Research on Economic Evaluation Method of Urban Distribution Network

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Abstract. With the rapid development of urbanization, the economic evaluation method of urban distribution network needs to be reformed. The current evaluation system is not excellent. An economic evaluation method of urban distribution network is proposed in this paper. A new evaluation method combining the equivalent year and the existing value method is studied. The proposed method can better make up for the shortcomings of the two methods. In the end, the feasibility of the method is verified by a case of a certain city.

1. Introduction
The distribution network is an intermediate link between users and power generation and transmission systems, and an important link to ensure that users are provided with high-quality and high-reliability electric energy.

The transmission and distribution of electric energy in the power system is called the power distribution system, which includes switchgear equipment, step-up transformers, step-down transformers, various circuit breakers, and overhead lines or cables of different voltage levels [1-3]. Each part that makes up this whole has its own function, and each part can operate reliably to meet the power demand of users.

In order to meet the development of society and people's needs, the developing country is accelerating the construction of urbanization [4]. The corresponding State Grid Corporation also needs to increase capital investment in the modification and expansion of urban power grids to provide electricity quality and enhance the reliability and stability of the system.

Compared with the distribution system, the power generation and transmission system has the advantages of clear investment and more concentrated equipment. In the past, my country was in a period of relative power shortage. Therefore, there is less research on the safety and reliability assessment methods of power generation and transmission grids. In recent years, with the development of economy and technology, great progress has been made in the basic construction of power sources in my country's power industry, and the power generation capacity of the system has generally been able to meet user needs. Based on the above analysis, it can be seen that the key factor to improve the power supply quality of the power system is to improve the reliability of the distribution network [5-6]. Because of this, the research on the reliability of the distribution system has become one of the hot spots in today's society.

So far, there are relatively few researches on the reliability and economic evaluation methods of urban distribution networks in our country, and most of the evaluation methods are limited to theoretical research and are difficult to apply in actual evaluation[7-9]. The distribution system has
complex structure, huge system, and various equipment involved. Its operation mode, system structure, quality of power components involved, and the requirements of electricity customers are very different due to the uneven development of their regions. Therefore, in different regions the reliability assessment of the distribution system should be based on the characteristics of the local system. At present, by studying the factors affecting the reliability and economy of the distribution network, effective measures that can improve the reliability of the distribution network are designed accordingly. Finally, through continuous improvement and upgrade of the power grid, the operational reliability of the distribution network is improved.

2. Method of economic evaluation of distribution network

The distribution network is a bridge connecting the power grid and customers, and is the last one responsible for supplying power to customers. Its operation mode is generally open loop. Once a failure occurs, it will cause power outages for downstream customers and cause greater economic losses. In order to improve the reliability of the distribution network, grid transformation and upgrading are required, but this requires a lot of investment. Therefore, there is a problem in the balance between improving the reliability of the distribution network and the funds invested to improve the reliability.

The quality of system power supply needs to improve the reliability of the distribution network, and improving the reliability of the distribution network will also reduce the energy loss of the grid. Therefore, the problem of energy shortage will be improved accordingly, which has a very important effect on my country's energy development. However, it is not enough to improve the reliability unilaterally to meet the requirements. Economic measures are needed to constrain and improve the weak links of the distribution network to maximize the reliability of the distribution network.

This article uses economic indicators to analyze the reliability and uses the user's power outage loss to evaluate the increased investment, with limited funds to achieve the highest reliability.

Define the function $U$, which represents the total cost of a transformation plan in each year. The cost is divided into different stages of project construction, which are the initial construction investment, operation and maintenance cost, grid operation loss cost, and power outage cost.

$$U(x) = G(x) + X(x) + S(x) + \alpha K(x)$$

(1)

where $U(x)$ represents the total cost of the program when converted to equivalent annual values; $G(x)$ represents the annual investment cost of the equipment under this calculation method; $X(x)$ represents the operation failure and the corresponding maintenance cost; $S(x)$ represents Distribution network loss costs; $K(x)$ represents the loss costs caused by power outages; $\alpha$ represents the coefficient of punishment due to power outages. The larger the coefficient, the higher the reliability requirements of the distribution network system.

