Research on the Risk Assessment of Urban Power Network Planning Based on Improved Risk Matrix

Jie Yao and Yu Jiang, *Member, IACSIT*

***Abstract*—The urban power network planning is the premise of the power grid construction, so more and more attention has been paid to its scientific nature and rationality. However, the multifarious risks in the urban power network planning have become the barriers of the city power grid development. Hence, it is extremely important to identify these risk factors. In this paper, we proposed an improved risk matrix algorithm innovatively. Then, it was applied to assess the risk of XX city's power network planning. In this algorithm, the conventional two-dimensional risk matrix has been reshaped by adding two more dimensional characteristics, including the risk rating and the risk's attention rating. Based on this four-dimensional risk matrix, the Borda method is used to calculate the sequence value of each risk factor, then we can use these sequence values to construct the judgment matrix by using AHP method so as to calculate the weight of the risk factors and then identify a couple of important risk factors that have great impact on the urban power network planning. Finally, some corresponding advices of risk aversion are proposed to guarantee the smooth operation of urban power network planning.**

***Index Terms*—Urban power network planning, risk assessment, risk matrix, borda method, AHP method.**

I. Introduction

City is the major load center of power system, and the operation of the urban power network depends upon whether the urban power network planning and construction is scientific and reasonable or not. As the premise of the power network construction, the importance of the urban power network planning is self-evident. However, the overall consumption of social electricity and the maximum load have increased significantly with the rapid development of urban economy. This causes that current electric power facilities and the power supply capability cannot meet the real demand fully, so higher level requirement has been put forward to the urban power network planning. If the various risk factors in the urban power network cannot be assessed more accurately, it will be difficult for us to identify the severity of the risks that may occur during the late construction and the operation process of the urban power network comprehensively. Therefore, in order to improve the power network planning of the electric power company and reduce its operational risk, we need to assess and analyze the risk factors which influence the operation of urban power network planning dynamically, accurately and reasonably, then try to find out the key factors so as to develop some practical and effective strategies for the risk management of power network planning.

Manuscript received October 17, 2013; revised December 18, 2013. This work was supported in part by the School of Economics and Management of Northeast Dianli University.

The authors are with Northeast Dianli University, Jilin City, China (e-mail: leeyooab@ 163.com, alex6623105@qq. com).

II. Basic Principal of Improved Risk Matrix Algorithm

A. *The Improved Risk Matrix Algorithm*

The risk matrix was proposed by The United States Air Force Electronic Systems Center in 1995. It is a risk assessment and management method that is based on the whole acquisition life cycle. It can not only identify the importance of risks during the process of acquisition management, but also assess the potential impact of the acquisition risks, so as to provide a scientific basis for making risk management decisions [1].

When we use the improved risk matrix algorithm to analyze and manage the influencing factors of urban power network planning, the basic idea is as follows: the demand and possibility are used to be the starting point of thinking. Then, we identify and analyze the risk factors which exist in the urban power network planning. The conventional risk matrix is composed of the probability of risk (RP) and the size of risk (RI). However, in this paper, we reformed the risk matrix innovatively according to the features of the urban power network planning. The original two-dimensional risk matrix has been reshaped by adding two more dimensional characteristics, including the risk rating and the risk's attention rating. Therefore a four-dimensional risk matrix is formed (Table I). Based on this improved risk matrix, the Borda method guided by four criterions is used to calculate the sequence value of each risk factor. And then we use AHP to calculate the risk factors' weight so that the impact of each risk factor can be quantified [2].

TABLE I: The Improved Risk Matrix

Objects of analysis	Dimensions of analysis				Results	
Risk factor (R)	Probability of risk rating (RP)	Size of risk (RI)	Risk rating (RR)	Risk's attention rating (AR)	Borda value	Ordering Borda value

The explanation of Table I is as followed.

1) Risk factor: the specific risk of the urban power network planning.
2) Probability of risk rating: the frequency of risks in the urban power network planning. In order to calculate it conveniently, the probability of risk can be classified into five levels. Level 1: this risk factor will not happen, and

DOI: 10.7763/IJIEE.2014.V4.421

its possible range is 0-10%; Level 2: this risk factor will less likely happen, and its possible range is 11%-40%; Level 3: this risk factor will probably happen, and its possible range is 41%-60%; Level 4: this risk factor will likely happen, and its possible range is 61%-90%; Level 5: this risk factor will very likely happen, and its possible range is 91%-100%.

