Research on Investment Evaluation Strategy of Distribution Network Focusing on Efficiency and Benefit

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Abstract. High quality development of distribution network pays more attention to improving investment efficiency and benefit. Distribution network equipments and related data indicators are various, and there are many manual interventions, thus it is difficult to focus on investment efficiency and benefit through information system with direct data acquisition. This paper focuses on the investment efficiency and benefit indicators, and refines key target indicators. On this foundation, the comprehensive evaluation index system of distribution network investment is constructed. The key investment issues can be find out through penetration and correlation analysis, which are verified by selecting typical areas for investment effectiveness analysis. Considering the investment demand and investment capacity as a whole, the regional investment focuses and directions are clarified according to the differentiation level of efficiency and benefit, which can accurately improve the efficiency and benefit of distribution network investment.

1. Introduction
In the early development of distribution network, the performance of distribution system is evaluated by "three rates", namely the reliability rate reflecting power supply continuity, line loss rate reflecting operation economy and voltage qualification rate reflecting power supply quality. Due to the lack of economic consideration of distribution network construction, the utilization rate of early equipment is low. Under the new situations and requirements, the development of distribution network should effectively enhance the construction economy and investment efficiency and benefit level under the premise of ensuring the power supply reliability and power quality.

Through the comparison and statistical analysis of historical results, the reliability analysis indexes of distribution network are sorted [1]. According to the characteristics of complex structure, dense load points and large amount of calculation, combined with the reliability analysis method of distribution network, the reliability evaluation method of complex distribution network is proposed in [2]. The connection modes of urban combined power grid including 110kV high-voltage distribution network and 10kV medium voltage distribution network are analyzed and compared from two aspects of economy and reliability [3].

With more concern of power grid operation economy, the research on distribution network evaluation gradually focuses on the comprehensive performance evaluation of distribution network operation, and the index analysis dimension covers many aspects. From the five aspects of implementation process, operation effect, financial effect, social benefit and sustainability, the index system and comprehensive evaluation model of distribution network investment project post evaluation are established [4]. However, the index setting is too complicated, the calculation of the bottom index is difficult, and the generality and operability are poor. The evaluation index system of
distribution network investment efficiency and benefit is constructed from two aspects of project benefit and management benefit [5]. The selected distribution network index is single and the selection range lacks objective scientific basis, which can not reflect the investment effect of distribution network scientifically. In [6], the post evaluation index system of distribution network investment performance is established from the operation effect and efficiency of investment construction. Based on the effect of historical investment, the distribution network investment allocation method is studied [7], and the equipment system is constructed from the dimensions of power supply quality, power grid structure, equipment level, power supply capacity and intelligent level to carry out investment allocation evaluation. The research in [8] on the investment decision-making system of distribution network also constructs the evaluation index system from the dimensions of power supply quality, power grid structure, equipment level, power supply capacity, intelligent level and power grid benefit.

Due to the large scale of basic data, more manual intervention, various distribution network equipment and complex actual operation conditions, there are differences between the index weight design and the actual power grid level, so the practicability and accuracy of the comprehensive evaluation method is insufficient. This paper focuses on the core indicators of efficiency and benefit, and finds out the key problems of distribution network investment through penetration and correlation analysis.

2. Comprehensive Evaluation System of Investment Efficiency and Benefit of Distribution Network

2.1. Key indicators
The complex and changeable external macroeconomic situation, the continuous deepening of the reform of the power system, and the increasingly strict supervision of state-owned assets and state-owned enterprises have put forward higher requirements for the standardization, effectiveness and economy of investment in the distribution network. In order to meet the new situation and requirements, this research focuses on the efficiency and benefits of distribution network investment. The key indicators are constructed by the economic and high efficiency factors, and are affected by the grid company's operation and development.

Based on the information system data, the asset efficiency indexes of the distribution network are designed by the theory of asset efficiency. The average outage time of users is the indicator for the time starting rate. This indicator focuses on the effectiveness of power supply, and is indirect correlation of equipment of distribution network. The equipment retirement and return time are designed for qualified product rate, and can be evaluated for the early return and retired equipment. The equipment utilization is designed for the performance start rate. It can be calculated by the data of load and transformer capacity from the information system. So load rate is designed as the key indicator of asset efficiency of the distribution network.

