Research on Asset Management of Power Grid Engineering Based on Asset Group

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Abstract. In recent years, with the slowdown in power generation, the reform of transmission and distribution prices has continued to deepen, and objectively requires more precise management of projects invested by power grid companies. This paper takes the asset group as the evaluation unit of grid engineering asset management, starts with the characteristics of the asset group, expounds the scope and division criteria of the asset group, and determines the asset group classification. The cost and benefit sharing method of the asset group is proposed. The actual cost method is used to collect the components of each asset. The electricity and cash flow based methods are used to separate the asset groups of the transmission and distribution networks. The proceeds are apportioned. The asset group input-output evaluation system was constructed.

Through the multi-dimensional selection of indicators reflecting the input and output of the asset group, a comprehensive evaluation of the operation of the asset group was made. The cost-benefit sharing method and input-output evaluation system proposed in this paper can effectively guide the asset management of power grid projects and assist the power grid companies in making decisions.

1. Introduction

After the power transmission and distribution price reform, the state approved the power transmission and distribution price in accordance with the method of "permitted cost plus reasonable income". Market entities such as power distribution companies were established one after another, and the market competition pattern gradually appeared. Complex operating environment objectively requires power grid enterprises to optimize financial policies and strategies. Innovating management methods and evaluating input-output benefits have become urgent tasks.

Existing literature mainly focuses on the benefit evaluation and comprehensive evaluation methods of power grid, distribution network and smart grid. Gong Jianfeng [1] et al. study the evaluation of power grid investment benefit under the investment opening environment, establishes the evaluation index of power grid investment benefit from the perspectives of system operation and power market respectively, and evaluates the market benefits of different investment modes. You Weiyang [2] et al. establish a comprehensive evaluation index system of power grid operation efficiency and investment benefit, and makes quantitative analysis from two aspects of operation efficiency of 220kV voltage grade equipment in various regions of a province.
and comprehensive investment benefit of projects put into production within a fixed period of time. Ye Bin [4] et al. comprehensively consider the impact of micro-grid and multiple loads on distribution network investment, and constructs an evaluation index system of distribution network input-output benefits. Zeng Bo [5] et al. construct a comprehensive evaluation index system of demand response benefits under smart grid conditions covering technology, economy, environment and other aspects. Jiao Fengshun [6] et al. comprehensively consider the explicit and implicit investment returns of the intelligent distribution network, and constructs a cost-benefit model of the intelligent distribution network. Qiu Huadong [8] et al. establish an evaluation index system for operational benefits, and comprehensively evaluates operational benefits by adopting an Improved Combined Weighting Matter-Element model. Zeng Bo [9] et al. propose a comprehensive evaluation method for environmental benefits of an intelligent distribution network based on the balanced principal component analysis. Wei Yanan [10] et al. select Vague set to establish a decision matrix, and uses an artificial intelligence algorithm to carry out information fusion and model optimization to obtain evaluation results. However, the existing research lacks consideration of the topological structure of the power grid, and most of them take the entire power grid or distribution network as the evaluation subject, lacking pertinence, and the evaluation results cannot accurately assist the investment decisions of the power grid companies.

In order to solve the above problems, the paper defines the division criteria of asset groups, puts forward the cost-benefit calculation method of asset groups, and focuses on the benefit distribution of asset groups to build a model. Finally, it puts forward the power grid input-output evaluation system with asset groups as the object of evaluation, selects evaluation indexes in multiple dimensions, adopts the comprehensive evaluation method of combination of analytic hierarchy process and entropy weight method, and conducts case analysis in combination with actual areas. The power grid input-output evaluation system proposed in this paper can effectively and carefully evaluate the power grid input-output situation and assist power grid companies to make effective decisions.

2. Division criteria for asset groups

According to the principle of "reflecting the operating characteristics of the power grid, the power transmission, transformation, distribution and sale functions can be independently completed, and the input and output can be independently measured". The power grid assets are divided into four types of asset groups of high-voltage lines, substations, feeders and stations as the basic unit of input and output evaluation. If the input-output evaluation of grid assets is carried out completely without considering the topology structure and operation mode of the grid, then the relationship between the electric energy value and the electric energy transmitted by the asset group will be split. However, if the topological structure and operation mode are considered too carefully, due to the large scale of the power grid and the change of power flow operation time, it not only increases the calculation difficulty, is not conducive to the application of the evaluation index system, but also is not necessary. Therefore, it is very important to select a relatively stable evaluation unit with appropriate scale. The concept of asset group can not only realize the independent measurement of electric energy, but also realize the collection of project costs. It is a unit of appropriate size and is connected with the existing project management methods.

