysis of the substation comprehensive investment benefit.

| Evaluation object                                      | First-level index                  | Second-level index                  | Index meaning                                      | Computation formula                                                        |
|--------------------------------------------------------|------------------------------------|------------------------------------|----------------------------------------------------|---------------------------------------------------------------------------|
| Comprehensive investment benefits of construction stations | Expected economic benefit          | Return on unit investment          | Economic benefits of project construction          | Index value = profit / investment in substation                             |
|                                                        | Expected power grid benefit        | Unit investment supply load        | Expected unit investment load growth benefits      | Index value = (expected maximum load - related station maximum load) / substation investment |
|                                                        | Grid structure promotion level    | Determine whether to optimize the grid structure | Yes / No                                           |                                                                           |
| Expected social benefit | Nonelectric user power-on quantity | Whether it satisfies the power supply demand of nonelectric user | Index value = expected nonelectric user power-on quantity |
|-------------------------|-----------------------------------|---------------------------------------------------------------|----------------------------------------------------------|
| New energy online electricity | Promote green development, promote the construction of three types of power grid | Index value = expected new energy online electricity |

| Operational efficiency | Average load rate | Reflect the overall operating efficiency level of related substations. | Index value = average load of substation high voltage side of current year / rated capacity of substation of current year |
|------------------------|------------------|----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| Safety and reliability | Whether it is the single substation | Reflect the reliability level of relevant substations. | Direct access |
| Power supply quality | Qualified rate of supply voltage | Reflect the quality of power transmission in related substations | Direct access |
| Power supply capacity | Maximum load rate | Reflect the capacity of relevant substation to meet the subordinate load requirements | Index value = maximum load of substation high voltage side of current year / substation capacity of current year |
| Economic benefit | Unit asset power supply | Reflect the operation benefit of related substation assets | Index value = average load of substation low voltage side of current year * operation time / original value of substation assets |
| | Maximum load per unit asset | Reflect the operation benefit of related substation assets | Index value = maximum load of substation low voltage side of current year / original value of substation assets |

| Evaluation object | First-level index | Second-level index | Index type | Index score principle | Index required data | Data unit | Responsible department |
|-------------------|------------------|-------------------|------------|-----------------------|---------------------|----------|------------------------|
| Comprehensive economic benefit of construction stations | Expected economic benefit | Return on unit investment | Positive type | <=0 scores 0 point >= all-time high scores 100 points The greater the period value is, the higher the score is | Calculated profit Substation investment | RMB 10,000 yuan | Finance Department |
| Expected power grid benefit | Unit investment supply load | Positive type | <=0 scores 0 point >= all-time high scores 100 points The greater | Expected maximum load of related substations | kw kw RMB 10,000 yuan | Development Department |
| Related station investment demand | Grid structure promotion level | Positive type | Yes = 100 points No = 0 point | Investment | Current grid structure of related stations Expected grid structure | Development Department |
|----------------------------------|--------------------------------|---------------|-----------------------------|-----------|---------------------------------------------------------------|------------------------|
| Expected social benefit          | Nonelectric user power-on quantity | Positive type | Yes = 100 points No = 0 point | Expected nonelectric user power-on quantity | Household | Sales Department |
| New energy online electricity    | Positive type | <=0 scores 0 point >= all-time high scores 100 points The greater the period value is, the higher the score is | Expected new energy online electricity | kwh | Development Department |
| Operational efficiency           | Average load rate | Positive type | <=50%, scores 0 point >=100% scores 100 points The greater the period value is, the higher the score is | Average load of substation high voltage side of current year | kw | Control Center |
| Safety and reliability           | Whether it is the single substation | Positive type | Yes = 100 points No = 0 point | Whether it is the single substation | Transportation and Inspection Department |
| Power supply quality             | Qualified rate of supply voltage | Negative type | <=99.9%, scores 100 points =0, scores 0 point The greater the period value is, the lower the | Qualified rate of bus supply voltage of substation high voltage side of current year | Transportation and Inspection Department |
| Evaluation object | First-level index | Second-level index | Index weight |
|-------------------|------------------|-------------------|--------------|
| Comprehensive investment benefits of construction stations | Expected economic benefit | Return on unit investment | 0.2 |
| | Expected power grid benefit | Unit investment supply load | 0.1 |
| | | Grid structure promotion level | 0.1 |
| | Expected social benefit | Nonelectric user power-on quantity | 0.05 |
| | | New energy online electricity | 0.05 |
| Related station investment demand | Operational efficiency | Average load rate | 0.1 |
| | Safety and reliability | Whether it is the single substation | 0.1 |
| | Power supply quality | Qualified rate of supply voltage | 0.05 |
| | Power supply capacity | Maximum load rate | 0.01 |
4. Substation Comprehensive Investment Demand Evaluation Model

4.1. Model logic
The substation investment demand evaluation model is mainly used to evaluate the investment demand of substations to be constructed, and assist the company in making the investment decisions, analyzing the substation investment demand evaluation logic, and building the evaluation model.

The model adopts the fuzzy membership degree method to calculate the second-level index score, and adopts the weighted summation method to calculate the first-level index score, construction station comprehensive investment benefit and relevant station investment demand score. Finally, the sum of construction station comprehensive investment benefit and relevant station investment demand score shall be the substation comprehensive investment demand; when it involves several related stations, the business department shall discuss and determine the only related station to be measured.

