AN EFFECTIVE AND APPLIED METHOD ON EVALUTION OF DISTRIBUTION NETWORK PLANNING

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ABSTRACT

Firstly, this paper proposes a practical comprehensive hierarchy and method on evaluation of distribution network planning. Secondly, the implementation steps for the evaluation of planning network are given, which include the determination of indices hierarchy and the evaluation of planning. In the end, this paper takes 10kV network distribution planning of a district in China for example in order to illustrate the specific evaluation steps and methods based on the hierarchy, at the same time, the case shows that the evaluation method has strong feasibility and practicability. The planning evaluation hierarchy and method proposed in this paper can not only seize the key elements influencing the characteristics of network planning, but also describe the planning integrally and quantitatively, and possess significant engineering practicability.

INTRODUCTION

Planning is vital for the development of power system; and the quality of planning has direct influence on security, reliability and economy of the power system in the future. Distribution network planning in China has improved greatly, however, there are some problems needed to be solved urgently, such as how to evaluate the results after distribution network planning; whether the planning alternative is optimized; how to prove the effectiveness of a planning after its implementation in practical network. The major cause leading to the problems above is the lack of comprehensive knowledge and understanding of the planning and also the lack of specific criteria for measuring planning alternatives. Therefore, it is urgently needed to study quantitative evaluation method for distribution network planning.

The evaluation hierarchy and method on network planning proposed in the paper can be used to evaluate not only the current network but also the planning network. A case study has proved that the planning evaluation hierarchy and method can describe the planning integrally and quantitatively, and possess significant practicability.

PRINCIPLE OF EVALUATION HIERARCHY ESTABLISHMENT

For one thing, the selection of indicators must reflect the actual situation of network as completely as possible during the establishment of evaluation index hierarchy. On the other hand, the validity of the information, the difficulty of data collection, as well as the quantity of computation should also be concerned. Therefore, the establishment of evaluation index hierarchy should meet certain principles as follows:

(1) Consistency with the purpose of evaluation
(2) Direct measurability
(3) Comparability
(4) Independence with each other
(5) Integral completeness

In addition to meeting the above principles, the establishment of planning evaluation hierarchy has its own characteristics as follows:

(1) The hierarchy of planning network pays more attention to the characteristics of the planning and evaluates the network more integrally, the establishment of which is more concise related to the complexity of the evaluation hierarchy of current network.
(2) The establishment of evaluation hierarchy of distribution network planning ought to be suitable to the characteristics of the urban development and load characteristics.
(3) The evaluation of planning network pays more attention to the relative changes of index value in addition to the absolute quantity.

EVALUATION INDEX HIERARCHY OF DISTRIBUTION NETWORK PLANNING

According to the principle of the hierarchy establishment, combining the features and purposes of network planning, applying the basic principle of AHP, this paper proposes evaluation index hierarchy of network planning.

Structure of Index Hierarchy

Security, reliability and economy is the basic requirement of power supply; the network planning alternative is generally determined according to the load forecasting with uncertainty, so planning network should meet the demand for load of different growth patterns in a certain stage. At the same time, it is needed to quantitatively analyze the coordination considering the integrity and consistency of the network. To sum up, combining the views of electrical experts, determine the evaluation index hierarchy of distribution network planning given in Fig. 1.

The hierarchy contains five primary indices, such as security, reliability, economy, adaptability and coordination. Each index includes a number of subordinate indicators in order to quantify the evaluation from different aspects. The five primary indices constitute a whole which can evaluate the planning efficiently.

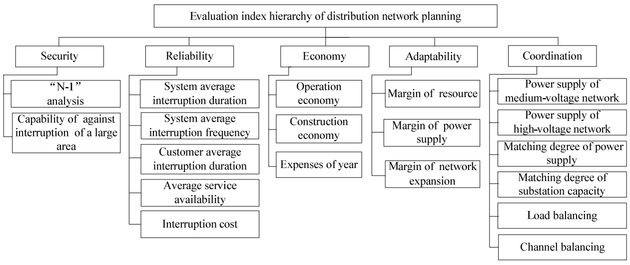

Fig.1. Structure of evaluation hierarchy of distribution network planning

Introduction of Index

A detailed introduction to the five primary indices in the evaluation hierarchy proposed above will be made.