The basic indicators of economic efficiency include electricity consumption, net value of fixed assets, electricity price, investment and cost. Return on the project investment is mainly through the formation of fixed assets. However, it is impossible to combine the project investment and the benefits as one to one correspondence, because the project and equipment data is not connected. Therefore, the rate of return on unit assets is designed for the investment efficiency. It is calculated by the electricity quantity, electricity price, and net value of fixed assets. Since electricity prices and costs cannot be refined to distribution network equipment, electricity sales per unit of assets are used as the key indicator for economic efficiency.

2.2. Constraint target indicators
In the process of high-quality sustainable development, power grid companies are responsible for multiple types of social responsibility management. Safety and reliability, high-quality services, strong grid structure, national economy and people’s livelihood are the target prerequisites for the company's distribution network investment and development. With breakthroughs in technological innovation,
the development goals of the distribution network are gradually improving. National and local demands are changing day by day, and grid development goals for different regions and different economic levels are relatively different. Therefore, the key indicators that focus on efficiency and benefit issues trace back to the physical origin of the power grid, and are relatively stable. Target indicators that meet the interests of all parties are diversified by the differences in regional construction levels, and have the Temporal and spatial change characteristics such as "one province, one policy".

Figure 1. Constraint target indicators

The comprehensive index system includes key indicators and target indicators, as shown in Figure 2. The key indicators directly reflect the efficiency and benefit of investment. There are temporal and spatial differences in the target indicators, which are "one province, one policy". This research focuses on the comprehensive goals and boundary conditions which include safety and reliability, power supply quality, grid structure, and power supply capacity.

The key indicators, load rate and the rate of return on unit assets, are used as "two rates" to carry out a penetration analysis of provinces, cities, and counties. At the same time, the auxiliary indicators such as equipment commissioning time, heavy overload duration of equipment, and equipment retirement rate within 5 years, are analyzed. According to the direct acquisition data of the information system, the key indicators reflect the investment efficiency and benefit in the distribution network. In order to meet the distribution network precision investment requirements, the key indicators are calculated to find and solve problems, and used as the starting point to implement the company's four-level connection. The target indicators are the boundary constraints of the distribution network construction. While searching for problems with the key indicators, it is necessary to analyze whether the target goals are up to standards.

Figure 2. The comprehensive index system

2.3. Analysis framework
The load rate indicators of the distribution network equipment include the average load rate and maximum load rate. Combined with the equipment's operating life, heavy overload duration, capacity
load ratio, imbalance degree and other related indicators, the investment efficiency level of the distribution network is deeply researched.

First, the average load rate is used to evaluate the equipment utilization rates of the distribution network in the whole company, provinces, cities and counties. Based on statistical analysis of equipment operation data, the reasons for inefficiency are found out by the indictors. Then, from the perspective of safety, the maximum load rate and duration are calculated to find out the heavy overload problem, and then find out the problems of inaccurate and unreasonable investment, and form a management optimization strategy. In addition, based on the special investment situation of various provincial companies, equipment utilization rate and heavy overload problem are studied with the investment structure. So the key indicator penetration analysis is carried out for provincial companies which have serious inefficiency problems, and heavy overload problems. The causes of these problems are researched, and the common and individual characteristics are found out, which can provide effective support for the company's distribution network investment efficiency evaluation.

3. Analysis on the Investment Effect of Distribution Network in Typical Area
This work analyses the essential indices of the distribution network in typical areas and correlate the target indices to investigate the key issues that affect the investment efficiency and benefits of the distribution network.

- The reasons for the inefficiency of urban network equipment are listed as follows.
  - Reduction of load and the utilization rate of distribution transformers caused by migration;
  - Over-expected deployment and inaccurate investment of distribution transformers due to unpaid residential distribution supply points, advanced placement of market competition, slow growth of suburban load and industrial load, etc.;
  - Seasonal demand with large peak-to-valley difference, with high efficiency in short-term but low in long-term time span, such as the coal-to-electricity project, electric heating load, and paddy field loads
  - The shortened radium of low-voltage supply in the new placement has guaranteed the reliability but induced the issues of high equipment capacity.

