Post Evaluation of Power Grid Project Based on Rough Set and Improved Multi-Level Extension Assessment

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Abstract. Post evaluation of power grid investment and construction project is an important part of power grid construction project. The effect of post evaluation will directly affect the quality level of project construction. Therefore, this paper proposes an improved post evaluation system based on rough set and fuzzy multi-level extension. Firstly, the main factors affecting the function effect of power grid construction project are analyzed. Then, the improved fuzzy multi-level extension evaluation model is constructed by combining fuzzy comprehensive evaluation theory with multi-level extension evaluation method. Finally, a 220 kV substation construction project is taken as an example to verify the validity and rationality of the model.

1. Introduction

In the face of many projects, power enterprises focus on the investment income of their construction projects. How to evaluate the functional effect of the project after it has been completed and put into operation for a period of time, so as to improve the practical effect and economic investment income of the project, improve the decision-making level, and improve the decision-making mechanism is a crucial point [1-2]. As a key link in power grid investment and construction project, post evaluation of power grid construction project [3-4] has become a new research hotspot.

To solve these problems, this paper proposes a post evaluation system based on rough set and improved fuzzy multi-level extension.

2. Weight determination of index system based on rough set theory

The post evaluation method used in this paper includes the establishment of index system, the introduction of rough set to determine the index weight, and the use of improved fuzzy multi-level extension method for evaluation.

2.1 Selection of evaluation index

In order to make the evaluation index system more practical, the selected evaluation indexes include both quantitative indexes and some qualitative indexes which are difficult to quantify. In this paper, the post evaluation of substation construction project function effect is divided into four aspects: operation ability evaluation, power grid structure evaluation, safety and reliability evaluation, energy saving and loss reduction evaluation.

(1) Operation capacity evaluation refers to the analysis and calculation of relevant indicators in the normal or faulty operation state of the substation to find out the shortcomings in operation, mainly including the main variable capacity load ratio, the main variable average load rate and the maximum utilization load hours. Among them, the main variable capacity load ratio is related to the flexibility of the power grid operation mode and the utilization rate of equipment; the main variable average load rate reflects the bearing capacity of the main transformer; the maximum load utilization hours reflect the maximum utilization degree of electric energy.

(2) The grid structure evaluation mainly assesses the rationality of the substation's own construction after its completion and the degree of coordination with the original network. Among them, the rationality of the substation layout and the rationality of the division of the power supply area are mainly the assessment of the rationality of the construction of the substation itself; the coordination degree of the machine network and the coordination degree of the main distribution network reflect the degree of coordination with the original network structure after the completion of the project.

(3) Safety and reliability evaluation focuses on ensuring the safe and stable operation of the system and providing users with high-quality and reliable power supply. Its evaluation indicators include the failure rate of the main equipment, the comprehensive voltage pass rate and the main variable N−1 pass rate. Among them, the failure rate of the main equipment and the N−1 pass rate reflect the safe and stable operation of the system; the comprehensive voltage pass rate reflects the quality of the power provided to the user.

(4) Energy saving and loss reduction evaluation mainly includes two aspects: equipment energy saving and network loss. Among them, the cable adoption rate reflects the energy-saving effect of the equipment of the project construction; the line loss rate and the rationality of reactive power compensation reflect the network loss

of the system. The evaluation index system established in this paper is shown in Table.1.

Table.1 Evaluation index system

General objective	First level indicators	Secondary indicators
Function effect evaluation C	Operation capability evaluationC_1	Capacity load ratio of main transformer C_{11}
		Average load ratio of main transformer C_{12}
		Maximum load utilization hours C_{13}
	Evaluation of power grid structure C_2	Machine network coordination C_{21}
		Rationality of substation layout C_{22}
		Rationality of power supply area division C_{23}
	Safety and reliability evaluation C_3	Failure rate of main equipment C_{31}
		Comprehensive voltage qualification rate C_{32}
		N-1 passing rate of main transformer C_{33}
	Evaluation of energy saving and loss reduction C_4	Cable utilization rate C_{41}
		Line loss rate C_{42}
		Rationality of reactive power compensation C_{43}