Security

The security of distribution network means the ability to keep continuous power supply for load against a group of potential accidents at any time. Just the security for the maximum load of the year is concerned in the planning.

"'N-1' analysis" and "Capability of against interruption of a large area" are used to quantitatively evaluate the ability above, "N" of which means the total number of certain important equipments (including power transformer and feeder, etc), "1"means the number of elements with fault.

Reliability

The distribution system reliability is the capability of uninterrupted power supply under the consideration of the capability of the component, the voltage limitation of the bus, the limitation of frequency, the scheduling maintenance outage and the reasonable failure outage.

"System average interruption duration", "System average interruption frequency", "Customer average interruption duration", "Average service availability" and "Interruption cost" can deficit the reliability.

Economy

"Operation economy" of network analyzes the power system from the loss rate of network and the utilization rate of equipment. "Construction economy" analyzes the economic benefit brought by the investment in power network from the aspects of investment and income of power supply. "Expenses of year" is calculated according to the network investment, operation and maintenance costs, as well as the expense of loss.

Adaptability

The network planning is based on the load forecasting whose uncertainty requires that there is broad space for development in the network; therefore, it is needed to evaluate the ability of network adapting to the load development.

Coordination

The coordination between the high-voltage network and the medium-voltage network is necessary; otherwise, the weaker network will weaken the power supply of the stronger ones.

IMPLEMENTATION STEPS FOR EVALUATION OF PLANNING NETWORK

Fig. 2 describes the implementation steps for evaluation of planning network, which include the determination of indices hierarchy and the evaluation of planning.

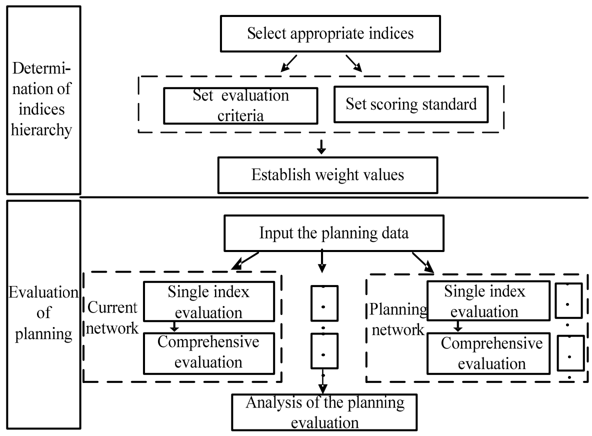

Fig. 2. Implementation steps for evaluation of planning network

In the stage of the indices hierarchy determination, it is needed to select appropriate indices, to set suitable evaluation criteria and scoring standard, and to establish the weight values for all indices.

The planning evaluation process includes three important parts: for one thing, to collect the original data such as the general situation of the network, planning report and so on; for another, to evaluate each single index on the current network and planning one; in the end, to provide supplementary analysis for the decision-making of distribution network planning through the comparison of the evaluation results on different planning schemes with each other.

Scores of indices are gained by converting the original data of index to a score according to a specific scoring standard. 100 basis, 10 basis and 5 basis are usually used in the scoring standard. There are many methods to determine the scoring standard, such as fuzzy membership degree method [2]. Weight values of indices which are represented by normalized vector depict the importance among indices of the same level.

Assume that there are two indicators in comparison, if the former is more important than the latter, the weight of the former is larger than the weight of the latter, vector (0.6, 0.4) can be used to depict it. We can use the method comparing two indictors with each other or experts deciding directly to determine the weight values of the attributes of the same level.

CASE STUDY

This paper takes 10kV network distribution planning of a district in China for example in order to illustrate the specific evaluation steps and methods based on the hierarchy and test the feasibility and practicability of the planning evaluation hierarchy and method.