3) Size of risk: the impact caused by the risk during the process of the urban power network planning. In order to calculate it conveniently, it can also be classified into five levels, which is 1,2,3,4 and 5 respectively.
4) Risk rating: the grade determined by the probability of risk and size of risk. It can be low (L), less low (L L), medium (M), high (H) and very high (V H) respectively (Table II).
5) Attention rating of risk: we add this dimension according to the previous research so that the decision-makers can grasp each risk factor in the urban power network planning clearly and pay corresponding attention to them, so as to put the limited resources into the scarcest place. Different attention ratings of risk are defined according to the different probability of risk and size of risk. It can be classified into 4 levels, which are control, absorption, attention and strict control.

TABLE II: RISK RATING AND ITS QUANTIZED VALUE

Probability of risk rating	Size of risk									
	Level 1		Level 2		Level 3		Level 4		Level 5	
	value	Level	value	Level	value	Level	value	Level	value	Level
Level 1	0.5	L	1	L	1.5	L L	2.5	M	3	M
Level 2	1	L	1.5	L L	2	L L	2.5	M	3.5	H
Level 3	1.5	L L	1.5	L L	3	M	3	M	4	H
Level 4	2.5	M	3	M	3	M	3.5	H	4.5	V
Level 5	3	M	3.5	H	4	H	4.5	V H	5	V H

B. Borda Method

We use the Borda method that is guided by four criterions to identify the sequence of the risk factor, and reduce the blindness and subjectivity of expert evaluation method. The concrete process is as follows.

Assumed that N is the total number of risk factor, i represents a specific risk, k represents a criterion. The improved risk matrix has 4 criterions: k =1 is used to represent the criterion of probability of risk I; k =2 is used to represent the criterion of size of risk P; k =3 is used to represent the criterion of risk rating R; k =4 is used to represent the criterion of risk rating A. If represents the risk rating of risk factor i which is guided by the criterion k (In the risk matrix method, the number of risk factors whose probability of risk or size of risk is larger than that of the risk I is used to be the risk level under the criterion k), the Borda value of i is given as follows [3].

$$b_i = \sum_{k=1}^{4} (N - r_{ik}) \tag{1}$$

In this paper, first we sort the risk factors according to their Borda value, and the results are used to represent the sequence of these risk factors. The larger the Borda value is, the greater impact the risk factor has on the urban power network planning. It will not only help us to sort out the important risk factors during the process of urban power network planning, but also provide convenience for us to construct the judgment matrix by using AHP method.

III. APPLICATION OF THE IMPROVEMENT RISK MATRIX IN THE RISK ASSESSMENT OF XX CITY'S URBAN POWER NETWORK PLANNING

In this paper, the research step of the risk management in XX city's urban power network planning is shown as follows (Fig. 1).

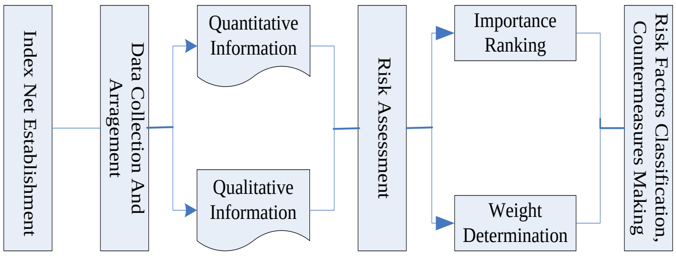

Fig. 1. The risk assessment steps of urban power network planning.

A. Establishment of the Risk Set

In order to comb the risk factors that may occur during the process of XX city's urban power network planning comprehensively and reasonably, Delphi Method and Brain Storming Method are used to make deep analysis on the internal and external environment that XX Electric Power Company are facing with from the following four dimensions including politics, economy, technology and management. Then the risk set of urban power network planning is established, as shown in Table III. It contains 1 first grade risk factor, 4 second-grade risk factors (B1-B4) and 17 third-grade risk factors (C1-C17) [4].