2.1. Annual equipment investment

$G$ represents the total investment of equipment in the investment method. For equipment with different lifespans, the cost of different equipment should be converted into the currency value of the equivalent annual value based on its lifespan, and then the equivalent annual value of all equipment should be added to obtain the annual investment of the equipment.

$$G(x) = \sum_{i=1}^{m} \left[ \frac{k(1+k)^{n_i}}{(1+k)^{n_i} - 1} p_i + a_i \right]$$

(2)

where $m$ represents the total number of all investment equipment required in the entire project; $n_i$ represents the use of the $i$-th equipment life; $k$ represents the current bank's annual interest rate; $p_i$ represents the initial cost of the $i$th equipment; magnetic represents the $i$th equipment prepare for the investment that will increase every year in the future.
Every power distribution network failure is caused by equipment failures, so the repair and replacement of equipment and the finding and repairing of faults will consume a lot of money. The annual troubleshooting costs are shown in formula (3).

\[ X(x) = \sum_{i=1}^{n} J_i(x) \]  

where \( X(x) \) represents the cost incurred due to troubleshooting in each year; \( n \) represents the number of overhauls per year; \( J_i(x) \) represents the cost of the \( i \)-th troubleshooting.

Because failures occur randomly, it is difficult to predict future failures. Using the method of failure probability and mathematical expectation, combined with historical statistical data, the annual failure maintenance cost is estimated. The formula is shown in Equation 4.

\[ X(x) = \sum_{i=1}^{m} g_i J_i(x) \]  

where \( m \) represents the total amount of maintenance equipment; \( g_i \) represents the probability of failure of the \( f \)-th equipment; \( J_i(x) \) represents the total cost of overhauling the \( f \)-th equipment.

2.2. Annual distribution network loss cost

The annual distribution network loss cost is represented by \( S \).

\[ S(x) = \sum_{i=1}^{j} I_i^2(x) r_i h_i p \]  

where \( j \) represents the total number of branches in the entire distribution network; \( I_i \) represents the current flowing through the \( f \)-th branch; \( r_i \) represents the impedance of branch \( i \); \( h_i \) represents the operating time of branch \( i \) per year; \( p \) represents the price of electricity.

2.3. Annual power loss costs

\( K(x) \) stands for annual power outage loss, which is the total economic loss to the power grid and customers caused by power failures. Due to differences in customer types and industries, it is very difficult to accurately calculate economic losses. Economic losses can generally be divided into direct losses and indirect losses. The former refers to the direct economic losses caused by power outages, and the latter refers to the additional costs caused by the adjustment of production plans by customers. Analyzing the two types of economic losses requires comprehensive consideration of industry, frequency, and duration. Therefore, the annual loss cost cannot be calculated as accurately as the replacement equipment cost. When some data cannot be accurately counted, such as load conditions and faulty outage time, then it is necessary to use the electricity production ratio method to estimate the user's outage loss \( K(x) \).

\[ K(x) = ENS(x) * c \]  

where \( ENS(x) \) represents the amount of electricity lost due to faults in the area each year; \( c \) represents the ratio of electricity production in the area.

When the power lost by the fault and the power outage time are known, \( K \) can be calculated according to formula (7):

\[ K(x) = \sum_{i=1}^{m} g_i * \sum_{j=1}^{h} t_i^* f(t_i^*, j) * p_j \]  

Where \( m \) represents the number of equipment in the distribution network; \( h \) represents the total number of lost loads in the area; \( g_i \) represents the annual failure rate of equipment \( i \); \( p_j \) represents
the total load of load \( j \); \( t_j \) represents the time of load/power loss due to equipment \( i \) failure, 
\( f(t_j, j) \) represents the total cost of load loss of load \( j \) in the range of power loss time \( t_j \).

3. Case analysis

This article evaluates the distribution network of a certain city.