2.1. Transmission Line Asset Group

The transmission line takes a complete transmission line named after separate dispatching as the asset group. For transmission line branch lines, the main line and branch line are merged as an asset group because there is neither switch nor measurement between the branch line and the main line, and the main line and branch line are distinguished only by naming. The physical demarcation point of the transmission line is consistent with the demarcation point of the transmission line with the inspection caliber. For cross-unit lines, as their electricity is indivisible, they are still treated according to the overall asset group.
2.2. Substation Asset Group
The equipment in the wall of a complete substation is a substation asset group. Including primary equipment, secondary equipment, communication equipment, station auxiliary equipment, etc. If there are multiple contributors to the same substation, the scope of the asset group includes all equipment contributed by power grid companies. After the transformation of substation equipment, the value of replaced equipment should be removed to increase the value of new equipment.

2.3. Feeder Asset Group
The feeder asset group refers to the 10, 20 kV outgoing lines of the substation. For non-contact single radial asset groups, a complete large feeder line is taken as the asset group (below the outgoing line interval of transformer substation, above the pile head on transformer or above the high-voltage incoming line cabinet). For medium-voltage lines with contact relationship, the mutually connected lines are packaged as asset groups.

2.4. Station Area Asset Group
The specific types of asset groups in Station area include box transformer, column transformer and main transformer in residential area. The scope of assets includes the transformer itself and its subordinate low-voltage lines. If there are multiple low-voltage lines under a transformer, an asset group shall be formed according to the principle of "one transformer and one area", and the association between low-voltage users and the asset group shall be realized according to the working requirements of marketing integration. If the relationship between the asset group and the users in the Station area changes due to load transfer and other reasons, the changed information shall prevail to synchronously complete the change of the user scope of the asset group.

3. Asset Group benefit Calculation Method
Based on electricity quantity and cash flow, the income of each asset group of the transmission network and the sales network with different voltage levels is divided respectively.

Since the transmission network has the characteristics of mutual connection and mutual supply transfer, the market situation affected by power grid investment is relatively wide and is not targeted at specific users, so it can be understood that the market attributes are the same. Electric energy is stepped up from the power supply side, connected to the power grid and transmitted before step-down distribution. Without considering loss, energy is conserved before and after transformation. Step-up and step-down only change the mode value and phase angle of current and voltage, and do not change the total power of electric energy. The value of each voltage level asset group is realized by transmitting electric energy (whether the same voltage level transmission or step-down transmission), and the value of unit electric quantity is the same. Different from the transmission network, the sales network has strong market characteristics besides directly transmitting electricity. Asset groups serving high-quality customers in the sales network are often paid more attention, and their value is not only reflected in the amount of electricity transmitted, but also in direct cash flow income.

According to the above analysis, the general idea of revenue calculation is as follows: based on the power transmission as the main line, according to the power supply relationship between different voltage levels, first calculate the asset cost relationship from high voltage level to low voltage level, and on the basis of distinguishing between the power supply of the current level and the electricity conducted by the higher level, deduct the electricity purchase cost from the electricity sales revenue, and then allocate the income from low voltage level to high voltage level step by step to form the revenue of each voltage level; Within a certain voltage level, it is further divided into two parts: transmission network and sales network. Finally, it is further divided into asset groups. Transmission network adopts revenue allocation method based on electricity quantity, and sales network adopts revenue allocation method based on cash flow. The calculation method includes the following steps: (1) calculation of the electric power balance model; (2) Income sharing for each voltage level; (3) the income distribution of each asset group within a certain voltage level.
(1) Power Balance Calculation

A power and electricity balance model is established for the power grid shared network. The entire public network has 6 voltage levels (excluding extra high voltage), which are <1kV, 10kV, 35kV, 110kV, 220kV, 500kV from low to high, and are respectively recorded as $k=1, 2, ..., 6$. The balance model of power grid system at peak load is as follows:

$$
S_k + \sum_{j=1}^{6} V^l_j = \frac{D_k + \sum_{l=1}^{6} S^l_k}{1 - L^L_k} \\
S^l_k = \frac{V^l_k}{1 - L^L_{k,l}} \\
\xi^l_k = \frac{S^l_k}{\sum_{l=1}^{6} S^l_k} \quad (l < k, j > k) \\
\sum_{l=1}^{6} S^l_k = \sum_{k=1}^{6} D^L_{k,\text{low}} + \sum_{k=1}^{6} D^L_{k,\text{low}} + \sum_{k=1}^{6} D_k
$$