2.2 Index weight based on rough set theory

For information systems S= (U, A, V, f), the importance of condition attribute c in condition attribute set C relative to decision attribute D is calculated as follows:

$$sig(c,C,D)=r_c(D)-r_{c-(c)}(D)=\frac{|POS_C(D)|-|POS_{C-(C)}(D)|}{|U|} \quad (1)$$

The weight of condition attribute ck is:

$$w_k=\frac{sig(c,C;D)}{\sum_{l=1}^{z} sig(c_l,C;D)} \quad (2)$$

The establishment of decision-making table should start from the grassroots indicators until the target decision-making table is established. Conditional attribute set C= (c1, c2, …, ck). The information system is numerically processed to delete duplicate content. The dependence of decision attribute D on condition attribute C is calculated as follows:

$$r_c(D)=\frac{|POS_C(D)|}{|U|}=\frac{\sum_{l=1}^{z}|POS_C(y)_k|}{|U|} \quad (3)$$

Each conditional attribute ck is removed in turn, and the dependence of the decision attribute on the remaining conditional attributes is calculated:

$$r_{c-c_k}(D)=\frac{|POS_{C-C_k}(D)|}{|U|}=\frac{\sum_{l=1}^{z}|POS_{C-C_k}(y)_k|}{|U|} \quad (4)$$

In this way, we can get the importance of each condition attribute:

$$\delta_D(C_k)=r_D(D)-r_{c-c_k}(D) \quad (5)$$

Finally, the index weight is obtained by formula normalization.

3. Improved evaluation model based on fuzzy multi-level extension

3.1 Determination of evaluation matter element

Suppose that the object to be evaluated contains m indexes, namely C1, C2, …, Cm. According to the definition of matter element in euthenics, the matter element model of the object to be evaluated is shown in equation (6).

$$M=(U_M,C_k,v_k)=\begin{bmatrix} U_M & C_1 & v_1 \\ & C_2 & v_2 \\ & \vdots & \vdots \\ & C_m & v_m \end{bmatrix} \quad (6)$$

where UM is the evaluation grade of the object to be evaluated; vk is the allowable value range of the k index of the object to be evaluated.

3.2 Determination of classical domain and node domain

All indexes of the object to be evaluated are divided into j (j=1, 2, … , n). Then, it is described as a matter-element model of comprehensive evaluation combining qualitative and quantitative analysis.

$$M_j=(U_{Mj},C_k,v_{jk})=\begin{bmatrix} U_{Mj} & C_1 & \langle a_{j1},b_{j1}\rangle \\ & C_2 & \langle a_{j2},b_{j2}\rangle \\ & \vdots & \vdots \\ & C_m & \langle a_{jm},b_{jm}\rangle \end{bmatrix} \quad (7)$$

where Mj is the matter-element model of the j evaluation grade; UMj is the evaluation effect of the object to be evaluated under the j evaluation grade; and $v_{jk}=\langle a_{jk},b_{jk}\rangle (j=1,2,\ldots,n;k=1,2,\ldots,m)$ represents the value range of the k evaluation index Ck when the evaluation grade is j.

According to the definition of nodal region, the allowable value range of each evaluation index is called nodal region of matter-element model for comprehensive evaluation of the object to be evaluated:

$$M_p=(U_{Mp},C_k,v_{pk})=\begin{bmatrix} U_{Mp} & C_1 & v_{p1} \\ & C_2 & v_{p2} \\ & \vdots & \vdots \\ & C_m & v_{pm} \end{bmatrix} \quad (8)$$

where Mp represents the node domain of matter-element model for comprehensive evaluation of the object to be evaluated; UMp represents the overall level of the object to be evaluated, and $v_{pk}=\langle a_{pk},b_{pk}\rangle$ refers to the allowable range of index Ck in UMp; $v_{jk}=\langle a_{jk},b_{jk}\rangle (j=1,2,\ldots,n;k=1,2,\ldots,m)$ is within the range of v_{pk}.

