Research on risk evaluation model of distribution network project based on extension matter element

Pan Ersheng[1], Li Hui[1], Wang Yongli[2], Peng Dong[1], Wang Zhidong[1], Zhang Fuli[2]

([1]National network economic and technical research institute co.LTD.Beijing102209, China [2]North China Electric Power University, Beijing102200, China)

Abstract: Power industry is the basic industry of China's national economy. Power grid construction is a basic construction related to the national economy and the people's livelihood. It has many characteristics, such as large investment, many participants and complex organizational relationship. There are many risks in the process of construction. In addition, with the development of economy, the risk of power grid planning is more and more complex. In order to improve the scientificity of urban power network planning, it is very important to evaluate its risk scientifically. Considering the characteristics of power grid projects and analyzing the shortcomings of past grid project risk assessment methods, this paper proposed a risk assessment model based on matter-element model and extension analysis theory. This model introduces the correlation function and the degree of association in the extension set, which can easily quantify the qualitative indicators. In this paper, an empirical analysis of a city power grid planning in China has been carried out. The results show that the method has strong feasibility and practicability.

1.Introduction

In recent years, with the development of the market economy, the investment environment and conditions have undergone tremendous changes, and grid projects have many problems, such as long implementation cycle, many uncertainties, economic risks and technological risks, and serious impact on the ecological environment. Grid planning faces more and more risks. Uncontrolled uncertainties and its impact on the grid are more complicated. People are beginning to recognize the importance of urban grid risk management [1]. Therefore, it is particularly important to use certain models and methods to evaluate the risk of each link in the power grid planning.

In view of the seriousness of the security situation in the development of the power industry, many electrical project management experts and project managers have combined with the characteristics of electrical engineering and conducted various studies on power security management in order to improve the level of safety management and solve the problem of safety management. Literature [2-4] points out that the common methods of risk assessment include the analytic hierarchy process and the network analysis. At present, there are three general risk assessment methods: quantitative analysis, qualitative analysis, quantitative and qualitative analysis. The specific methods include analytic hierarchy process, fuzzy network analysis, expert scoring and risk matrix analysis [5-8]. Document [9] points out that in grid construction projects, risk assessment is planning, identifying and responding to possible risks, and using scientific risk research methods to reduce risks. Literature [10] uses a fuzzy comprehensive evaluation model to carry out a case analysis. Matter element model and extension analysis are the evaluation methods to solve the diversity and fuzziness of evaluation models. They have been widely applied in many fields, such as pattern recognition, scientific decision and comprehensive evaluation[11]. Document [12] used matter-element model and extension analysis respectively to evaluate relay protection business reliability and urban industrial water saving. The example shows that this method can make better comprehensive evaluation and decision for different attribute indicators.

At present, power grid construction projects are in the new era of electricity reform. The whole power grid construction will face a new risk situation. Therefore, on the basis of risk evaluation of power grid construction projects at home and abroad, this paper takes power enterprise distribution network project as the research object, combines the concept of risk management, management process and response theory, constructs the risk analysis model of distribution network project, through analyzing the characteristics of power enterprise distribution network project in China, carries on the risk identification, constructs the risk index evaluation system.

2.The theory and method of matter element extension model

2.1 Constructing an automatic demand response user grade evaluation matter element

N is the risk grade evaluation of power grid project; C is the characteristic of comprehensive evaluation; V is the characteristic value; R is the evaluation of risk grade for power grid project; Record as R=(N,C,V), if N has multiple n features (C_1, C_2, $C_3 \ldots C_n$), the corresponding value of each feature is V_1, V_2, $V_3 \ldots V_n$. It is expressed as:

$$R = \begin{vmatrix} N & C_1 & V_1 \\ & C_2 & V_2 \\ & \vdots & \vdots \\ & C_n & V_N \end{vmatrix} \tag{1}$$

2.2 Determining the classical domain, the node element matrix and the normalization treatment

Classical domain matter element matrix for risk assessment of power grid project(R_N) is expressed:

$$R_N = (N_i, N_n, V_n) = \begin{vmatrix} N_i & C_1 & (a_{i1}, b_{i1}) \\ & C_2 & (a_{i2}, b_{i2}) \\ & \vdots & \vdots \\ & C_n & (a_{in}, b_{in}) \end{vmatrix} \tag{2}$$

Domain matter element matrix for risk level evaluation of power grid projects (R_p) is expressed:

$$R_p = \left(N_p, N_n, V_n\right) = \begin{vmatrix} N_p & C_1 & (a_{p1}, b_{p1}) \\ & C_2 & (a_{p2}, b_{p2}) \\ & \vdots & \vdots \\ & C_n & (a_{pn}, b_{pn}) \end{vmatrix} \tag{3}$$

However, there are some limitations in the matter-element extension model. Therefore, it is necessary to improve the matter-element extension model. The method is to normalize the classical domain matter element and the evaluated matter element.

