Research on Safety Evaluation Method of Hydropower Plant based on Extension Theory

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Abstract. The theory of extenics is used to evaluate the safety of hydropower plants. The theory of matter element analysis and the theory of extension set are introduced into the evaluation, applying the concept of extenics, create a set of matter element analysis model, structure a set of evaluation index system for safety of hydropower plants. By calculating the extension correlation degree between each index and each evaluation grade, the safety of the hydropower plant is evaluated. At the same time, the weight coefficient is determined by the analytic hierarchy process. In the realization of comprehensive and quantitative evaluation, ensure the objectivity of the whole process of evaluation and avoid the influence of human subjective factors.

1. Introduction

Hydropower resources are a kind of renewable resources. The use of this resource is low cost, high efficiency and stable power supply performance. It is a well resource in the development of energy. The construction of the hydropower station has provided important support for the safety and sustainable development of the society. However, the location of hydroelectric power station construction is very special. It involves flood control and construction. If it is not handled properly, it will also be a dangerous source for major disasters. Therefore, during the construction and operation, we need to strengthen the safety supervision of hydropower plants, and evaluate it with a set of practical evaluation criteria, so as to facilitate timely detection of problems and take early measures.

The safety assessment of a hydropower station is a complex concept. Its evaluation value is influenced a series of indexes. Each index is not a flat relationship, it is a hierarchical comprehensive system. The traditional evaluation method cannot deal with all kinds of uncertain factors and subjective factors, and cannot get satisfactory evaluation results.

There is no feasible method to evaluate the safety of the hydropower plant in the existing technology. Lack of a comprehensive and unified safety evaluation index system. This is harmful to the long-term stable operation of the hydropower plant. A certain degree of difficulty is added to the safety evaluation of the hydropower plant. So a good set of evaluation methods is very necessary.

2. Evaluation Index System for Safety of Hydropower Plant

For the safety problems existing in the production of hydropower plants, the risk factors that easily lead to accidents are all need to be foreseen in advance and to be judged. The scientific, comprehensive, effective and representative evaluation index system is an important guarantee for the accurate and reliable evaluation of the results. According to the "Grade division of water conservancy and hydropower projects and standard of flood", "Specification for design of construction organization for water conservancy and hydropower projects", Guidelines for evaluation of reservoir dam safety which issued by the Ministry of water resources of People's Republic of China, on the basis of relevant expert opinions in consulting construction, management, construction and supervision, a comprehensive index system for safety evaluation of power plants is set up. This index system adopts a two-tier structure. The first level rule level is divided into four first level indicators, each level index includes three indicators, each index takes account of the corresponding impact factors, and the structure is clear. See Figure 1(At the end of the article).

3. Application of Extenics to Safety Evaluation of Hydropower Plants

3.1. Extension Matter-Element Model for Establishing Safety Evaluation of a Hydropower Plant

Ordered three tuples of things P, feature C and V value are used as the basic elements to describe things, which are recorded as R= [P, C, and V]. A matter element expression that describes the safety of a power plant is

$$R\left[P,C,V\right]=\begin{bmatrix} P & c_1 & v_1 \\ & c_2 & v_2 \\ & c_3 & v_3 \\ & c_4 & v_4 \end{bmatrix} \tag{1}$$

Safety of the hydropower plant is divided into four grades of excellent, good, attention and serious, so the classical domain matter element for the safety evaluation of a hydropower plant is

$$R_{0j}=\left[P_{0j},C_{0j},V_{0j}\right]=\begin{bmatrix} P_{0j} & c_1 & v_{01j} \\ & c_2 & v_{02j} \\ & c_3 & c_{03j} \\ & c_4 & v_{04j} \end{bmatrix}=\begin{bmatrix} P_{0j} & c_1 & <a_{01j},b_{01j}> \\ & c_2 & <a_{02j},b_{02j}> \\ & c_3 & <a_{03j},b_{03j}> \\ & c_4 & <a_{04j},b_{04j}> \end{bmatrix} \tag{2}$$

Joint domain matter element is

$$R_p=\left[P,C,V_p\right]=\begin{bmatrix} P & c_1 & v_{p1} \\ & c_2 & v_{p2} \\ & c_3 & c_{p3} \\ & c_4 & v_{p4} \end{bmatrix}=\begin{bmatrix} P & c_1 & <a_{p1},b_{p1}> \\ & c_2 & <a_{p2},b_{p2}> \\ & c_3 & <a_{p3},b_{p3}> \\ & c_4 & <a_{p4},b_{p4}> \end{bmatrix} \tag{3}$$

3.2. Using Analytic Hierarchy Process to Determine the Weight Coefficient

The analytic hierarchy process (AHP) is a kind of analysis method which is suitable for multi objective and multi criteria, this approach divides the factors of a complex problem into an orderly level of correlation, it can effectively combine quantitative analysis with qualitative analysis to make the weight more objectivity.