B. Collection and Processing of Data

After the risk set was established, we interviewed 12 experts who worked in Electric Power Company of XX City, then graded each risk factor's probability of risk rating, size of risk, risk rating and risk's attention rating in the form of questionnaire respectively.

Firstly, we calculated the average value according to the questionnaire, and further processing was made by using the principle of rounding. Secondly, the quantitative value of each factor's risk level was obtained based on its risk rating and quantized value in Table II. Then, we calculated the Borda value of each risk factor by using Borda method which is guided by four criterions. Finally, an improved risk matrix was established, as shown in Table IV.

TABLE III: RISK SET OF XX CITY'S URBAN POWER NETWORK PLANNING

First grade risk factor	Second grade risk factor	Third grade risk factor
Risk of XX city's urban power network planning	B1：Political risk	C1:Government supports the urban power network planning insufficiently, and there is no legal guarantee to the substation location and the land acquisition along the corridor of the transmission line
		C2:Substation construction is hindered by the residents nearby
		C3:Risk of land policy
	B2：Economic risk	C4:Risk of transmission and distribution price policy
		C5:Risk of engineering cost
		C6:Risk of the uncertainty of the need of electricity load
		C7:Risk of the uncertainty of the transmission and distribution price
		C8:Risk that loan interest rate changes on the financial impact to the Grid Company
	B3：Technological risk	C9:Risk of power supply reliability of the planning scheme
		C10: Risk of the reasonability, adaptability and scalability of the network structure and connection modes
		C11:Risk of the ability of resisting natural disasters of the power grid design
		C12:Risk of the distributed power supply and microgrid accessing
		C13:Risk of the reasonable and reliability of equipment selection
	B4：Management risk	C14:Risk of the coordination management to generation expansion planning and the urban planning
		C15:Risk of the load forecasting management
		C16:Risk of the substation location, location of the corridor of the transmission line management
		C17:Risk of the set of the power planning institutions and special-purpose management

C. Calculation of the Weight of Each Risk Factor

The Ordering Borda value calculated above can only express the priority of the risk factors that we should pay attention to during the process of XX city's urban power network planning, so each risk factor need to be weighted and quantified. In this paper, AHP method is used to calculate the weight. And the steps are as follows [5].

1) Construction of the judgment matrix

The ordering Borda value in Table IV is used as the corresponding elements in the judgment matrix A (In order to be comprehended easily, the comparative scale is defined from 1 to 14 according to the comparative intensity of each risk factor's influence).

2) Calculation of the weight and check of the consistency

According to the judgment matrix A above, AHP method is used to calculate the weight of each risk factor, and the results are shown below.

W_i =[0.052729,005447,0.022914,0.030368,0.012638,0.150268,0.009224,0.006935,0.092513,0.197114,0.153895,0.117706,0.069135,0.017171,0.009224,0.012638,0.040083]

TABLE IV: THE IMPROVED RISK MATRIX IN XX CITY'S URBAN POWER NETWORK PLANNING

Objects of analysis	Dimensions of analysis				Results	
Risk factor (R)	Probability of risk rating (RP)	Size of risk (RI)	Risk rating (RR)	Risk's attention rating (AR)	Borda Value	Ordering Borda value
C1	3	3	3	3	47	6
C2	2	2	1.5	1	13	14
C3	3	3	3	2	40	9
C4	2	4	2.5	3	43	8
C5	3	3	3	3	33	11
C6	4	4	3.5	4	64	2
C7	2	4	2.5	2	31	12
C8	2	3	2	1	22	13
C9	3	4	3	4	59	4
C10	4	5	4.5	4	68	1
C11	3	5	4	4	64	2
C12	4	4	3.5	3	60	3
C13	3	4	3	3	55	5
C14	2	4	2.5	2	38	10
C15	3	2	1.5	3	31	12
C16	2	3	2	3	33	11
C17	2	4	2.5	2	45	7