The classical domain matter element (R_N) after normalizing is shown as:

$$R_N = (N_i, N_n, V_n) = \begin{vmatrix} N_i & C_1 & (\frac{a_{i1}}{b_{p1}}, \frac{b_{i1}}{b_{p1}}) \\ & C_2 & (\frac{a_{i2}}{b_{p2}}, \frac{b_{i2}}{b_{p2}}) \\ & \vdots & \vdots \\ & C_n & (\frac{a_{in}}{b_{pn}}, \frac{b_{in}}{b_{pn}}) \end{vmatrix} \tag{4}$$

The unevaluated matter element after normalizing is shown as:

$$R_0 = (N_0, N_n, V_n) = \begin{vmatrix} N_0 & C_1 & \frac{V_1}{b_{p1}} \\ & C_2 & \frac{V_2}{b_{p2}} \\ & \vdots & \vdots \\ & C_n & \frac{V_N}{b_{pn}} \end{vmatrix} \tag{5}$$

2.3 Calculating correlation coefficient and correlation degree

The correlation function of the risk grade evaluation index of grid project is defined as:

$$K_j(V_i) = \begin{cases} \frac{-\rho(V_i, V_{ij})}{|V_{ij}|} & V_i \in V_{ij} \\ \frac{\rho(V_i, V_{ij})}{\rho(V_i, V_{pn}) - \rho(V_i, V_{in})} & V_i \notin V_{ij} \end{cases} \tag{6}$$

$$V_{ij} = |b_{in} - a_{in}| \tag{7}$$

$$\rho(V_i, V_{ij}) = \left|V_{dn} - \frac{1}{2}(b_{in} + a_{in})\right| - \frac{1}{2}(b_{in} - a_{in}) \quad (i = 1,2, \dots n; j = 1,2, \dots n) \tag{8}$$

$$\rho(V_i, V_{pn}) = \left|V_{dn} - \frac{1}{2}(b_{pn} + a_{pn})\right| - \frac{1}{2}(b_{pn} - a_{pn}) \quad (i = 1,2, \dots n) \tag{9}$$

2.4 Calculating the comprehensive correlation degree and determining the evaluation grade

The comprehensive correlation degree indicates the degree of conformity of all evaluation indices with each evaluation level, and the formula is as follows:

$$K_i(p) = \sum_{i=1}^{n} w_i K_j(V_i) \quad (i = 1,2, \dots n) \tag{10}$$

If $K_{ij} = \max\{K_i(p)\}$ is to be evaluated object i index belongs to the comprehensive benefit evaluation j grade.

2.5 Determine weights

The number of information obtained in the evaluation decision is one of the decisive factors of the evaluation precision and reliability, and the former methods of weight determination are mainly analytic hierarchy process and entropy weight method. When the value of the object on a certain index is the same, the entropy reaches the maximum, which indicates that the index does not provide any useful informations and can be removed from the evaluation index system, so the entropy weight method results are more objective. But it can not reflect the expert's knowledge, experience and the opinion of decision-makers, synthesizes the advantages and disadvantages of the two, gets the subjective and objective combination of Evaluation Index comprehensive weight w:

$$w = \partial w_i + (1 - \alpha) w_i' \tag{11}$$

Where: w_i - the AHP to determine the index weight;

α - the weight of the compromise coefficient, this paper takes 0.5;

w_i' - the weight determined by the entropy weight method, according to the following formula:

$$w_i = \frac{(1 - H_i)}{n - \sum_i^n H_i} \tag{12}$$

Among them, $H_i = -\frac{1}{\ln m} \sum_{j=1}^{m} \frac{f_{ij}}{\ln f_{ij}}$, $f_{ij} = \frac{v_{ij}}{\sum_{j=1}^{m} v_{ij}}$, v_{ij} is the measure of the $i(i = 1,2, \dots n)$ of an object in the type $j(j = 1,2, \dots n)$.

