Study on the Evaluation Model of Investment Effectiveness of Power Transmission and Transformation Projects Serving Rural Revitalization

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Abstract—Promoting rural revitalization in an all-around way is the key task of China in its current economic and social development. As a crucial infrastructure, the power grid plays a vital supporting and guaranteeing role in serving rural revitalization strategy. However, due to the large investment in power transmission and transformation projects, coupled with the huge demand for the construction and transformation of power transmission and transformation projects during the process of rural revitalization, it is particularly important to judge the investment effectiveness of power grids. In this regard, it is necessary to evaluate and calculate the investment effectiveness of projects before investment, and prioritize projects consistent with the investment benefits of rural revitalization. This paper took the investment effectiveness of power transmission and transformation projects serving rural revitalization as the research subject, and conducted an in-depth exploration of the overall evaluation system. It first analyzed the investment categories of the power grid serving rural revitalization. Starting from the effectiveness requirements of power grid transmission and transformation projects serving rural revitalization, an evaluation index system of investment effectiveness of the power grid serving rural revitalization benefits was established. Then, this paper selected typical regional projects for empirical analysis and calculation and the evaluation results verified the feasibility of the evaluation method, providing support for accurate investment of power grid enterprises serving rural revitalization.

Keywords: Power grid; rural revitalization; power transmission and transformation project; evaluation of investment effectiveness

1 Introduction

The strategy of rural revitalization featuring thriving businesses, an eco-friendly environment, social etiquette and civility, effective governance, and prosperity was put forward in 2017.

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Among these 20-character policy requirements, the requirements related to investment in power transmission and transformation projects focus on thriving businesses, an eco-friendly environment and prosperity. Among these three requirements, the investment direction of power grid transmission and transformation projects should focus on agricultural modernization and modern rural industrial development, residential environment and ecological environment protection, and spatial pattern changes brought about by rural revitalization.

In terms of the construction of agricultural modernization and modern rural industrial system, rural production capacity, structure and format will bring new growth points, which requires the power grid to empower rural industrial development, enhance the reliability and convenience of power supply, boost the development of characteristic industries according to local conditions, promote efficient and clean production, optimize marketing services and help rural revitalization. In promoting the improvement of the rural residential environment and ecological environment protection, it is necessary to encourage clean and electrified energy use and improve the ecological environment. The promotion of rural new energy development, clean heating, landscape integration, electric energy substitution, etc. will bring about a significant increase in electricity consumption, and the construction of distributed grid connection projects and the implementation of "coal-to-electricity engineering" will improve the business level of power grid production, operation and service.

For power grid investment, for one thing, efforts should be made to strengthen the construction of rural distribution networks to solve the problems of low voltage and low power supply reliability in rural power grid; for another, measures should be taken to enhance the transformation of rural distribution network, meet the needs of capacity expansion and transformation brought about by rural industrial development, fortify the upgrading of power grid infrastructure, and improve the intelligent level of the power grid.

2 Construction of an investment effectiveness evaluation index system for power transmission and transformation projects serving rural revitalization

At present, the evaluation of investment effectiveness of distribution network transmission and transformation projects includes analytic hierarchy process, grey relation analysis, fuzzy comprehensive evaluation, graph model and entropy weight method. As the state scales up input in the construction of distribution network and rural power grid in recent years, there are more and more research on the evaluation of investment benefit of distribution network. Reference [1] studied the effectiveness evaluation system of distribution network planning based on grids, and established a hierarchical evaluation index system by combining analytic hierarchy process with fuzzy comprehensive method. Reference [2] studied the distribution network investment allocation method and project optimization based on historical inpvestment effectiveness, and put forward an iterative distribution network investment allocation model combined with historical investment effectiveness. Reference [3] put forward an optimization method of medium voltage distribution network projects, which took into account index constraints and investment benefits, and probed into the correlation between project attributes and evaluation indexes based on the grey relation analysis method. Reference [4] studied the investment decision-making evaluation system of distribution network project of CS Company through interview and Delphi method, and determined the relative weight of each factor based on analytic hierarchy process, questionnaire and nominal group technique. Reference [5] constructed an evaluation index system of investment effectiveness from six aspects, such as distribution network structure, power supply capacity, power supply quality, equipment level, automation level and green energy, and introduced a dynamic comprehensive evaluation method with speed characteristics. Reference [6] used the fishbone diagram method to mine the influencing factors, and constructed the evaluation index system of distribution network investment benefit by combining analytic hierarchy process and Delphi method, and established the evaluation system of distribution network investment benefit based on triangular fuzzy number dynamic multi-attribute decision making. Reference [7] studied the effectiveness evaluation method of rural distribution network construction based on the public service value model, and evaluated the effectiveness of rural distribution network transformation and upgrading from two dimensions of output performance and cost effectiveness. Reference [8] put forward an optimization model of investment decision of distribution network construction projects based on engineering attributes, and used the ANP-AEW-TOPSIS method to sort and screen single distribution network construction projects under various engineering attributes. Reference [9] studied the annual investment evaluation mechanism of Xining distribution network from five aspects: Process, technical performance, sustainability, investment benefit and impact. Reference [10] constructed an evaluation index system of distribution network investment efficiency, gave the fuzzy range of evaluation index by the operation of fuzzy interval based on Type-2 fuzzy algorithm, and evaluated the construction effect of each distribution network project according to the calculated fuzzy membership value. Reference [11] put forward the evaluation index system of current power grid and planned power grid planning effectiveness and the corresponding quantitative evaluation method from the needs of distribution network stakeholders. Reference [12] comprehensively evaluated the rural power grid construction and transformation in three typical counties with different development levels by using fuzzy evaluation method, and established a comprehensive evaluation index system of 16 items in 3 categories for rural power grid transformation and upgrading. Reference[13] put forward the model and method of quantitative evaluation to improve the reliability of the distribution network in Xiamen Island, and analyzed the investment cost of various improvement measures.