- Correspondingly, the reasons for the inefficiency of rural power grids include:
  - Reduction of load and the utilization rate of distribution transformers caused by rural demolition and relocation, population outflow, the closure of small businesses in the county due to environmental pressures;
  - Over-expected deployment and inaccurate investment of distribution transformers due to low occupancy rates in county communities, under-expected load development in the county, slow rural load development, etc.;
  - Inefficient utilization of some equipment caused by uneven low-efficiency load segmentation due to the complex operation and maintenance environment;
  - The shortened radium of low-voltage supply in the new placement, average increase in the capacity of distribution transformers in household-scale, the high-standard construction of new rural distribution transformers, and the power supply in remote areas have ensured the reliability but induced the issues of high equipment capacity;
  - Seasonal demand with large peak-to-valley difference, with high efficiency in short-term but low in long-term time span, such as power-pumping projects, coal-to-electricity projects, agricultural drainage transformation, and characteristic industries Loads and paddy field loads

The common reasons for the heavy overload problem of 10kV distribution network equipment are mainly the uneven segmentation of low-voltage loads in the region, the over-expected climbing of suppressed load release, and the impact of the seasonal load. The common reasons for continuous heavy overloading are mainly external construction environmental issues and the limited development potentiality of regional load.
4. Investment strategy of distribution network

4.1. Region and investment classification

According to the difference of investment demand and investment ability, this paper divides regions into four categories. The regional classification is applicable to both provincial and municipal companies.

Category I: The investment demand is large and the investment ability is strong.
Category II: The investment demand is small and the investment ability is strong.
Category III: The investment demand is large and the investment ability is weak.
Category IV: The investment demand is small and the investment ability is weak.

![Figure 3. Investment area classification of distribution network](image)

![Figure 4. Four quadrants of investment area classification in distribution network](image)

Taking the average level of investment demand and investment ability as the starting point, the greater the circular shadow area, the greater the investment efficiency and benefit.

The investment ability of local companies can be evaluated by constructing virtual income. Moreover, the virtual income is calculated according to the electricity revenue, purchase cost, original value of assets under the jurisdiction, and average depreciation rate of provincial companies.

According to the connotation and characteristics of the project, the distribution network investment projects are divided into four categories: policy investment, security investment, economic investment and strategic investment.

![Table 1. Connotation and characteristics of four investment projects](image)
4.2. Investment focus and direction

According to the regional classification, the investment priorities of the four types of regions are determined.

For category I areas (with large investment demand and strong investment ability), it is necessary to consider policy and security investment as a whole. On the basis of meeting the basic investment demand of distribution network, the investment direction should be optimized, and economic and strategic investment should be considered simultaneously.

For category II areas (with small investment demand and strong investment ability), strategic and economic investment are mainly considered, policy projects can be carried out according to demand. The development and upgrading of distribution network can be promoted by improving the level of intelligence. The inter-regional assistance task can be undertaken when there is residual investment ability.

For category III areas (with large investment demand and weak investment ability), priority should be given to security and economic investment to meet the basic investment needs. Policy investment should be arranged in a balanced way based on the principle of "one multi capability" to avoid repeated construction; and strategic investment should be considered moderately.

For category IV areas (with small investment demand and weak investment ability), the security and economic investment can be considered as a whole, and the investment options with low cost and high efficiency can be excavated; the policy projects can be carried out according to the demand.

5. Conclusions

Considering the issues of complex indicators, low accuracy of basic data, and varied manual interventions in the investment evaluation of distribution network, this paper proposes an efficiency-and-benefits-focused (core plus key goals) comprehensive indicator framework. The framework takes the essential indicators of efficiency and benefit as the starting point, analyses the key objectives to meet the boundary conditions, and then evaluate the investment efficiency and benefits of the national distribution network. The evaluation results show that the reasons for the inefficiency are mainly caused by the excessive capacity of the equipment and the small load. Among the reasons for the inefficiency of urban network equipment, the decline in the relocation load caused by the renovation of the old urban area, the inefficient housing allocation caused by the low occupancy rate of the community, and the under-expected growth of industrial and commercial loads are more prominent when compared with other reasons. Among the reasons for the inefficiency of rural network equipment, low-efficiency distribution transformer led by the low occupancy rate of the county towns, the shortened power supply radius for newly added locations in remote areas, and the impact of the agricultural seasonal loads are more prominent when compared with other reasons. Among the reasons for heavy overload are mainly affected by the rapid load growth, seasonal load short-term heavy overload and external environmental restrictions. Based on the shortcomings of the investment efficiency and benefits of the distribution network, combined with investment needs, the investment strategy of four types of regions should be formed according to local conditions, which provides theoretical and practical support for the precise investment of the distribution network.

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