3.3 Determination and calculation of correlation function

Through the establishment of the correlation function, the calculation of the correlation between the object to be evaluated and the classical domain and the node domain of the matter-element model can be more accurate without relying on subjective judgment or statistics. The calculation of the correlation between the matter element model to be evaluated and its classical domain and node domain is shown in equation (9).

$$\rho\left(v_k, v_{jk}\right)=\left|v_k-\frac{a_{jk}+b_{jk}}{2}\right|-\frac{a_{jk}-b_{jk}}{2}$$
$$\rho\left(v_k, v_{pk}\right)=\left|v_k-\frac{a_{pk}+b_{pk}}{2}\right|-\frac{a_{pk}-b_{pk}}{2} \quad (9)$$
$$\left(k=1,2,\ldots,m; j=1,2,\ldots,n\right)$$

The above two expressions represent the "closeness" of points v_k and v_{pk} , v_{jk} respectively. If $\rho\left(v_k, v_{pk}\right)\geq 0$, it means that v_k is not in the interval v_{pk} ; if $\rho\left(v_k, v_{pk}\right)\leq 0$, it means that v_k is in the interval v_{pk} , and different negative values indicate that v_k is in different positions in v_{pk} .

The "bit value" of v_k and interval v_{pk} , v_{jk} is shown in equation (10).

$$D\left(v_k, v_{pk}, v_{jk}\right)=\rho\left(v_k, v_{pk}\right)-\rho\left(v_k, v_{jk}\right) \quad (10)$$

After formula (11) is obtained, the correlation degree of the k index Ck of the matter element to be evaluated with respect to the j evaluation grade can be calculated.

$$K_j\left(v_k\right)=\frac{\rho\left(v_k, v_{jk}\right)}{\rho\left(v_k, v_{pk}\right)-\rho\left(v_k, v_{jk}\right)} \quad (11)$$
$$\left(k=1,2,\ldots,m; j=1,2,\ldots,n\right)$$

3.4 Fuzzy multi-level extension evaluation

In order to reflect the grade of the object to be evaluated more accurately, the characteristic value of the grade variable is calculated by formula (12) (13) to obtain the more accurate subordinate grade of the object to be evaluated, and then the overall development trend of the object to be evaluated is determined.

$$\bar{K}_j\left(U_M\right)=\frac{K_j\left(U_M\right)-\max_j K_j\left(U_M\right)}{\max_j K_j\left(U_M\right)-\min_j K_j\left(U_M\right)} \quad (12)$$

$$j^*=\frac{\sum_{j=1}^{m} j\bullet\bar{K}_j\left(U_M\right)}{\sum_{j=1}^{m}\bar{K}_j\left(U_M\right)} \quad (13)$$

where, j^* is the eigenvalue of the grade variable of the object to be evaluated.

In order to further evaluate the quality of each level index of the project, the calculation formula of the score of each level index and the total goal is shown in the following formula (14) - (15).

$$G_k=\sum_{x=1}^{b} N_{kx}W_{kx} \quad (14)$$

$$G=\sum_{k=1}^{m} G_k \quad (15)$$

where: k is the number of the first level evaluation indexes in the evaluation project; x is the number of the second level indexes under a certain level evaluation index; Nkx is the single score of the x second level index under the k first level index; Wkx is the weight coefficient of the x second level index under the k first level index; Gk is the score of the k first level index; G is the overall score of the evaluation project.

4. Case analysis

This paper takes a 220kV substation construction project as an example to verify the scientificity and rationality of the fuzzy multi-level extension evaluation model.

According to the scoring rules of China Southern Power Grid Co., Ltd. on the division of post-project evaluation grades, this paper divides the post-functional evaluation of substation construction projects into four grades: poor, general, better and good, which correspond to each grade, and the specific scores of each grade range are divided as follows:

1) $60<U_{M1}=U_M\leq 75$, the functional effect of the strain power station construction project was evaluated as "poor".