From the above analysis, it can be seen that different evaluation methods have their own strengths and weaknesses. In practical application, proper evaluation method should be selected according to the research subject, and different evaluation methods can be combined to achieve more accurate evaluation results for some projects. As power grid transmission and transformation projects serving rural revitalization feature multiple voltage levels, many types of engineering construction, and many engineering investment channels, the constructed first-level index of investment benefit evaluation includes policy requirements, service level and social benefits after taking full account of the social benefits of the project and the guiding factors of government policies, and the power grid services are comprehensively evaluated from three aspects: Requirements of the national government, solution of practical problems of people's livelihood and social benefits after the implementation of the project. As a result, the evaluation index system of investment effectiveness of rural revitalization power transmission and transformation project is established as shown in Fig.1.

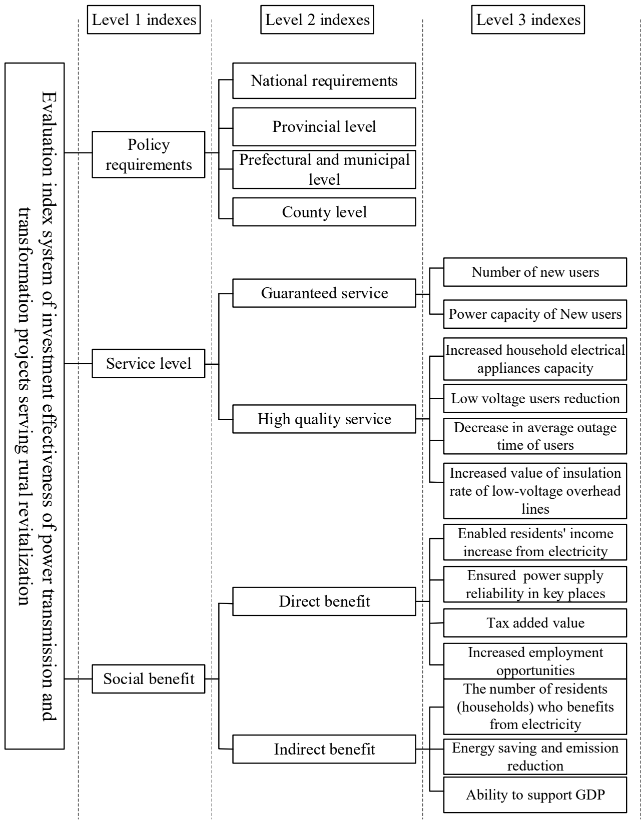

Fig.1 Evaluation Index System of Investment Effectiveness of Power Transmission and Transformation Projects Serving Rural Revitalization

3 Evaluation method of investment effectiveness of power transmission and transformation projects serving rural revitalization

3.1Quantitative method of qualitative indexes

The evaluation of investment effectiveness of power transmission and transformation projects serving rural revitalization needs to reduce the index scores of all three-level indexes to the interval [60, 100] scores by the analytic hierarchy process, and the qualitative index scores are scored according to the two-end values. Taking "N-1" as an example, through "N-1" verification, the evaluation score is 100, otherwise the score is 60; values are taken continuously in the allowable interval as quantitative indexes, and the evaluation scores change with the change of index values. The indexes with positive trend of index values are analyzed as extremely large, the indexes with the reverse trend of index values are analyzed as extremely small, and the indexes with a range of index values are discussed as interval types.