Where:

- $S_k$ is Power supply load of voltage grade $k$ (including power supply output of power plants of local voltage grade and power supply power outside the region);
- Removing the power supply load after the loss is changed from the high voltage level $j$ to the low voltage level $k$;
- $D_k$ for Power consumption load of voltage grade $k$;
- $L^L_k$ for Line loss rate of voltage grade $k$;
- $L^L_{k,l}$ for The loss rate of step-down when supplying power to the low voltage level $l$ for the high voltage level $k$;
- $S^l_k$ for Power supply load from high voltage level $k$ to low voltage level $l$;
- $V^l_k$ for Removing the power supply load after loss change from the high voltage level $k$ to the low voltage level $l$;
- $\xi^l_k$ for Power supply ratio obtained from high voltage level $k$ for voltage level $l$;
- $D^L_{k,\text{low}}$ for Line loss for voltage class $k$;
- $D^L_{k,\text{low}}$ for Power transformation loss of voltage grade $k$.

Among them, the power supply load $S_k$, power consumption load $D_k$, line loss rate $L^L_k$ and substation loss rate $L^L_{k,l}$ are known numbers, and the rest are unknown numbers. Through iterative calculation, the power supply and consumption of each voltage level are balanced, thus calculating the power supply proportion relation between each voltage level and checking the data of each voltage level.

(2) Divide the income by voltage level

Then, based on the power and electricity balance model and the asset cost of each voltage level as basic data, the cost of each voltage level itself and the cost of high voltage level transmission are calculated, the electricity sales revenue is regarded as the electricity transmission and distribution service revenue after deducting the electricity purchase cost, and is calculated step by step from the low voltage level to the high voltage level. First, the electricity sales revenue is reserved for the voltage revenue of the current level according to the proportion of the power supply quantity of the voltage power supply of the current level, and the remaining part is distributed according to the proportion relationship between the electricity conduction percentage ratio and the contribution cost of the current level and the conduction cost of the higher level-the high voltage level is retained and returned respectively until the distribution of the electricity sales revenue among the voltage levels is completed.
1) Cost calculation for each voltage level
First, the cost corresponding to each voltage level is calculated based on the assets of each voltage level. Then, the cost of the high voltage level is transferred to the low voltage level based on the power supply proportion relationship between the voltage levels calculated by the power and electricity balance model. Finally, the total cost of a certain voltage level including the direct formation of the current level and the acceptance of the conduction by the higher level is formed. The cost used in this model is the original value of fixed assets. The calculation formula is as follows:

\[
C_I = \sum_{k \in K} \sum_{l \in L} C_{I\text{share},kl} \times \frac{S_k}{D_k} + \sum_{j \in K} S_j
\]

\[
C_I = \sum_{l \in L} C_{I\text{share}} + C_{I\text{basic}}
\]

\[
C_I = C_{I\text{total}} \times \frac{D_l}{D_l + \sum_{i \in L} S_i}
\]

Where:
- \(C_{I\text{share}}\) is the own cost of voltage level \(I\);
- \(C_{I\text{share},kl}\) For the voltage level \(I\), the cost of the higher voltage level to supply power \(k\) according to the power supply proportion;
- \(C_{I\text{total}}\) For the voltage level \(I\), the sum of the costs of the higher voltage level to be borne by the power supply according to the power supply proportion;
- \(C_{I\text{final}}\) For voltage level \(I\), the final cost is calculated according to the proportion of electricity sold at this level to the sum of electricity sold and transmitted.

2) According to the level of power supply proportion
The current level power supply load of voltage \(S_I\), level \(I\) is, the power supply load received after voltage reduction from high voltage level \(V_I\) \(l < k\), the electricity sales income of voltage level \(I\) is \(I_1\), the electricity purchase cost of provincial power grid is \(C_{I\text{buy}}\) (the sum of the electricity purchase cost \(C_{I\text{buy}}\) in the province and the electricity purchase cost in the province \(C_{I\text{out}}\)), and the sum of the income received from lower power grid is \(\sum B_{p,2,2,l}\) (the calculation formula will be introduced below). If the voltage level \(I\) is the lowest voltage level, then \(\sum B_{p,2,2,l} = 0\). The income to be distributed for voltage level \(I\) is:

\[
I_1 = I_1 - C_{I\text{buy}} \times \frac{D_I}{\sum_{j \in L} D_j} + \sum_{p \in L} B_{p,2,2,l}
\]