**Assumption 1:** Load balance is distributed in \( a, b, c, d \).

**Assumption 2:** Consider single-circuit radiation and loop power supply modes.

The focus of this article is to analyze the relationship between equipment investment and power outage loss, and the loss caused by line loss has little difference between the two methods. The line loss of the two wiring uses statistical values.

![Figure.1 Single circuit radiation structure](image1)

![Figure.2 Ring network structure](image2)

The reliability parameters of this region are as follows:

1. The interval between \( a, b, c, d \) is 3km, and the feeder failure rate is 0.1 times/year/km.
2. Operating time, 0.3h for section switch and 1h for tie switch.
3. The switch failure rate is 0.01 times/year, and the duration is 5h.
4. The failure probability of the electrical protection, the probability of false trip is 0.01, and the probability of rejection is 0.001.

The economic parameters are as follows:

1. The static investment of overhead lines is 210,000 yuan/km, and the dynamic investment is 0.
2. Operating and maintenance costs of 80,000 yuan/km/year, with a lifespan of 20 years.
3. The cost of the isolating switch is 30,000 yuan, and the average service life is 20 years.
3) The cost of the breaker is 0. 30,000 yuan, with an average life span of 15 years.

The focus of this article is to analyze the relationship between equipment investment and power outage loss, and the loss caused by line loss is not big in the two ways. The line loss of the two wiring uses statistical values, and the economic cost is based on the above formula 1.

When \( \alpha = 0 \) (without considering the annual power loss), the total economic cost statistics table under the two connection modes is shown in Table 1.

| Load density | Single circuit radiation structure | Ring network structure |
|--------------|----------------------------------|-----------------------|
| 1            | 97.21                            | 141.3                 |
| 5            | 121.3                            | 168.4                 |
| 10           | 141.6                            | 183.5                 |
| 15           | 160.12                           | 200.1                 |
| 20           | 181.13                           | 234.2                 |
| 25           | 200                              | 250.33                |

When \( \alpha = 2 \) (considering annual power outage loss), the total economic cost statistics table under the two connection modes is shown in Table 2.

| Load density | Single circuit radiation structure | Ring network structure |
|--------------|----------------------------------|-----------------------|
| 1            | 110.09                           | 141.4                 |
| 5            | 161.22                           | 165.3                 |
| 10           | 211.2                            | 193.3                 |
| 15           | 281.3                            | 212.44                |
| 20           | 331.12                           | 230.5                 |
| 25           | 398.6                            | 280.6                 |

When \( \alpha = 4 \) (considering annual power outage loss), higher reliability is required. The relationship between load density and total economic cost under the two types of connections is shown in Table 3.

| Load density | Single circuit radiation structure | Ring network structure |
|--------------|----------------------------------|-----------------------|
| 1            | 120.09                           | 141.32                |
| 5            | 191.63                           | 170.36                |
| 10           | 284.3                            | 210.23                |
| 15           | 390.36                           | 220.45                |
| 20           | 481.42                           | 243.53                |
| 25           | 612.39                           | 292.36                |

Through the comparative analysis of the above table, the following rules can be found:

1) When \( \alpha = 0 \) (without considering annual power outage loss), since only static equipment investment is considered, and dynamic equipment investment is not taken into account, it can improve reliability and reduce power outage loss, so single loop is more economical than ring power supply.

2) When \( \alpha = 2 \) (considering the annual power outage loss), reliability needs to be considered. The load density is larger and the equipment investment increases, which can improve the system reliability, thereby reducing economic losses, and the advantages of loop wiring gradually appear, so the loop The power supply is more economical than a single circuit.
When $\alpha=4$ (considering the annual power outage loss), the reliability requirements are higher, the greater the load density, the better the economy of the loop power supply, and the increase in equipment investment can greatly improve the reliability, thereby reducing the economic loss.

4. Conclusion
This article mainly studies the economic evaluation method of urban distribution network. First, it analyzes the basic content of the reliability assessment of the urban distribution network. It focuses on the analysis of the economic evaluation method of the distribution network. The feasibility of the method is verified through calculation examples and the relationship between the equipment investment and the reliability of the power grid is obtained through statistics and calculations.

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