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An Application in Evaluating Grid Planning Risk in Western Resource-based Cities Based on Extension Synthesize Evaluation and TOPSIS

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Abstract: Since grid planning risk in western resource-based cities is prominent and has strong uncertainties, it is necessary to measure and evaluate the risk before power grid planning. In this study, evaluation index system of the grid planning risk is constructed, AHP is used to determine the index weight, extensive comprehensive evaluation is taken to build the evaluation model, TOPSIS method is applied to verify the evaluation results. The empirical analysis shows that the evaluation model is feasible, wish to provide a reference for grid planning risk evaluation in western resource-based cities.

Key words: Grid planning risk, western resource-based cities, extension synthesize evaluation, TOPSIS

INTRODUCTION

Due to western resource-based cities' own characteristics and the requirements of the new situation, the power grid planning risk is high, mainly including the following aspects: first, grid planning own risk in western resource-based cities is high, because of rich in natural resources, its economic development is faster than conventional cities. And lots of electricity projects are newly constructed and the construction speed is often higher than the requirements of the plan. Moreover, due to the western China bears a lot of resources, the construction of multi-energy power grid planning has been a major feature in western resource-based cities, grid planning has to consider the problem of power point layout and connected power generation, so, the uncertainty of the external environment of grid planning causes a lot of risks. Second, the smart grid environment highlights the risks of grid planning in western resource-based cities, such as the multi-energy grid infrastructure constructions will impact on grid planning, the impact of West-East electricity transmission project, the risk of the tariff aspects caused by intelligent scheduling of multi-energy, the risk from low-carbon economy and energy saving policy background, such as the promotion of low-carbon economic development model, especially restrictions to the model of high energy consumption and high emissions from carbon emissions quotas which shocked the traditional western power grid planning and construction. In summary, the grid planning risks in western resource-based cities are prominent, risk assessment work is very important before grid planning.

Although Chinese scholars have made many achievements in grid planning risk assessment (Yan, 2000; He *et al*., 2011a; Sun *et al*., 2009), there are little researches about grid planning risk evaluation in western resource-based cities (Arroyo *et al*., 2008; He *et al*., 2011a, b; Liu *et al*., 2007). To better grasp the size as well as the respective degree of grid planning risk in western resource-based cities, this study takes extension synthesize evaluation method to evaluate the level of risks and take advantage of the nearness of the double-base ideal point (TOPSIS) to verify accuracy of the evaluation result, in order to obtain more satisfactory rating results.

EXTENSION SYNTHESIZE EVALUATION THEORY

Theoretical foundation: Extension science a new science founded by Chinese scholar Caiwen which studies possibility of expanding and the rules and methods of innovation with a formal mode. Extension science is a theory combining organically of quality and quantity of the things which studies and solves conflicting problems in qualitative and quantitative perspectives and its theoretical pillar matter-element theory and extension set theory, its logic cell is the matter element (Li, 2000). Extension synthesize evaluation is a evaluation method based on extension set which can not only portray the respective degree of evaluation object existence state quantitatively, but also can characterize the boundary of a behavior with another (Hou and Huang, 2005).

Evaluation model: In extension synthesize evaluation, matter elements are expressed by ordered triples R = (N, C, V). If matter element N have n features $C(c_1, c_2, \cdots, c_n)$ and m matter elements $R_1 = (N_1, C, V_1)$, $R_2 = (N_2, C, V_2)$, $R_m = (N_m, C, V_m)$ to be evaluated own the same characteristics C, then Matter Element body R with same characteristic can be expressed as:

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$$R=\begin{bmatrix} N & N_1 & N_2 & \cdots & N_m \\ c_1 & v_{11} & v_{12} & \cdots & v_{1m} \\ c_2 & v_{21} & v_{22} & \cdots & v_{2m} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ c_n & v_{n1} & v_{n2} & \cdots & v_{nm} \end{bmatrix} \quad (1)$$

Among them, N_1-the matter elements to be evaluated:

N_1 = All subjects of the matter elements $N_1, N_2,\cdots,N_m$ to be evaluated
v_{ij} = The physical elements of Ith feature of The j-th matter elements to be evaluated, $i = 1, 2,\cdots,n$; $j = 1, 2,\cdots m$

Taking this as the basis, establishing extension synthesize evaluation method, by representation of matter element with the same characteristics, determining the scope of each feature measure, description of characteristic values of matter elements to be evaluated, calculation of the associate degree and eventually coming to the category the matter elements to be evaluated belongs to.