The income of voltage level \(I\) distributed to this level according to the power supply proportion of this level is as follows:

\[
B_{I,1} = I_1 \times \frac{S_I}{S_I + \sum_{l \in L} V_I}
\]

The income that needs to be redistributed according to the proportion of electricity transmission and the proportion of contribution cost at the corresponding level and transmission cost at the higher level is as follows:
\[ B_{i,2} = I_{i} \sum_{l=1}^{k} \frac{V_{i}^{l}}{S_{l} + \sum_{i=1}^{k} V_{i}^{l}} \]  

(5)

Where: when the voltage level \( l \) is the highest voltage level, \( V_{i}^{l} = 0 \); When the voltage level \( l \) is not the highest voltage level and a single high voltage level supplies power to it across voltage levels, \( \sum_{i=1}^{k} V_{i}^{l} \) is \( V_{i}^{l} \). When the voltage level \( l \) is not the highest voltage level and there are multiple high voltage levels supplying power across the voltage levels, the sum of the power supply loads \( \sum_{i=1}^{k} V_{i}^{l} \) obtained from the high voltage level for the voltage level \( l \) is obtained.

3) According to the proportion of electricity transmission and the proportion of contribution cost at the same level and conduction cost at the higher level

For \( B_{i,2} \), according to the proportion of electricity transmission and the proportion of contribution cost at the same level and transmission cost at the higher level, the distribution will be made again. The level's own cost is \( C_{i}^{\text{basic}} \) defined as the cost \( C_{i}^{\text{contribute}} \) of participating in redistribution after deducting the level's power supply ratio from the level's contribution cost:

\[ C_{i}^{\text{contribute}} = C_{i}^{\text{basic}} \sum_{l=1}^{k} \frac{V_{i}^{l}}{S_{l} + \sum_{i=1}^{k} V_{i}^{l}} \]  

(6)

When there are \( k \) voltage levels with conduction relation to voltage level \( l \), the contribution cost of this level \( C_{i}^{\text{contribute}} \) is divided into \( k \) shares according to the conduction proportion of electric quantity (\( k=1 \) when there is only a single conduction relation):

\[ C_{i}^{\text{contribute,k}} = C_{i}^{\text{contribute}} \sum_{l=1}^{k} \frac{V_{i}^{l}}{S_{l} + \sum_{i=1}^{k} V_{i}^{l}} \]  

(7)

Will \( B_{i,2} \) need to be distributed again is also divided into \( k \):

\[ B_{i,2}^{k} = \sum_{l=1}^{k} V_{i}^{l} \]  

(8)

The conduction cost of the higher level is \( C_{i}^{\text{share,k}} \), where the conduction cost of voltage grade \( k \) to \( l \) is \( C_{i}^{\text{share,k}} \), and the corresponding shared benefit of the cost of this level is:

\[ B_{1,2,1} = \sum_{l=1}^{k} B_{i,2}^{k} \frac{C_{i}^{\text{contribute,k}} + C_{i}^{\text{share,k}}}{C_{i}^{\text{contribute}} + C_{i}^{\text{share,k}}} \]  

(9)

The sum of the income returned to the high voltage level is:

\[ B_{1,2,2} = \sum_{l=1}^{k} B_{i,2}^{k} \frac{C_{i}^{\text{share,k}}}{C_{i}^{\text{contribute,k}} + C_{i}^{\text{share,k}}} \]  

(10)

Among them, the high voltage level \( K \) that supplies power to the voltage level \( l \) receives the return revenue as follows:

\[ B_{1,2,2,k} = B_{1,2}^{k} \frac{C_{i}^{\text{share,k}}}{C_{i}^{\text{contribute,k}} + C_{i}^{\text{share,k}}} \]  

(11)

In the end, the total benefit from voltage level \( l \) is:

\[ B_{l} = B_{l,1} + B_{l,2,1} \]  

(12)

(3) Allocation of asset groups of various voltage levels

Revenue from transmission network and sales network:

\[ B_{l}^{\text{trans,} j} = B_{l} \times \frac{Q_{l}^{\text{trans,} j}}{Q_{l}^{\text{trans}} + Q_{l}^{\text{sale}}} \]  

(13)
\[ B_{i}^{\text{trans}} = B_{i} \times \frac{Q_{i}^{\text{trans}}}{Q_{i}^{\text{trans}} + Q_{i}^{\text{net}}} \]  

(14)

Where:
- \( Q_{i}^{\text{trans}} \), \( Q_{i}^{\text{net}} \) respectively corresponding to the voltage level \( l \) transmission network and the sales network;
- \( B_{i}^{\text{trans}} \), \( B_{i}^{\text{net}} \), respectively, is the voltage level \( l \) transmission network and sales network corresponding revenue.