Basic Data of the Planning Evaluation

TABLE 1 PARTIAL DATA OF CURRENT NETWORK

No	Classification	Name of Date	Value	Unit
1	Security	Through rate of single power transformer interruption in 110(35) kV substation	100	%
		Through rate of single feeder interruption of 10 kV	100	%
		Maximum load loss rate of "N-1"	0	%
		Average load loss rate of "N-1"	0	%
		Through rate of two power transformers interruption in 110(35) kV substation	0	%
		Maximum load loss rate of "N-2"	18.85	%
		Average load loss rate of "N-2"	9.55	%
2	Adaptability	Margin of substation expansion	109.8	%
		Margin of feeder space	3.92	%
		Margin of channel	3.21	%
		Margin of power supply	3.42	%
		Margin of network expansion	29.58	%
…	…	…	…	…

TABLE 2 PARTIAL DATE OF PLANNING NETWORK

No	Classification	Name of Date	Value	Unit
1	Security	Through rate of single power transformer interruption in 110(35) kV substation	100	%
		Through rate of single feeder interruption of 10 kV	100	%
		Maximum load loss rate of "N-1"	0	%
		Average load loss rate of "N-1"	0	%
		Through rate of two power transformers interruption in 110(35) kV substation	0	%
		Maximum load loss rate of "N-2"	8.65	%
		Average load loss rate of "N-2"	3.07	%
2	Adaptability	Margin of substation expansion	109.79	%
		Margin of feeder space	12	%
		Margin of channel	11	%
		Margin of power supply	4.5	%
		Margin of network expansion	25.1	%
…	…	…	...	...

The district area is 348.4 hectares and contains three 35kV substations; its 10kV network is composed mainly of cables, secondarily of overhead lines. The area is in the development of the mid-term whose function is mainly business, education, scientific research and living. 30 appropriate evaluation indices are selected from the hierarchy according to the characteristic of the case. First of all, the collection of basic data in planning evaluation is needed before calculating the indices. Table 1 and table 2 show the date needed in the case.

There are 30 basic data of the planning evaluation in Table 1, 6 of which are got from the planning report of the area, 24 of which are calculated according to the report.

There are 35 basic data of the planning evaluation in Table 2, 6 of which are got from the planning report of the area, 29 of which are calculated according to the report.

Establishment of Scoring Standard

Table3 summarizes the partial scoring standard of the case. Take "Through rate of single power transformer interruption in 110(35) kV substation" for example to clarify Table 3. The urban district requires a higher power supply security because it is in the development of mid-term, so it can be appropriate to raise the scoring standard of "Through rate of single power transformer interruption in 110(35) kV substation". While the value of the index is 90%, 60% and 40%, the score of the index is 80, 60 and 40. If the value is 100% and 0%, the score is 100 and 0.

TABLE 3 PARTIAL SCORING STANDARD OF COMPREHENSIVE EVALUATION INDEX

Scoring Standard \ Score				100	95	90	80	75	70	60	40	0
Security	"N-1" analysis	Through rate of single power transformer interruption in 110(35) kV substation	Proportion(%)	100			90		80	60	40	0
		Through rate of single feeder interruption of 10 kV	Proportion(%)	100			90		80	60	40	0
		Maximum load loss rate of "N-1"	Proportion(%)	0			20			40	60	80
		Average load loss rate of "N-1"	Proportion(%)	0			20			40	60	80
	Capability of against interruption of a large area	Through rate of two power transformers interruption in 110(35) kV substation	Proportion(%)	100			90		80	60	40	0
		Maximum load loss rate of "N-2"	Proportion(%)	0			20			40	60	80
		Average load loss rate of "N-2"	Proportion(%)	0			20			40	60	80
…	…	…	…	…	…	…	…	…	…	…	…	…

Establishment of Weight Values

The method of expert group decision-making is applied to determine the weight values of the attributes of the same level, in order to quantitatively depict the importance among indices. While in the process of establishment, the importance of index and the rate of incidence must be concerned, and the sum of weight values which belong to indices of the same level must be 1. In addition, we should consider these influence of the factors such as the development stage of the urban, load characteristics, the composition of consumer and so on. For example, compared with the initial stage of development, the urban district in the period of rapid growth requires a higher system margin, so the weight value of "adaptability" should be larger.

Table 4 summarizes the weight values of partial indices in the corresponding levels of the case, data in "()" stands for the weight value. For instance, "(0.4)" in "Maximum load loss rate of 'N-1' (0.4)" means that the weight value of "Maximum load loss rate of 'N-1' " is 0.4.

Comprehensive Evaluation and Comparison

Firstly, the basic data of the planning evaluation collected will be converted into scores ranging from 0 to 100 according to evaluation scoring standard which is determined by the preceding method.