THEORY OF TOPSIS

The TOPSIS (technique for order performance by similarity to ideal solution) was first put forward by Hwang and Yoon. According to this technique, the best alternative would be the one that is nearest to the positive-ideal solution and farthest from the negative ideal solution. The positive-ideal solution is a solution that maximizes the benefit criteria and minimizes the cost criteria, whereas, the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria.

The steps of TOPSIS are:

- **Step 1:** Establish a decision matrix for the ranking. The structure of the original data's matrix can be expressed as follows:

$$D=\begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_n \end{array}\begin{bmatrix} F_1 & F_2 & \cdots & F_j & \cdots & F_m \\ F_{11} & F_{12} & \cdots & F_{1j} & \cdots & F_{1m} \\ F_{21} & F_{22} & \cdots & F_{2j} & \cdots & F_{2m} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ F_{i1} & F_{i2} & \cdots & F_{ij} & \cdots & F_{im} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ F_{n1} & F_{n2} & \cdots & F_{nj} & \cdots & F_{nm} \end{bmatrix} \quad (2)$$

where, A_i denotes the alternatives I, $i = 1,2,\cdots,n$; F_j represents jth attribute or criterion, $j = 1, 2,\cdots m$, related to ith alternative and f_{ij} is a crisp value indicating the performance rating of each alternative A_j with respect to each criterion F_j.

- **Step 2:** Calculate the normalized decision matrix $R(= [r_{ij}])$. The normalized value r_{ij} is calculated as:

$$r_{ij}=\frac{f_{ij}}{\sqrt{\sum_{i-1}^{n} f_{ij}^{\;2}}}\quad i=1,2,\ldots,n;\, j=1,2,\ldots m \quad (3)$$

- **Step 3:** Calculate the weighted normalized decision matrix through multiplying the normalized decision matrix by its associated weights. The weighted normalized value v_{ij} is calculated as:

$$V_{ij} = w_i \times r_{ij} \quad i = 1, 2,\cdots,n;\, j = 1,2,\cdots m \quad (4)$$

where, w_i represents the weight of the ith attribute or criterion

- **Step 4:** Determine the positive-ideal A^+ and negative-ideal solutions A^-:

$$\begin{aligned} A^+ &= \{v_1^{\;+}, v_2^{\;+},\ldots v_i^{\;+},\} \\ &= \{(\max_j v_{ij} \mid j\in I'), (\min_j v_{ij} \mid j\in I'') \end{aligned} \quad (5)$$

$$\begin{aligned} A^- &= \{v_1^{\;-}, v_2^{\;-},\ldots v_i^{\;-},\} \\ &= \{(\min_j v_{ij} \mid j\in I'), (\max_j v_{ij} \mid j\in I'') \end{aligned} \quad (6)$$

where, I' is associated with the benefit criteria and I'' is associated with the cost criteria.

- **Step 5:** Calculate the separation measures, using the n-dimensional Euclidean distance. The separation of each alternative from the positive-ideal solution D_j^+ is given as:

$$D_j^{\;+}=\sqrt{\sum_{i=1}^{n}(v_{ij}-v_i^{\;+})^2}\quad j=1,2,\ldots m \quad (7)$$

Similarly, the separation of each alternative from the negative-ideal solution D_j^- is as follows:

$$D_j^{\;-}=\sqrt{\sum_{i=1}^{n}(v_{ij}-v_i^{\;-})^2}\quad j=1,2,\ldots m \quad (8)$$

- **Step 6:** Calculate the relative closeness to the idea solution and rank the level order. The relative closeness of the alternative A_j can be expressed as:

$$E_i=\frac{D_j^{\;-}}{D_j^{\;+}+D_j^{\;-}}\quad j=1,2,\ldots m \quad (9)$$

In which the E_i value lies between 0 and 1. The larger the index value, the better the evaluation level.

EVALUATION INDEX SYSTEM FOR GRID PLANNING RISKS IN WESTERN RESOURCE-BASED CITIES

Based on the characteristics of western resource-based cities and reference to literatures of grid planning risk assessment, evaluation Index System for grid planning risk is designed in Table 1.

GRID PLANNING RISK EVALUATION MODEL IN WESTERN RESOURCE-BASED CITIES AND EMPIRICAL RESEARCH

Evaluation case: This study takes Hotan City in Xinjiang as an example to evaluate its power grid planning risk according to the evaluation index system.