Profits from transmission network asset groups:
\[
B_{\text{trans},i,j}^{\text{net}} = B_{i}^{\text{trans}} \times \frac{Q_{\text{trans},i,j}^{\text{net}}}{\sum_{i=1}^{n} Q_{\text{trans},i,j}^{\text{net}} + \sum_{j=1}^{m} Q_{\text{trans},i,j}^{\text{net}}} 
\]  

(15)

\[
B_{\text{net},i,j}^{\text{trans}} = B_{i}^{\text{net}} \times \frac{Q_{\text{trans},i,j}^{\text{net}}}{\sum_{i=1}^{n} Q_{\text{net},i,j}^{\text{trans}} + \sum_{j=1}^{m} Q_{\text{net},i,j}^{\text{trans}}} 
\]  

(16)

Where:
- \( n \) and \( m \) are the number of transformers and lines in the transmission network with voltage level \( l \) respectively;
- The power quantity of the \( i \)-th transformer and the \( j \)-th line in the transmission network with voltage grade \( l \) respectively, \( Q_{\text{trans},i,j}^{\text{trans}} \), \( Q_{\text{trans},i,j}^{\text{net}} \);
- \( l \) transformer and \( j \) line in the transmission network with voltage level \( l \) respectively, \( B_{\text{trans},i,j}^{\text{trans}} \), \( B_{\text{trans},i,j}^{\text{net}} \).

Revenue from sales network asset group:
\[
B_{\text{trans},i,j}^{\text{net}} = B_{i}^{\text{trans}} \times \frac{Q_{\text{trans},i,j}^{\text{net}}}{\sum_{i=1}^{n} Q_{\text{trans},i,j}^{\text{net}} + \sum_{j=1}^{m} Q_{\text{trans},i,j}^{\text{net}}} 
\]  

(17)

\[
B_{\text{net},i,j}^{\text{trans}} = B_{i}^{\text{net}} \times \frac{Q_{\text{trans},i,j}^{\text{net}}}{\sum_{i=1}^{n} Q_{\text{net},i,j}^{\text{trans}} + \sum_{j=1}^{m} Q_{\text{net},i,j}^{\text{trans}}} 
\]  

(18)

Where:
- The cash income of the \( i \) transformer and the \( j \) line in the sales network with voltage grade \( l \) respectively, \( R_{\text{trans},i,j}^{\text{trans}} \), \( R_{\text{trans},i,j}^{\text{net}} \);
- Revenue from the \( i \) transformer and the \( j \) line in the distribution network with voltage level \( l \) respectively, \( B_{\text{trans},i,j}^{\text{trans}} \), \( B_{\text{trans},i,j}^{\text{net}} \).

4. Construction of Input-Output Evaluation System Based on Asset Groups

4.1. Selection of Evaluation Indicators

Using the method of RCV model[11], starting from the resources (input), capabilities and values (output) of the asset group, imitating the ideas of R/C (efficiency of converting resources into capabilities), V/C (efficiency of converting capabilities into values) and V/R (efficiency of converting resources into values), the indexes are generated in the corresponding quadrants according to relevant elements, and then 8 evaluation indexes of the asset group are obtained by screening the indexes from the angles of data availability, index independence and sensitivity. They are: power failure loss, power consumption loss, average load rate, unit asset sales revenue, historical power growth rate, RMB 10,000 asset operation and maintenance fee, operation and maintenance fee growth rate and asset group profit rate.

4.2. Evaluation Methods

(1) Weight calculation

In order to make the determination of the weight of evaluation index more scientific and accurate, the comprehensive value of its weight is taken as the final weight of the index by combining analytic hierarchy process [12] and entropy weight method [13]. The two methods complement each other. They
can not only reflect the importance of the index according to the degree of difference and reduce subjective factors, and reflect the importance of the index itself. The calculation formula of the comprehensive weight is as follows:

\[
z_j = \hat{\omega}_j + (1 - \hat{\omega})c_j
\]  

(19)

Where: \(\hat{\omega}_j\) and \(c_j\) are the weight of entropy weight method corresponding to item j index and the weight of analytic hierarchy process respectively; \(\hat{\omega}\) is the proportion of weight calculated by entropy weight method is 20%; \(z_j\), For the j index comprehensive weight.