4.2. Model framework
The model includes the data input table, parameter setting table, index score calculation table and index results output table. The index parameter setting table includes the index parameter setting and the index weight setting. In the index trend (type) selection, the model index is divided into the positive, negative and interval types, in which the positive type refers to the greater the index value is, the higher the score is; the negative type refers to the smaller the index value is, the higher the score is; the interval type means when the index value is within the scope of certain range, the score is the highest, and decreases to two sides.

| Parameter No. | Parameter name | Economic benefit | Unit asset power supply | Maximum load per unit asset |
|---------------|----------------|------------------|-------------------------|-----------------------------|
| 1             | Tread          | Positive         | Positive                | Positive                    |
| 2             | Index measurement method | Method of equal interval | Method of equal interval | Method of equal interval |
| 3             | Minimum of business | 0.05            | 0.00                    | 0.00                        |
| 4             | Maximum of business | 1.00            | 1.00                    | 1.00                        |

4.3. Case Study
Collect the data and information of substations to be built and related stations of power supply company, and calculate the index values, as shown in Table 4 and Table 5.
Table 4. Comprehensive investment benefit calculation index value of construction stations

| No. | Calculated substation | Return on unit investment | Unit investment supply load | Grid structure promotion level | Nonelectric user power-on quantity | New energy online electricity |
|-----|----------------------|--------------------------|-----------------------------|-------------------------------|----------------------------------|-------------------------------|
| 1   | Substation A         | 0.04                     | 0.05                        | Yes                           | 0                                | 620                           |
| 2   | Substation B         | 0.11                     | 0.3                         | No                            | 150                              | 6258                          |
| 3   | Substation C         | 0.03                     | 0.01                        | Yes                           | 0                                | 0                             |
| 4   | Substation D         | 0.01                     | 0.02                        | No                            | 0                                | 4896                          |
| 5   | Substation E         | 0.09                     | 0.1                         | Yes                           | 2                                | 0                             |
| 6   | Substation F         | 0.07                     | 0.03                        | Yes                           | 30                               | 2212                          |
| 7   | Substation G         | 0.02                     | 0.02                        | No                            | 0                                | 499                           |
| 8   | Substation H         | 0.06                     | 0.04                        | Yes                           | 2                                | 5278                          |
| 9   | Substation I         | 0.03                     | 0                           | Yes                           | 0                                | 525                           |
| 10  | Substation J         | 0.005                    | 0.03                        | Yes                           | 0                                | 470                           |

Table 5. Investment demand measurement index value of related stations

| No. | Related station   | Average load rate | Whether it is single substation | Qualified rate of supply voltage | Maximum load rate | Unit asset power supply | Maximum load per unit asset |
|-----|-------------------|-------------------|---------------------------------|----------------------------------|-------------------|-------------------------|-----------------------------|
| 1   | Substation A-1    | 13.1%             | Yes                             | 99.99%                           | 63%               | 18.29                   | 4.8                         |
| 2   | Substation B-2    | 18.9%             | No                              | 99.97%                           | 61%               | 22.68                   | 2.7                         |
| 3   | Substation C-3    | 6.0%              | No                              | 99.87%                           | 26%               | 65.19                   | 14.1                        |
| 4   | Substation D-4    | 7.0%              | No                              | 99.97%                           | 31%               | 322.75                  | 37.4                        |
| 5   | Substation E-5    | 41.2%             | No                              | 99.92%                           | 103%              | 428.64                  | 47.1                        |
| 6   | Substation F-6    | 8.1%              | No                              | 99.94%                           | 41%               | 64.20                   | 62.0                        |
| 7   | Substation G-7    | 7.6%              | No                              | 99.96%                           | 31%               | 21.08                   | 4.4                         |
| 8   | Substation H-8    | 13.7%             | Yes                             | 99.92%                           | 33%               | 61.48                   | 22.2                        |
| 9   | Substation I-9    | 15.1%             | No                              | 99.93%                           | 66%               | 198.05                  | 44.8                        |
| 10  | Substation J-10   | 3.1%              | No                              | 99.90%                           | 24%               | 19.88                   | 3.5                         |

The model is used to calculate the comprehensive investment benefits of construction stations of each substation and investment demand scores of related stations, as shown in Table 6, Table 7 and Table 8.

Table 6. Comprehensive investment benefit calculation index score of construction station

| No. | Area name | Return on unit investment | Unit investment supply load | Grid structure promotion level | Nonelectric user power-on quantity | New energy online electricity |
|-----|-----------|---------------------------|----------------------------|-------------------------------|----------------------------------|-------------------------------|
| 1   | Substation A | 26.67 | 8.33 | 100.00 | 0.00 | 9.84 |
| 2   | Substation B | 73.33 | 50.00 | 0.00 | 100.00 | 99.33 |
| 3   | Substation C | 20.00 | 1.67 | 100.00 | 0.00 | 0.00 |
| 4   | Substation D | 6.67 | 3.33 | 0.00 | 0.00 | 77.71 |
| 5   | Substation E | 60.00 | 16.67 | 100.00 | 1.33 | 0.00 |
| 6   | Substation F | 46.67 | 5.00 | 100.00 | 20.00 | 35.11 |
From the calculated result, among the 10 substations to be built, 1 substation is more than 90 points, 4 substations between 50 to 60 points, and 1 substation less than 10 points; through the analysis of the index data, the calculated result is proved to be scientific and reasonable, in line with the actual situation; combined with the electricity reform supervision requirements and high quality development goal of the company, it advises to suspend the construction of substations below 30 points, and corresponding part of the investment demand shall change the investment plan.

5. Conclusion
In this paper, based on the research of the electricity reform policy, it focuses on the substation assets, to improve the high quality development of the company and power grid, establish the substation comprehensive investment demand evaluation index system, specify the index calculation, index score
standard, and index weight, build the evaluation model, and draw the index data of 10 substations to be built and related stations, to carry out the calculation, and give the rational investment advice through the analysis of the calculated result, and assist in the investment decision making.

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