3. A model of power grid project risk assessment based on extension theory

3.1 Evaluation index system of power grid project risk

Designing the Risk Grade Evaluation index system of power grid project is the key step of establishing the risk grade evaluation model of the grid project, which determines the scientificity and practicability of the evaluation model. Based on the nature, characteristics and target of evaluation, this paper sets up a response user Grade Evaluation index system from 4 dimensions of external forces, project management, technical level and market factors, and a total of 12 three-level evaluation indexes. Table 1 is the evaluation Index system of grid project risk grade.

Table 1. Evaluation Index system of grid project risk grade

Target Layer	Level two indicator layer (benchmark level)	Level three indicator layer (indicator layer)
Grid Project Risk Level A	External factors B1	Electricity risk of air conditioner in summerC11
		Natural disaster RiskC12
		Risk of terrorist attackC13
	Project ManagementB2	Organizational Structure riskC21
		Quality riskC22
		Consider the risk of damageC23
	Technology B3	Load Forecasting AccuracyC31
		Design ReliabilityC32
		The risk of distributed power accessC33
	Market factors B4	Risk of land expropriation and relocationC41
		Risk of rising equipment pricesC42
		Risk of load fluctuationC43

3.2 Classification of power grid Project risk assessment

Refer to the existing relevant standards for General Electric Power User ratings, as well as the actual situation and characteristics of the users who participate in the automatic demand response, this paper divides the potential automatic demand response user rating into the risk (Ⅴ level), the higher risk (Ⅳ level), the general risk (Ⅲ level), the less risk (Ⅱ level), Risk-free (Ⅰ level) five levels, five risk levels correspond to five different project risk patterns. For the extension matter-element evaluation method, the project risk grade is the evaluation matter element, the 12 evaluation index is the matter element characteristic, the following table is the matter element, the characteristic and the measure value of the grid project risk grade evaluation index.

3.3 Risk Assessment Modeling

By fuzzy statistic analysis on the probability and risk loss degree of urban power grid planning in typical cities in China, the specific values of each index are obtained. The value of the R_{N1},R_{N2},R_{N3},R_{N4},R_{N5},R_P and R_0 of each risk class in the matter-element model is as follows:

$$R_{N1}=\left|\begin{array}{ccc} N_1 & C_1 & (7,9) \\ & C_2 & (7,9) \\ & C_3 & (7,9) \\ & C_4 & (80\%,100\%) \\ & C_5 & (0,1) \\ & C_6 & (7,9) \\ & C_7 & (85\%,88\%) \\ & C_8 & (7,9) \\ & C_9 & (7,9) \\ & C_{10} & (7,9) \\ & C_{11} & (7,9) \\ & C_{12} & (7,9) \end{array}\right| \quad R_{N2}=\left|\begin{array}{ccc} N_2 & C_1 & (5,7) \\ & C_2 & (5,7) \\ & C_3 & (5,7) \\ & C_4 & (60\%,80\%) \\ & C_5 & (1,3) \\ & C_6 & (5,7) \\ & C_7 & (88\%,90\%) \\ & C_8 & (5,7) \\ & C_9 & (5,7) \\ & C_{10} & (5,7) \\ & C_{11} & (5,7) \\ & C_{12} & (5,7) \end{array}\right| \quad R_{N3}=\left|\begin{array}{ccc} N_3 & C_1 & (3,5) \\ & C_2 & (3,5) \\ & C_3 & (3,5) \\ & C_4 & (40\%,60\%) \\ & C_5 & (3,5) \\ & C_6 & (3,5) \\ & C_7 & (90\%,95\%) \\ & C_8 & (3,5) \\ & C_9 & (3,5) \\ & C_{10} & (3,5) \\ & C_{11} & (3,5) \\ & C_{12} & (3,5) \end{array}\right|$$