(2) Index scoring

Indicators are divided into positive indicators and negative indicators. Positive index is the index item with the larger index value, while negative index is the index item with the smaller index value. Among the 8 indexes, the average load rate, the income from electricity sales per unit asset, the historical electric growth rate and the profit rate of the asset group are 4 positive indexes. Failure outage loss, power consumption loss, ten thousand yuan asset operation and maintenance fee, and the growth rate of operation and maintenance fee are four negative indicators. In order to reflect the positive and negative situation of the three indicators of historical electricity growth rate, asset group profit rate and operation and maintenance fee growth rate, the scoring grades of the individual indicators are K=-5, -4, -3, -2, -1, 1, 2, 3, 4 and 5, totaling 10 grades.

(3) Comprehensive evaluation model

When the asset group is newly put into operation, resulting in a historical power consumption of 0 and a historical operation and maintenance fee of 0, the historical power consumption growth rate and the operation and maintenance fee growth rate cannot be calculated due to a denominator of 0, or cannot be calculated due to accidental missing of system data reading, and only 6 indexes of failure power outage loss, power consumption loss, average load rate, unit asset electricity sales revenue, 10,000 yuan asset operation and maintenance fee and asset group profit rate are calculated.

The calculation formula of the comprehensive score is as follows:

\[
V = \sum_{j=1}^{8} z_j K_j
\]

(20)

In the formula, the score \(V\) is the total score and the score \(K_j\) is the single index. When calculating 8 indexes, n takes 8; For 6 indexes, n is 6. The calculation results of comprehensive weights are shown in Table 1 and Table 2 respectively.

Table 1. 8 indicators comprehensive weight

| voltage classes | Asset group types | power failure loss | power consumption loss | average load rate | unit asset sales revenue | 10,000 asset operation and maintenance fee | asset group profit rate | historical power growth rate | operation and maintenance fee growth |
|-----------------|------------------|--------------------|------------------------|------------------|--------------------------|-----------------------------------------|------------------------|-----------------------------|-----------------------------------|
| 500kV Transmission line | 0.0239 | 0.0643 | 0.0934 | 0.2385 | 0.0659 | 0.3171 | 0.1445 | 0.0524 |
| 500kV Substation | 0.0239 | 0.0350 | 0.0808 | 0.1812 | 0.0534 | 0.2657 | 0.1200 | 0.0400 |
| 220kV Transmission line | 0.0239 | 0.0497 | 0.1011 | 0.2330 | 0.0599 | 0.3527 | 0.1335 | 0.0462 |
| 220kV Substation | 0.0239 | 0.0530 | 0.1151 | 0.2164 | 0.0698 | 0.3195 | 0.1411 | 0.0612 |
| 110kV Transmission line | 0.0239 | 0.0371 | 0.0839 | 0.2365 | 0.0539 | 0.3317 | 0.1923 | 0.0408 |
| 110kV Substation | 0.0239 | 0.0441 | 0.1117 | 0.2218 | 0.0625 | 0.3041 | 0.1840 | 0.0479 |
| 35kV Transmission line | 0.0239 | 0.0366 | 0.0877 | 0.2150 | 0.0540 | 0.3011 | 0.2413 | 0.0405 |
| 35kV Substation | 0.0239 | 0.0587 | 0.1122 | 0.2144 | 0.0784 | 0.3074 | 0.1430 | 0.0621 |
| 10kV Feifer | 0.0239 | 0.0352 | 0.0966 | 0.2269 | 0.0535 | 0.3161 | 0.2076 | 0.0401 |
| <=1kV Station Area | 0.0240 | 0.0352 | 0.1011 | 0.2216 | 0.0539 | 0.3330 | 0.1910 | 0.0401 |
Table 2. 6 indicators comprehensive weight

| Voltage classes | Asset group types | Power failure loss | Power consumption loss | Average load rate | Unit asset sales revenue | 10,000 asset operation and maintenance fee | Asset group profit rate |
|----------------|------------------|--------------------|------------------------|-------------------|--------------------------|------------------------------------------|------------------------|
| 220kV          | Transmission line| 0.0299             | 0.0667                 | 0.1448            | 0.2811                   | 0.0782                                   | 0.3994                 |
| 110kV          | Transmission line| 0.0299             | 0.0838                 | 0.1410            | 0.2666                   | 0.1067                                   | 0.3721                 |
| 110kV          | Substation       | 0.0299             | 0.0703                 | 0.1358            | 0.2626                   | 0.1344                                   | 0.3671                 |
| 35kV           | Transmission line| 0.0299             | 0.0503                 | 0.1263            | 0.3098                   | 0.0765                                   | 0.4072                 |