$$A=\begin{pmatrix}
1 & 9 & 4 & 3 & 6 & 1/5 & 7 & 8 & 1/3 & 1/6 & 1/5 & 1/4 & 1/2 & 5 & 7 & 6 & 2\\
1/9 & 1 & 1/6 & 1/7 & 1/4 & 1/13 & 1/3 & 1/2 & 1/11 & 1/14 & 1/13 & 1/12 & 1/10 & 1/5 & 1/3 & 1/4 & 1/8\\
1/4 & 6 & 1 & 1/2 & 3 & 1/8 & 4 & 5 & 1/6 & 1/9 & 1/8 & 1/7 & 1/5 & 2 & 4 & 3 & 1/3\\
1/3 & 7 & 2 & 1 & 4 & 1/7 & 5 & 6 & 1/5 & 1/8 & 1/7 & 1/6 & 1/4 & 3 & 5 & 4 & 1/2\\
1/6 & 4 & 1/3 & 1/4 & 1 & 1/10 & 2 & 3 & 1/8 & 1/11 & 1/10 & 1/9 & 1/7 & 1/2 & 2 & 1 & 1/5\\
5 & 13 & 8 & 7 & 10 & 1 & 11 & 12 & 2 & 1/2 & 1 & 2 & 4 & 9 & 11 & 10 & 6\\
1/7 & 3 & 1/4 & 1/5 & 1/2 & 1/11 & 1 & 2 & 1/9 & 1/12 & 1/11 & 1/10 & 1/8 & 1/3 & 1 & 1/2 & 1/6\\
1/8 & 2 & 1/5 & 1/6 & 1/3 & 1/12 & 1/2 & 1 & 1/10 & 1/13 & 1/12 & 1/11 & 1/9 & 1/4 & 1/2 & 1/3 & 1/7\\
3 & 11 & 6 & 5 & 8 & 1/2 & 9 & 10 & 1 & 1/4 & 1/3 & 1/2 & 2 & 7 & 9 & 8 & 4\\
6 & 14 & 9 & 8 & 11 & 2 & 12 & 13 & 4 & 1 & 2 & 3 & 5 & 10 & 12 & 11 & 7\\
5 & 13 & 8 & 7 & 10 & 1 & 11 & 12 & 3 & 1/2 & 1 & 2 & 4 & 9 & 11 & 10 & 6\\
4 & 12 & 7 & 6 & 9 & 1/2 & 10 & 11 & 2 & 1/3 & 1/2 & 1 & 3 & 8 & 10 & 9 & 5\\
2 & 10 & 5 & 4 & 7 & 1/4 & 8 & 9 & 1/2 & 1/5 & 1/4 & 1/3 & 1 & 6 & 8 & 7 & 3\\
1/5 & 5 & 1/2 & 1/3 & 2 & 1/9 & 3 & 4 & 1/7 & 1/10 & 1/9 & 1/8 & 1/6 & 1 & 3 & 2 & 1/4\\
1/7 & 3 & 1/4 & 1/5 & 1/2 & 1/11 & 1 & 2 & 1/9 & 1/12 & 1/11 & 1/10 & 1/8 & 1/3 & 1 & 1/2 & 1/6\\
1/6 & 4 & 1/3 & 1/4 & 1 & 1/10 & 2 & 3 & 1/8 & 1/11 & 1/10 & 1/9 & 1/7 & 1/2 & 2 & 1 & 1/5\\
1/2 & 8 & 3 & 2 & 5 & 1/6 & 6 & 7 & 1/4 & 1/7 & 1/6 & 1/5 & 1/3 & 4 & 6 & 5 & 1
\end{pmatrix}$$

Finally, we can work out that CI of A is 0.0925, which is less than 0.1. It means that the judgment matrix has passed the consistency check and the weight we calculated is reasonable.

D. Analysis of the Results and the Countermeasures

According to the value of w_i, we can notice that w_6, w_{10}, w_{11} and w_{12} are larger relatively. Thus, the most serious risks during the process of the urban power network planning are the risk coming from the uncertainty of the electricity load demand, the risk coming from the reasonability, adaptability and scalability of the network structure and connection modes, the risk coming from the ability of resisting natural disasters of the power grid design and the risk of the distributed power supply and microgrid accessing respectively. When making the subsequent urban power network planning, the planning makers should not only consider about the risks mentioned above sufficiently, but also find some feasible methods to avoid them. For example, when facing with the risk from the uncertainty of the electricity load demand, firstly the planning makers need to make load forecast accurately, and then identify and analyze the risk sources of the urban electric power load carefully. Secondly, considering about the uncertainty risk coming from the change of the land nature and the load density, the spatial load forecasting is recommended. What's more, we should make a scientific forecasting for the saturated load in the little section according to its growing characteristics. Finally, we should strengthen the risk management of load forecasting continuously. Considering about the uncertainty risk of electricity demand in each urban area sufficiently, we especially need to make an accurate load forecasting for every single substation, try to improve the accuracy of forecasting and the scientificalness of the site selection and volume setting for the substation, so as to reduce the planning risk.