2) $0<U_{M2}=U_M\leq 60$,the functional effect of the strain power station construction project was evaluated as "general".

3) $75<U_{M3}=U_M\leq 90$, the functional effect of the strain power station construction project is evaluated as "better".

4) $90<U_{M4}=U_M\leq 100$ At that time, the functional effect of the strain power station construction project was evaluated as "good".

The first-level indicator C = (C1, C2, C3, C4) in the evaluation index is used to determine the decision-making attributes, and the decision-making attributes are divided into the above 4 levels, defined as D= (good, good, general, poor), and the decision-making attributes are digitized into D=(1,2,3,4). The actual operating data of 13 220kV substations were selected and scored according to the evaluation index grade interval in Table 4. Taking the operation ability evaluation C1 as an example, the second-level index scoring decision table based on rough set theory, as well as the classical domain and section domain are shown in Table 2 and Table 3. In Table 3, j= 1, 2, 3, 4 represent the above four evaluation levels, the same below.

Table.2 Secondary index scoring decision table

Field	Operational capability Rate C1			Decision properties
	C_{11}	C_{12}	C_{13}	D
u_1	1	3	3	2
u_2	1	2	1	1
u_3	3	4	4	3
u_4	3	3	3	3
u_5	1	3	3	2
u_6	1	2	1	1
u_7	2	3	4	3
u_8	1	3	3	2
u_9	4	4	3	3
u_{10}	3	4	3	2
u_{11}	1	4	3	3
u_{12}	4	4	3	3
u_{13}	1	3	3	2

Table.3 Classical field and section field of operational capacity evaluation

index	Classical field				section field
	j=1	j=2	j=3	j=4	
C_{11}	0-60	60-75	75-90	90-100	0-100
C_{12}	0-60	60-75	75-90	90-100	0-100
C_{13}	0-60	60-75	75-90	90-100	0-100

The fuzzy multi-level extension evaluation results of post evaluation of substation construction project function effect are shown in Table. 4.

Table.4 Fuzz-multi level extension assessment results for the post evaluation on function effects for substation construction project

index	Correlation degree				Comprehensive evaluation score	Grade
	j=1	j=2	j=3	j=4		
C	-0.5927	-0.3483	0.1342	-0.1414	83.85	3
C_1	-0.5458	-0.2732	0.1919	-0.2706	82.25	3
C_2	-0.7226	-0.5561	0.1097	0.0427	88.90	3
C_3	-0.6000	-0.3600	0.0210	-0.0549	84.00	3
C_4	-0.4957	-0.1931	0.3403	-0.3186	79.83	3

5. Conclusion

Through the computational analysis applied by the fuzzy-multi-level extendable improvement evaluation method in the post-functional effect evaluation of substation construction projects, the following conclusions can be drawn:

(1) The index weight is determined based on rough set theory, which weakens the influence of human subjective factors on the evaluation results and makes the evaluation results more scientific and reasonable;

(2) The fuzzy-multi-level extendable improvement evaluation method can not only give the subordinate level of each level evaluation index and the overall goal, but also give the ranking of the results of the evaluation effect of each level evaluation index, which is convenient to find out the key factors affecting the evaluation of the functional effect of power grid investment and construction projects;

(3) Fuzzy evaluation theory makes full use of the ambiguity of various factors in the evaluation of the functional effect of substation construction projects, and reasonably deals with the uncertainty of decision-making factors and the ambiguity of expert experience.

In summary, the improved fuzzy-multi-level extendable evaluation method established in this paper is more suitable for post-evaluation of the functional effect of substation construction projects, reflecting the perfect combination of qualitative analysis and quantitative analysis, realizing the comprehensive evaluation of post-functional effect evaluation of substation construction projects, and avoiding the impact of subjective assumptions. The improved fuzzy multi-level extension evaluation method established in this paper is more suitable for the post evaluation of substation construction project function effect, reflects the perfect combination of qualitative analysis and quantitative analysis, realizes the comprehensive evaluation of post evaluation of substation construction project function effect, and avoids the influence caused by subjective assumption.

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