5. Analysis of Examples

Taking an asset group in a city as an example, the city has 7,985 asset groups, 224 transmission line asset groups, 57 substation asset groups, 627 feeder asset groups and 7,077 Station asset groups. The statistical results of the calculation of the original value and income of the asset groups are shown in Table 3.

Table 3. The number and original value of various asset groups of various voltage levels in the region

| Asset group types          | Voltage classes | Amount | Original value / (k yuan) | Original value proportion / % |
|----------------------------|-----------------|--------|---------------------------|-------------------------------|
| Transmission line asset group | 500kV           | 4      | 168410.2                  | 1.91                          |
|                            | 220kV           | 25     | 403919.5                  | 4.57                          |
|                            | 110kV           | 107    | 1308465                   | 14.82                         |
|                            | 35kV            | 88     | 455303                    | 5.16                          |
| Substation asset group     | 500kV           | 1      | 105340.7                  | 1.19                          |
|                            | 220kV           | 11     | 1006226.3                 | 11.39                         |
|                            | 110kV           | 34     | 1090228.1                 | 12.35                         |
|                            | 35kV            | 11     | 110352.4                  | 1.25                          |
| Feeder asset group         | 10kV            | 627    | 2910901                   | 32.96                         |
| Station area asset group   | <1kV            | 7077   | 1271881.1                 | 14.40                         |
| In total                   |                 | 7985   | 8831026.8                 | 100                           |

Benefit allocation of asset groups is carried out according to the benefit allocation method of asset groups introduced in 3.2. The statistical results of income calculation for each asset group are shown in Table 4.

Table 4. Asset group income calculation result

| Asset group types          | Voltage classes | Average original value / (k yuan) | Benefit / (k yuan) | Benefit proportion / % |
|----------------------------|-----------------|----------------------------------|--------------------|------------------------|
| Transmission line asset group | 500kV           | 168410.2                         | 74036.2            | 3.45                   |
|                            | 220kV           | 403919.5                         | 226745.8           | 10.58                  |
|                            | 110kV           | 1308465                         | 437182.7           | 20.39                  |
|                            | 35kV            | 455303                          | 230129.6           | 10.73                  |
| Substation asset group     | 500kV           | 105340.7                        | 23967.4            | 1.12                   |
|                            | 220kV           | 1006226.3                      | 242008.4           | 11.29                  |
|                            | 110kV           | 1090228.1                      | 183194.8           | 8.54                   |
|                            | 35kV            | 110352.1                      | 49017.2            | 2.29                   |
| Feeder asset group         | 10kV            | 2910901                        | 531670.2           | 24.80                  |
| Station area asset group   | <1kV            | 1271881.1                      | 145964.3           | 6.81                   |
| In total                   |                 | 8831026.8                      | 2143916.6          | 100                    |

In order to measure the relative level of income and cost of asset groups in the region, the results of calculating the input-output level of each asset group are shown in Table 5.
According to the type of asset group, the average input-output ratio is: transmission line asset group > substation asset group > feeder asset group > station area asset group. According to the voltage level, the average input-output ratio of asset groups with high voltage level is relatively high. The total ratio of asset groups greater than 1 is 29.68%, and the average input-output ratio of asset groups is greater than 1, which indicates that the asset groups in the city are generally in a profit state.

According to the index evaluation system established in section 3, 7985 asset groups in the region are evaluated, and the scores of different asset groups under each voltage level are counted, and the proportion of different scored asset groups is counted. The statistical results of transmission lines, substations, feeders and station area asset groups are shown in Table 6, Table 7, Table 8 and Table 9 respectively.