In addition, by summing the weight value of third grade risk factors, we can conclude that technological risk is the most serious second grade risk factor which has great impact on the urban power network planning of XX city. Therefore, some suggestions can be proposed for the construction of the urban power network planning from macroscopic respect (the technological respect). We suggest that the planning makers should pay much more attention to the innovative, scientific and prospective feature of technology during the construction process of the power network. The grid structure should be optimized according to the actual situation of different cities, the scalability of connection modes should be paid attention to, and the unnecessary waste caused by repeated construction should also be avoided. Meanwhile, we also should pay attention to the reasonability and reliability when selecting the equipments for every substation in order to strengthen the capacities to withstand natural disasters.

IV. Conclusion

In this paper, we proposed an improved risk matrix algorithm innovatively, and then it was used to assess the risks in XX city's urban power network planning and identify some serious risk factors. During the following process of planning and construction, these risks were avoided or reduced properly, so it sufficiently guaranteed the successful implementation of the urban power network planning. In the improved risk matrix algorithm, some additional quantitative calculations were merged into the conventional evaluation method, it reduced the subjective factors in the process of risk assessment to some extent. Therefore this method is practical and can be popularized.

Acknowledgment

The authors wish to acknowledge the helpful comments and suggestions from my colleagues and students in Northeast Dianli University in Jilin City, China. And this paper is financial supported by the scientific research promotion project of Northeast Dianli University.

References

[1] R. Paul, P. R. Garvey, and Z. F. Lansdowne, "Risk matrix: An approach for identifying, assessing, and ranking program risks," *Air Force Journal of Logistics*, vol. 25, pp. 16-19, July 1998.

[2] Z. F. Lansdowne and B. S. Woodward, "Applying the Borda method," *Air Force Journal of Logistics*, vol. 20, pp. 27-29, August 1996.

[3] W.-A. Yang, "Risk matrix method and its application in the expressway management risk assessment," *Highway and Car*, vol. 6, pp. 190-192, December 2006.

[4] K.-C. Liu and Y.-D. Hu, "The method of power network planning based on risk judgment," *Journal of Chinese Mechanical Engineering*, vol. 22, pp. 69-73, June 2007.

[5] X.-D. Xu, Y. Zhao, and C.-Y. Yue, "Group decision making in AHP with the Borda method," *Journal of Huazhong Science and Technology University*, vol. 8, pp. 39-41, June 1999.

Jie Yao was born in Jilin City, China, on June 13, 1972. The educational background is as follows. First, Doctor of Management, Jilin University, Changchun, China, 2004-08, Major: Technological Economics and Management; Second, Master of Economics, Jilin University, Changchun, China, 1994-97, Major: Technological Economics; Third, Bachelor of Engineering, Jilin Institute of Chemical Engineering, Jilin, China, 1989-93, Major: Chemical Engineering.

She has ever been working in Northeast Dianli University, Jilin City, China, as an assistant from 1997 to 1998, as a lecture from 1999 to 2003, as an associate professor from 2004 to 2008 and as a professor from 2009 till now. She has also been a visiting scholar in Utah State University in spring and summer of 2006. Previous publications: Comparative Study on the Roles of China's and USA's SMEs in National Economic Growth (Changchun City, Jilin Province: Publishing House of Jilin University, 2010). Current and previous research interest is on the technological economic analysis of projects.

Prof. Yao is a member of IACSIT, and the member NO. is 80331453. She has ever won the science and technology prize of youth in Jilin city in 2009, won the award of young teacher's model in Northeast Dianli University in 2006 and won the science and technology prize of youth in Jilin city in 2003.