Evaluation index weight determination: Use Analytic Hierarchy Process (AHP) to determine the evaluation index weight. Get the judgment matrix A and judgment matrix B_1, B_2, B_3, B_4 between indexed level two by 1-9 scale method:

$$A=\begin{bmatrix} 1 & 1/2 & 2.5 & 1/1.5 \\ 2 & 1 & 3 & 1.5 \\ 1/2.5 & 1/3 & 1 & 1/1.25 \\ 1.5 & 1/1.5 & 1.25 & 1 \end{bmatrix},$$

$$B_1=\begin{bmatrix} 1 & 3.3 & 2.1 & 4.5 & 3.2 \\ 1/3.3 & 1 & 1/2.2 & 1/3.4 & 1/2.6 \\ 1/2.1 & 2.2 & 1 & 1.1 & 2.3 \\ 1/4.5 & 3.4 & 1/1.1 & 1 & 2.5 \\ 1/3.2 & 2.6 & 1/2.3 & 1/2.5 & 1 \end{bmatrix}, B_2=\begin{bmatrix} 1 & 3.2 & 1/3.1 & 2.3 & 1/2.2 \\ 1/3.2 & 1 & 1/4.8 & 1/1.9 & 1/2.8 \\ 3.1 & 4.8 & 1 & 2.9 & 2.1 \\ 1/2.3 & 1.9 & 1/2.9 & 1 & 1/2 \\ 1/2.2 & 2.8 & 1/2.1 & 2 & 1 \end{bmatrix}$$

$$B_3=\begin{bmatrix} 1 & 3.1 & 3.3 & 2.1 \\ 1/3.1 & 1 & 2 & 2.3 \\ 1/3.3 & 1/2 & 1 & 1/2.8 \\ 1/2.1 & 1/2.3 & 2.8 & 1 \end{bmatrix}, \qquad B_4=\begin{bmatrix} 1 & 1/3.5 & 1/4 & 1/1.5 \\ 3.5 & 1 & 1/2.2 & 1.8 \\ 4 & 2.2 & 1 & 2.4 \\ 1.5 & 1/1.8 & 1/2.4 & 1 \end{bmatrix}$$

Use mathematical software MATLAB to calculate above the maximum eigenvalue λ_{max} of the judgment matrix, consistency deviation index CI($CI = \lambda_{max}$-m/m-1), random consistency ratio CR(CR = CI/RI) and the weight vector, seen as follows.

We can seen from the above table, the random consistency ratio CR is less than 0.1, the judgment matrix has satisfactory consistency. Table 2 shows the weights for indexes level two are (results to three decimal places):

$$W = (0.097, 0.017, 0.044, 0.042, 0.025; 0.068, 0.027, 0.161, 0.044, 0.094; 0.062, 0.033, 0.014, 0.026; 0.025, 0.069, 0.113, 0.040)$$

Extension synthesize evaluation for grid planning risk

Evaluation language set determination: Determine the evaluation language set as follows by expert scoring method.

Determine classic matter-element and section domain material element: According to the evaluation criteria shown in Table 3, record the evaluation level from low high as N_1, N_2,$\cdots$$N_5$, record indicators, respectively as c_1, c_2,$\cdots$,c_{18}, get the section domain material element R':

$$R'=\begin{bmatrix} N & c_1 & [0,100] \\ & \vdots & \vdots \\ & c_7 & [0,1000] \\ & \vdots & \vdots \\ & c_{18} & [0,100] \end{bmatrix}$$

Determine the matter element to be evaluated: For the indexes, get the index values by combination of survey and expert scoring, obtain the classic material.

Table 1: Evaluation indexes for grid planning risks in western resource-based cities

Indexes level one	Indexes level two
Policy risks U_1	Legal protection risk U_{11}
	Grid planning construction projects blocked risk U_{12}
	Transmission and distribution tariff policy risk U_{13}
	Land policy risk U_{14}
	Energy saving policy risk U_{15}
Technical risks U_2	Planning programs supply reliability risk U_{21}
	The grid structure applicability and scalability risk U_{22}
	Natural disasters resist capacity risk U_{23}
	Future distributed power and microgrid access risk U_{24}
	Equipment reliability risk U_{25}
Economic risks U_3	Load nncertainty risk U_{31}
	Transmission and distribution tariffs uncertainty risk U_{32}
	Financing risk U_{33}
	Grid construction cost and cycle risk U_{34}
Manage risks U_4	Coordination and management risk of power planning and urban planning U_{41}
	Load forecasting management risk U_{42}
	Substation and line siting and land protection management risk U_{43}
	The grid planning special management risk U_{44}