Table 5. Input and output level statistics

| Asset group types   | voltage classes | Average input-output ratio | input-output ratio >1 proportion/% |
|---------------------|----------------|---------------------------|-----------------------------------|
| Transmission line asset group | 500kV | 6.62747556 | 100.00 |
|                      | 220kV | 8.205957222 | 84.00 |
|                      | 110kV | 1.806587066 | 66.36 |
|                      | 35kV  | 2.940740109 | 72.73 |
|                      | In total | 2.696248434 | 71.43 |
| Substation asset group | 500kV | 5.53921462 | 100.00 |
|                      | 220kV | 2.977431104 | 90.91 |
|                      | 110kV | 1.054698635 | 58.82 |
|                      | 35kV  | 2.369111687 | 81.82 |
|                      | In total | 1.779293797 | 70.18 |
| Feeder asset group | 10kV | 0.680568356 | 40.19 |
| Station area asset group | <1kV | 0.301368715 | 27.10 |

According to table 5, according to the type of asset group, the average input-output ratio is: transmission line asset group > substation asset group > feeder asset group > station area asset group; According to the voltage level, the average input-output ratio of asset groups with high voltage level is relatively high. The total ratio of asset groups greater than 1 is 29.68%, and the average input-output ratio of asset groups is greater than 1, which indicates that the asset groups in the city are generally in a profit state.

Table 6. Transmission line asset group evaluation results

| Index statistics | 500kV Transmission line asset group | 220kV Transmission line asset group | 110kV Transmission line asset group | 35kV Transmission line asset group |
|------------------|------------------------------------|------------------------------------|------------------------------------|------------------------------------|
| -3 ~ -2          | 0.00%                              | 0.00%                              | 0.00%                              | 1.14%                              |
| -2 ~ -1          | 0.00%                              | 0.00%                              | 9.35%                              | 6.82%                              |
| -1 ~ 0           | 0.00%                              | 8.00%                              | 2.80%                              | 11.36%                             |
| 0 ~ 1            | 25.00%                             | 0.00%                              | 21.50%                             | 9.09%                              |
| 1 ~ 2            | 25.00%                             | 8.00%                              | 14.02%                             | 19.32%                             |
| 2 ~ 3            | 25.00%                             | 20.00%                             | 37.38%                             | 23.86%                             |
| 3 ~ 4            | 25.00%                             | 44.00%                             | 14.02%                             | 22.73%                             |
| 4 ~ 5            | 0.00%                              | 20.00%                             | 0.93%                              | 5.68%                              |

Table 7. Substation asset group evaluation results

| Index statistics | 500kV Substation asset group | 220kV Substation asset group | 110kV Substation asset group | 35kV Substation asset group |
|------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| -3 ~ -2          | 0.00%                         | 0                             | 0.00%                         | 0.00%                         |
| -2 ~ -1          | 0.00%                         | 0                             | 0.00%                         | 0.00%                         |
| -1 ~ 0           | 0.00%                         | 0                             | 2.94%                         | 9.09%                         |
| 0 ~ 1            | 0.00%                         | 9.09%                         | 20.59%                        | 0.00%                         |
| 1 ~ 2            | 0.00%                         | 9.09%                         | 20.59%                        | 18.18%                        |
| 2 ~ 3            | 0.00%                         | 27.27%                        | 17.65%                        | 27.27%                        |
| 3 ~ 4            | 100.00%                       | 27.27%                        | 38.24%                        | 36.36%                        |
| 4 ~ 5            | 0.00%                         | 27.27%                        | 0.00%                         | 9.09%                         |

Table 8. Feeder asset group evaluation results

| Index statistics | 10kV Feeder asset group |
|------------------|-------------------------|
| -3 ~ -2          | 0.00%                   |
Table 9. Station area asset group evaluation results

| Index statistics | <1kV Station area |
|------------------|-------------------|
| -2 ~ -1          | 3.03%             |
| -1 ~ 0           | 8.29%             |
| 0 ~ 1            | 43.06%            |
| 1 ~ 2            | 7.34%             |
| 2 ~ 3            | 8.45%             |
| 3 ~ 4            | 25.68%            |
| 4 ~ 5            | 4.15%             |

6. Conclusion
In order to accurately evaluate the input-output level of the power grid, this paper constructs an input-output evaluation system based on asset groups by selecting indexes reflecting the input and output of the power grid from multiple dimensions. The power grid is divided into four types of asset groups, which can realize the input-output evaluation of asset groups under different voltages and make a comprehensive evaluation of the operation of asset groups. According to the evaluation results, power grid companies can optimize the investment of asset groups with poor benefits. The evaluation system includes 8 indexes, and the weights of the indexes are determined by analytic hierarchy process and entropy weight method. This paper verifies the effectiveness of the cost-benefit allocation method and the proposed asset group-based evaluation system through an example analysis based on actual regions, which can provide scientific and effective guidance for the subsequent investment of the power grid.

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