3.2Quantitative method of quantitative indexes

The analysis of extremely small, extremely large and interval indexes for investment effectiveness evaluation of power transmission and transformation projects serving rural revitalization is as follows:

3.2.1Extremely large index

Usually, the larger the value of extremely large indicators, the higher the score.Taking the qualified rate of comprehensive voltage as an example. If the average outage time of users is reduced by P_a after the power grid project serving people's livelihood in a certain area is put into operation, the maximum value of the average outage time reduction value of users in other reference power supply areas is M and the minimum value is m, then the evaluation score P_a^* expression of this extremely large index as in formula (1) below:

$$P_a^* = 40 \times \frac{P_a - m}{M - m} + 60 \tag{1}$$

3.2.2Extremely small index

Similarly, for extremely small indexes, the larger the indicator value, the lower the score. Taking the average power outage time index per household as an example. If the average household power outage time after the power grid project serving people's livelihood is put into operation in a certain area is P_b hours, the maximum average household power outage time after the other projects are put into operation is N hours and the minimum average household power outage time is n hours, then the average household power outage time index after the power grid project serving people's livelihood is put into operation is converted into an extremely large index $P_b^{'}$, which is expressed by $N - P_b$, and its corresponding index score P_n^* expression as in formula (2) below:

$$P_b^* = 40 \times \frac{P_b^{'}}{N - n} + 60 = 40 \times \frac{N - P_b}{N - n} + 60 \tag{2}$$

3.2.3 Interval index

To facilitate statistical analysis, the index value corresponding to interval index should be in a certain interval. Taking the load rate index of distribution transformer as an example. If the average load rate of distribution transformer in a certain area is P_c and its best stable interval is [c_1, c_2], the index can be converted into an extremely large index $P_c^{'}$, and its expression as in formula (3) below:

$$P_c' = \begin{cases} 1 - \dfrac{c_1 - P_c}{\max\{c_1 - q,\ Q - c_2\}}, & (P_c < c_1) \\ 1 & (c_1 \le P_c \le c_2) \\ 1 - \dfrac{P_c - c_2}{\max\{c_1 - q,\ Q - c_2\}}, & (P_c > c_2) \end{cases} \tag{3}$$

In the formula, Q and q are the maximum and minimum values of the average load rate P_c of distribution transformer in the actual court area respectively.

According to the above discussion, the expression of the evaluation score P_c^* for converting interval indexes into extremely large indexes as in formula (4) below:

$$P_c^* = 40 \times P_c' + 60 \tag{4}$$

3.3 Index weight setting

The importance of indexes to the comprehensive evaluation of the power grid serving livelihood investment benefits depends on the weight coefficient, and the rationality of index weight setting directly affects the accuracy of index evaluation results.

The commonly used comprehensive evaluation index assignment methods include the analytic hierarchy process, expert consultation experience assignment method, ring-on-ring scoring rank method, etc. Considering the particularity of power grid projects serving people's livelihood, the index weight assignment of investment benefit evaluation index system of the power grid serving people's livelihood should adopt analytic hierarchy process, expert consultation experience assignment method or a combination of the two.

4 Evaluation examples of major power transmission and transformation projects

To verify the practicability of the above evaluation model, this section selects four representative rural power grid projects serving rural revitalization for analysis, namely Project A, Project B, Project C and Project D, and adopts the index system mentioned in the previous section to compare and select the projects. The basic situation of the projects is as follows.

10 kV Coal-to-Electricity Power Grid Construction Project A: This project mainly meets the requirements of rural revitalization for improving the rural ecological environment, and upgrades the power grid according to the electricity demand of heating facilities put forward by power customers. It adopts 10 kV special line power supply to meet the power supply demand of customers' heating facilities. After the project is put into operation, it is estimated that the annual electricity sales will be increased by 1 million kWh, which will reduce carbon emissions

by 977 tons and improve urban air quality.

10 kV Power Supply Project B at Relocation Site: This project is a supporting power grid construction project implemented by the government to improve the rural residential environment. The government plans to build 65 relocated households. The foundation of half of the houses on site has been completed, and the construction team is under construction, but the power grid has not yet been made available. To supply power for relocated residents, the government required that the 10 kV power grid be extended as soon as possible. After the completion of the project, it is estimated that the average household distribution capacity will be 3.08 KVA/household, the maximum load will be about 130 kW, and the annual electricity sales will be increased by 130,000 kWh.