$$R_{N4} = \begin{vmatrix} N_4 & C_1 & (1,3) \\ & C_2 & (1,3) \\ & C_3 & (1,3) \\ & C_4 & (20\%, 40\%) \\ & C_5 & (5,7) \\ & C_6 & (1,3) \\ & C_7 & (95\%, 98\%) \\ & C_8 & (1,3) \\ & C_9 & (1,3) \\ & C_{10} & (1,3) \\ & C_{11} & (1,3) \\ & C_{12} & (1,3) \end{vmatrix} \quad R_{N5} = \begin{vmatrix} N_5 & C_1 & (0,1) \\ & C_2 & (0,1) \\ & C_3 & (0,1) \\ & C_4 & (0,20\%) \\ & C_5 & (7,9) \\ & C_6 & (0,1) \\ & C_7 & (98\%, 99.6\%) \\ & C_8 & (0,1) \\ & C_9 & (0,1) \\ & C_{10} & (0,1) \\ & C_{11} & (0,1) \\ & C_{12} & (0,1) \end{vmatrix} \quad R_P = \begin{vmatrix} N_P & C_1 & (0,9) \\ & C_2 & (0,9) \\ & C_3 & (0,9) \\ & C_4 & (0,100\%) \\ & C_5 & (0,9) \\ & C_6 & (0,9) \\ & C_7 & (0,100\%) \\ & C_8 & (0,9) \\ & C_9 & (0,9) \\ & C_{10} & (0,9) \\ & C_{11} & (0,9) \\ & C_{12} & (0,9) \end{vmatrix}$$

$$R_0 = \begin{vmatrix} N_0 & C_1 & 3.30 \\ & C_2 & 3.21 \\ & C_3 & 3.35 \\ & C_4 & 84\% \\ & C_5 & 6.62 \\ & C_6 & 2.65 \\ & C_7 & 96\% \\ & C_8 & 2.50 \\ & C_9 & 2.60 \\ & C_{10} & 2.05 \\ & C_{11} & 2.82 \\ & C_{12} & 2.50 \end{vmatrix}$$

4.Case study

This section is a case study of a 220KV transmission and transformation project in Inner Mongolia Autonomous Region of China. The total investment of the project is about 170198705 yuan, after the power grid construction, the power grid structure is clear and simple, the power supply range is reasonable, the power supply reliability is enhanced, the basic can satisfy the fast development of the power supply demand, and consider the combination with the long-term load development, can be moderately ahead of the urban. The data used in this paper comes from the Feasibility study report of the power grid construction project, for the identified power grid project risk factors, in the evaluation process, please have different background knowledge and experience of the project risk assessment experts such as risk managers, project management experts, senior technical Engineers, etc. to the identified risk indicators to grade, Then the matter element analysis method carries on the comprehensive appraisal to this project risk. R_0 provides indicators for the project to be evaluated.

4.1 Index weight Calculation

This section calculates the weight of the evaluation index according to section 2.5, and finally obtains the results of each index weight as shown in the following table.

Table 2. Weight table of risk grade evaluation index for power grid project

Indicators	C11	C12	C13	C21	C22	C23	C31	C32	C33	C41	C42	C43
Weight	0.089	0.079	0.063	0.066	0.095	0.081	0.094	0.09	0.087	0.086	0.085	0.085

4.2 Evaluation Index Correlation degree calculation

The correlation degree of the object Grade Evaluation index about the project risk grade represents the degree of the object to be evaluated in the five evaluation grade. The evaluation indexes of the risk grade of the grid project are calculated, which are related to five evaluation levels of high risk (Ⅴ level), higher risk (Ⅳ level), general risk (Ⅲ level), less risk (Ⅱ level) and risk-free (Ⅰ level), as shown in the following table:

Table 3. Correlation degree of each evaluation index of grid project risk grade

Indicators	Ⅴ level	Ⅳ level	Ⅲ level	Ⅱ level	Ⅰ level
C11	-0.03655357	-0.00741666	0.01335	-0.03026	-0.04704285
C12	-0.03221217	-0.00485087	0.008295	-0.028282	-0.04277285
C13	-0.02597368	-0.00595945	0.011025	-0.02079	-0.03285
C21	-0.0528	-0.0484	-0.0396	-0.0132	0.0132
C22	-0.01307971	0.01805	-0.038475	-0.05731666	-0.0667375
C23	-0.03108139	0.014175	-0.00945	-0.03807	-0.05033571
C31	-0.03133333	-0.0188	0.013428571	-0.0564	-0.06266666
C32	-0.03375	0.0225	-0.015	-0.045	-0.05785714
C33	-0.03314285	0.0174	-0.0116	-0.04176	-0.05468571
C41	-0.02912903	0.04085	-0.02723333	-0.05074	-0.06081428
C42	-0.03334051	0.00765	-0.0051	-0.03706	-0.05075714
C43	-0.031875	0.02125	-0.01416666	-0.0425	-0.05464285

As can be seen from the table above, there is always a corresponding value for the correlation degree of each evaluation index, that is, each index is subordinate to a certain evaluation level, and the degree of correlation degree represents the extent to which the index belongs to a certain rank.