Different scores describe the network evaluated from different aspects, but it is insufficient in presenting its overall conditions. Therefore, a calculation must be literately invoked to get the score of upper level in the hierarchy by AHP [2], until the overall score is finally gained. It may be defined as

$$S^{(k+1)} = \sum_{j=1}^{n} S_j^{(k)} W_j^{(k)}$$

$S^{(k+1)}$ stands for attribute $A^{(k+1)}$'s score in level k+1, n for attributes' number in lever k of $A^{(k+1)}$), $S_j^{(k)}$ for attribute j's score in level k of $A^{(k+1)}$, and $W_j^{(k)}$ for j's weight here.

The higher overall score indicts that the distribution network's performances have achieved a higher level in every aspect such as technical reasonableness, system security, as well as economics, etc. Table 4 summarizes the partial results of the distribution network comprehensive evaluation.

The conclusion can be obtained from the evaluation results compared with the current network, that the planning network in the near future has been improved in some aspects as follows:

(1) Capability of against interruption of a large area: the capability of transferring load in the planning network increases nearly by 20 percent, the load loss rate of 'N-2' analysis is cut down, so the capability of against interruption of a large area is improved.
(2) Utilization rate of equipment: increases 17 percent, from 47.12% in current network to 54.8% in planning network.
(3) Margin of feeder space: 6 positions are reserved in the planning network, 4 of which are new.
(4) Matching degree of substation capacity: the index is improved obviously, the score of which increases from 58 to 84.
(5) Load balancing: there is a difference of 41 percent between the maximum load rate and the minimum load rate of substation in current network whose load balancing is poor, while the score of the index in planning network reaches 100.

To sum up, the analysis of the results has shown that the planning network improves the primary problems of the current network, the overall score increases from 76.42 to 81.48, especially the adaptability is markedly improved and the score of the coordination increases from 64.65 to 80.4, so the planning alternative is feasible.

TABLE 4 PARTIAL COMPREHENSIVE EVALUATION OF CURRENT AND PLANNING NETWORK

Classification		Comprehensive Evaluation Hierarchy					Evaluation to the Effectiveness of a Planning
		Evaluation Index			Date	Score	
Security (0.2)84.2/87.6	"N-1" Nnalysis (0.5)100/100	Through rate of "N-1" (0.2)100/100	Through rate of single power transformer interruption in 110(35) kV substation(0.5)	Number(Seat)	3/3	100/100	
				Proportion(%)	100/100		
			Through rate of single feeder interruption of 10 kV(0.5)	Number(Strip)	71/56	100/100	
				Proportion(%)	100/100		
		Maximum load loss rate of "N-1" (0.4)		Proportion(%)	0/0	100/100	
		Average load loss rate of "N-1" (0.4)		Proportion(%)	0/0	100/100	
	Capability of against interruption of a large area (0.5)68.4/75.2	Through rate of "N-2" (0.2)0/0	Through rate of two power transformers interruption in 110(35) kV substation(1)	Number(Seat)	0/0	0/0	Unemproved
				Proportion(%)	0/0		
		Maximum load loss rate of "N-2" (0.4)		Proportion(%)	18.85/8.65	81/91	Improved slightly
		Average load loss rate of "N-2" (0.4)		Proportion(%)	9.55/3.07	90/97	Improved slightly
…	…	…		…	…	…	…
Comprehensive Evaluation	76.42/81.48						

Notes: for each index in Tab.5, data in front of "/" stands for the value and score of current network, data in back of "/" stands for the value and score of planning network; data in "()" stands for the weight value; score increasing more than 20 percent is taken for "improved obviously", score increasing to 100 is taken for "completely resolved".

CONCLUSION

This paper proposes the evaluation index hierarchy of distribution network planning on the basis of the analysis of principle of evaluation hierarchy establishment. Then the implementation steps for the evaluation of planning network are given. In the end, this paper takes 10kV network distribution planning of a district in China for example in order to illustrate the specific evaluation steps and methods based on the hierarchy, at the same time, the case shows that the evaluation method proposed in this paper has strong feasibility and practicability.

The case study has proved that the planning evaluation hierarchy and method can not only seize the key elements influencing the characteristics of network planning, but also describe the planning integrally and quantitatively, and possesses significant engineering practicability.

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BIOGRAPHIES

Saiyi WANG was born in Ningbo, Zhejiang Province of P.R. China, on January 30, 1978. He received his Ph.D. in electrical engineering in Tianjin University. He is the vice-director in Planning & Development Department of the company and his research interest is distribution system planning.