Capacity expansion and reconstruction project C of 10 kV court area: There are too many users near the substation and distribution station in P Village where Project C is located, and heavy overload often occurs during the load concentration period, with low average household capacity and long power supply radius. Low-voltage conductors are bare conductors, which may easily lead to safety accidents and pose a threat to the personal and property safety of nearby residents. The aging of equipment and lines in the court area is more prominent and faults occur frequently. After the completion of the project, it can effectively solve the problems of heavy overload of distribution transformer, insufficient power supply capacity and long power supply radius in the court area, and provide high-quality and reliable power supply for local residents, benefiting a total population of 770.

10 kV Power Grid Reconstruction Project D: The project is located in a remote mountainous area, and the low-voltage power supply network in the village is funded by villagers. Due to the lack of professional management and maintenance, villagers install electric wires without authorization, posing great safety threats. There are 285 electricity users in the village, which are currently powered by two courts with a total capacity of 300 kVA. Due to unreasonable distribution of courts, the maximum power supply radius of low-voltage lines reaches 900 meters, and the low voltage phenomenon of final users is particularly serious during peak power consumption. It is estimated that after the renovation, the potential safety hazards of equipment will be eliminated, the average household capacity will reach 2.285 KVA, and the maximum power supply radius of low voltage will be shortened to less than 500 meters, which can significantly improve the power supply capacity and quality, fully meet the production and living electricity demand of local residents, and facilitate residents to use large-capacity household appliances. In this way, rural electricity consumption will increase. Using the index evaluation method in Chapter 1 and Chapter 2 the indexes of the four projects are scored, and the scoring results are shown in Table 1.

Table 1 Scoring Results of Each Index of Case Projects

	Policy requirements				**Service level**						**Social benefit**						
Project	**National requirements**	**Provincial level**	**Prefectural and municipal level**	**County level**	**Guaranteed service**		**High quality service**				**Direct benefit**				**Indirect benefit**		
					Number of newusers (households)	Power capacity of new connected users (KW)	Increased household electrical appliances Capacity (KW)	Low voltage users reduction	Decrease in average outage time of users (hour)	Increasing value of insulation rate of low-voltage overhead lines (%)	Enabled residents' income increase from electricity(RMB10,000)	Ensured power supply reliability in key places	Tax added value (RMB10,000)	Increase employment opportunities (people)	The number of residents (households) who benefits from electricity	Energy saving and emission reduction (tons)	Ability to support GDP (RMB10,000)
Project A	Yes	No	No	No	4	0.165	0.35	0	13.22	100	0.0028	Yes	52.58	13	4	1009.04376	0.2525
Project B	Yes	No	Yes	No	65	0.013	3.46	35	0.79	100	0.01	Yes	50	20	195(65)	0	875.36
Project C	Yes	No	No	No	0	0	0.54	20	0.05	100	0.0103	No	12.27	11	770(273)	0	859.79
Project D	Yes	No	No	No	0	0	1.4	45	0.1	100	0.0017	No	6.37	88	1425(285)	-	122

Based on the evaluation results shown in Table 1, it can be seen that the four projects are all construction projects required by national policies, and projects A and B play a greater role in guaranteed power supply services, and should be paid greater attention to. The evaluation results of investment benefits of projects A, B, C and D are 0.73, 0.75, 0.68 and 0.66 respectively, which are consistent with the guidelines of power grid infrastructure serving rural revitalization, and the priority order of service investment benefits is Project B > A > C > D.

5 Conclusion

According to the key points of rural revitalization policy, this paper analyzed the requirements for power grid investment. Based on the characteristics of power transmission and transformation projects serving rural revitalization, full consideration should be given to the social benefits of the projects and the guiding factors of government policies. The evaluation index system of investment effectiveness of power transmission and transformation projects serving rural revitalization was established from three first-level dimensions: policy requirements, service level and social benefits. A comprehensive evaluation of power grid services was made from the requirements of the national government, the solution of practical problems of people's livelihood and the social benefits after the implementation of the project. The weight of the evaluation index was assigned by combining the analytic hierarchy process with the expert consultation experience assignment method. Four 10 kV power transmission and transformation projects A, B, C and D serving rural revitalization were selected to verify the evaluation method. The analysis results showed that the evaluation results are objective when applying this method to evaluate the rural revitalization distribution network projects, which meets the requirements of the national rural revitalization policy, and also provides a new idea for the investment effectiveness evaluation of other rural distribution network projects.

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