4.3 Project Risk Assessment Level

In table 1,table 2,table 3,the data and index weights are put into the formulas to obtain the degree of membership of each two-level evaluation index on the risk grade.

Table 4 Evaluation criteria layer and comprehensive evaluation result of the risk grade of grid project

Category	*Evaluation Project*				
	Ⅴ level	Ⅳ level	Ⅲ level	Ⅱ level	Ⅰ level
B1	-0.007434 372	-0.001418 749	0.0025380 3	0.0025380 3	-0.006237 188
B2	-0.007244 965	-0.000331 475	-0.007034 175	-0.009399 953	-0.009546 055
B3	-0.008866 262	0.0017716	-0.001096 914	-0.012984 72	-0.015855 467
B4	-0.008048 416	0.0059696	-0.003979 733	-0.011126 24	-0.014189 029
Integrated correlation degree	-0.384271 278	0.056447 997	-0.114526 429	-0.461378 667	-0.567962 738
Extension index	2.352974946				
Risk level	Ⅳ level				

According to the results of table 4, the project to be evaluated is ⅴ level of risk level of grid project, Ⅳ level, Ⅲ level, Ⅱ level, Ⅰ level of the comprehensive correlation degree of 0.38, 0.05, 0.11, 0.46, 0.56, which on behalf of the evaluation project on the risk level Ⅳ level of the most comprehensive relevance, according to the principle of maximum membership , the risk level of the evaluation project is Ⅳ level, the project risk is greater.

5. Conclusion

The risk factors affecting urban power network planning are many and complex, and the attribute of the factors are very different, so we need to study the method of urban power grid risks considering multiple attributes, and provide scientific theoretical support for the decision of urban power grid planning. Based on matter-element model and extension analysis theory, this paper establishes the risk Evaluation Index system of urban power grid planning, through the matter element model and the extension analysis, establishes the grade evaluation method of urban power grid planning risk based on fuzzy analytic hierarchy process, and proves its feasibility by the example analysis, provides a new method for solving similar problems.

References

[1] Lim C.S. Recurring Project Overrun and Project Management Problems in Engineering and Construction Industries[J]. 2001.
[2] Mills A. A systematic approach to risk management for construction[J]. Structural Survey, 2001, 19(5):245-252.
[3] Mills A. A systematic approach to risk management for construction[J]. Structural Survey, 2001, 19(5):245-252.
[4] Zhang Y, Tan X, Xi H, et al. Real-time risk management based on time series analysis[C]. Intelligent Control and Automation, 2008. Wcica 2008. World Congress on. IEEE, 2008:2518-2523.
[5] Yu Y. Risk Management Game Method of the Weapons Project Based on BP Neural Network[C]. International Conference of Information Technology, Computer Engineering and Management Sciences. IEEE Computer Society, 2011:113-117.
[6] Crousillat E.O, Dorfner P, Alvarado P, et al. Conflicting objectives and risk in power system planning[J]. IEEE Transactions on Power Systems, 1993, 8(3):887-893.
[7] Lao X. Analysis of Risk Classification and Risk Management and Control of Power Grid Operation[J]. Modern Industrial Economy & Informationization, 2017.
[8] Yan X.X, Yu-Xiao X.U. Game Analysis between Stakeholders of Urban Ecological Risk Management and Control[J]. Value Engineering, 2017.
[9] Éric Dubois, Heymans P, Mayer N, et al. A Systematic Approach to Define the Domain of Information System Security Risk Management[M]. Intentional Perspectives on Information Systems Engineering. Springer Berlin Heidelberg, 2010:289.
[10] Jia G. Research on risk management of electric power project [D]. North China Electric Power University (Beijing), 2008.
[11] Guo R.J, Wang J.X. Study on the risk assessment of Power Grid Considering the influence of meteorological conditions [J]. Yunnan electric power technology, 2009, 37 (2): 29-31.
[12] Wang Y.J, Zheng X.H, Wei Q.C, et al. Research on Urban Industrial Water-saving Evaluation Based on Extension Matter Element Model[C]. International Conference on Management Science and Engineering. IEEE, 2007:2271-2276.