Table 2: Node specific offline parameters

Judgment matrix	λ_{max}	CI	CR	Weight vectors
A	4.1085	0.036	0.04	(0.2246, 0.3937, 0.1347, 0.2470)
B_1	5.3004	0.0751	0.0671	(0.4317, 0.0739, 0.1940, 0.1874, 0.1130)
B_2	5.1460	0.0365	0.0326	(0.1729, 0.0683, 0.4087, 0.1122, 0.2388)
B_3	4.2301	0.0767	0.0852	(0.4630, 0.2448, 0.1023, 0.1899)
B_4	4.0477	0.0159	0.0177	(0.0994, 0.2786, 0.4595, 0.1625)

Table 3: Grid planning risk evaluation grading standards

	Grading standards				
	Low	Relatively low	normal	Relatively high	High
Indexes	0-20	20-40	40-60	60-80	80-100

Table 4: Grid planning risk evaluation grading standards

Index	Low	Relatively low	Normal	Relatively high	High
U_{11}	-0.825	-0.767	-0.650	-0.300	0.300
U_{12}	-0.700	-0.600	-0.400	0.200	-0.143
U_{13}	-0.975	-0.967	-0.950	-0.900	0.100
U_{14}	-0.308	0.200	-0.100	-0.400	-0.550
U_{15}	-0.738	-0.650	-0.633	0.050	-0.045
U_{21}	-0.633	-0.529	-0.340	0.150	-0.083
U_{22}	-0.097	-0.074	-0.022	0.100	-0.170
U_{23}	-0.725	-0.633	-0.450	0.100	-0.833
U_{24}	-0.775	-0.700	-0.550	-0.100	0.100
U_{25}	-0.700	-0.600	-0.400	0.200	-0.143
U_{31}	-0.283	0.350	-0.175	-0.450	-0.588
U_{32}	-0.344	-0.045	0.100	-0.300	-0.475
U_{33}	-0.115	0.150	-0.425	-0.617	-0.713
U_{34}	-0.357	-0.100	0.250	-0.357	-0.438
U_{41}	-0.361	-0.115	0.300	-0.233	-0.425
U_{42}	-0.700	-0.600	-0.400	0.200	-0.143
U_{43}	-0.725	-0.633	-0.450	0.100	-0.833
U_{44}	-0.553	-0.457	-0.309	-0.050	0.050

$$\begin{aligned}\bar{R} &= (c_1, c_2 \cdots, c_{18}) \\ &= (86,76,98,18,79,67,120,78,82,76,33,42,23,45,23,38,78,62)\end{aligned}$$

Calculate the correlation function and associated degrees: Based on the formula for calculating the correlation function in the Extension Theory, the associated value and comprehensive correlation degree of grid planning risk level in Hotan city are shown in Table 4 and 5.

According to the calculation results of Table 5, $K_j = \max K_j(p) = K_2(p)$, it can be seen that the Hotan city grid planning risk is on a low level.

Validation of evaluation results: The idea of evaluate the risk level of the instance above is:

- Take the score of power grid planning in classic material element as the evaluation point
- Take the minimum risk indicator of risk classification standard in Table 3 while the maximum risk identified as the worst point
- Calculate the distance with the Euclidean distance of evaluation object to the optimal point D_i^+ and the worst point D_i^- and calculate the relative closeness E_i

Table 5: Comprehensive correlation degree of grid planning risk level in Hotan city

Degree	Comprehensive correlation degree
Low	-0.630
Relatively low	-0.476
normal	-0.380
Relatively high	-0.076
high	-0.333

Calculation results are as follows:

$$D_i^+ = \sqrt{\sum_{j=1}^{18} w_j^2 (c_j - c_j^+)^2} = 21.44,\ D_i^- = \sqrt{\sum_{j=1}^{18} w_j^2 (c_j - c_j^-)^2} = 84.67$$

$$E_i = \frac{D_i^-}{D_i^+ + D_i^-} = 0.7979$$

The relative closeness is close to the extension synthesize evaluation result, TOPSIS calculation result shows the risk evaluation result is accurate and credible.

CONCLUSION

Due to western resource-based cities' own characteristics, as well as requirements for grid planning and construction from smart grid and low-carbon economy, grid planning risk in western resource-based cities is prominent, it is necessary to evaluate it more accurately. Based on the above considerations, this paper constructs the evaluation indexes for risk level of grid planning level, uses AHP method to determine the index weight, establishes the evaluation model based on extension synthesize evaluation, scientifically grasps power grid planning risk level and using TOPSIS method to verify evaluation results, to ensure scientific and objective evaluation results. Hope that the work done in this article can provide a reference for grid planning risk evaluation and metrics in China's western resource-based cities.

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