According to the safety evaluation system for hydropower plants, and the relative relationship between the upper and lower levels and the relative relationship between the indexes of the same level, structure judgment matrix, that is, the above level of a certain factor is the criterion, it has a dominant relationship with the next level offactors, by comparing the relative importance of the next level of factors to a certain factor on the next level, and giving a certain value. On the basis of the comparison scale of the judgment matrix, all the indexes are listed and a square matrix of N x N is formed. Then, according to the relative importance of indicators, each index is compared with each other and scored, and the judgement matrix c= (C ij) n * n is obtained. Finally, the score of each index is summed up and normalized, and then the weight of each index is obtained based on the square root method.

3.3. Calculation Correlation Degree

Order $v_{0ij} =< a_{0ij}, b_{0ij} >$, $v_{pi} =< a_{pi}, b_{pi} >$, then VI's elementary association functions for v_{0ij} and v_{pi} are

$$K_j(v_i) = \begin{cases} -\dfrac{\rho(v_i, v_{0ij})}{|v_{0ij}|}, v_i \in v_{0ij} \\ \dfrac{\rho(v_i, v_{0ij})}{\rho(v_i, v_{pi}) - \rho(v_i, v_{0ij})}, v_i \notin v_{0ij} \end{cases} \tag{4}$$

Among

$$\rho(v_i, v_{0ij}) = \left| v_i - \frac{1}{2}(a_{0ij} + b_{0ij}) \right| - \frac{1}{2}(b_{0ij} - a_{0ij}) \tag{5}$$

$$\rho(v_i, v_{pi}) = \left| v_i - \frac{1}{2}(a_{pi} + b_{pi}) \right| - \frac{1}{2}(b_{pi} - a_{pi}) \tag{6}$$

$$|v_{0ij}| = \frac{|b_{0ij} - a_{0ij}|}{2} \quad (i=1,2,\ldots,n;\ j=1,2,\ldots,m) \tag{7}$$

The degree of correlation of the safety of the power plant to be evaluated with respect to level j is

$$K_j(P_0) = \sum_{i=1}^{n} a_i K_j(v_i) \tag{8}$$

3.4. Determine the Safety Grade of the Power Plant to be Evaluated

If $K_{j0} = \max K_j(P_0)$, then the evaluation scheme P0's security level belong to grade J0.

4. Example Analysis

Take Taiping Wan hydropower station as an example. Taiping Wan hydropower station is a power station jointly operated by People's Republic of China and Democratic People's Republic of Korea. In the lower reaches of the Yalu River and Pushi River Interchange. The west of the power station is liaoning province Dandong City Zhen'an District Taiping Town. The east is Pyonganbuk Shuozhou County side of the mountains. China is responsible for the design and construction, after the completion of the construction, it is run by the management of China.

The specific operation process for the safety evaluation of the hydropower plant is as follows:

Table 1. Evaluation index score.

index	Production equipment c1			Metal structure c2			Power plant building c3			Security measures and management c4		
numerical value	c11	c12	c13	c21	c22	c23	c31	c32	c33	C41	C42	C43
	86	73	87	81	72	76	62	78	85	69	80	82

Step 1: Scoring index factors

According to the safety evaluation index system of hydropower plants set up before, experts from relevant parties are invited to evaluate and score various safety performance indicators. The specific results are shown in Table 1. Meanwhile, the grade of safety performance is identified, that is, excellent, good, general and poor

Step 2: the determination of weight

Structure judgment matrix

On the basis of consulting experts such as construction, management, construction and supervision, according to the scale method, the importance of each element is compared and the judgement matrix of each layer is constructed.

$$c = \begin{pmatrix} 1 & 1/2 & 1/2 & 1 \\ 2 & 1 & 1 & 2 \\ 2 & 1 & 1 & 2 \\ 1 & 1/2 & 1/2 & 1 \end{pmatrix}$$

$$c_1 = \begin{pmatrix} 1 & 2 & 3 \\ 1/2 & 1 & 2 \\ 1/3 & 1/2 & 1 \end{pmatrix} c_2 = \begin{pmatrix} 1 & 2 & 3 \\ 1/2 & 1 & 2 \\ 1/3 & 1/2 & 1 \end{pmatrix} c_3 = \begin{pmatrix} 1 & 1 & 2 \\ 1/2 & 1 & 2 \\ 1/2 & 1/2 & 1 \end{pmatrix} c_4 = \begin{pmatrix} 1 & 3 & 4 \\ 1/3 & 1 & 2 \\ 1/4 & 1/2 & 1 \end{pmatrix}$$

are the judgment matrix of the standard layer and the index layer.

Calculate the weight of each factor

According to the above judgment matrix and the square root method, the weight W of the target layer is calculated. Index layer $c_{11} \sim c_{13}$ to standard layer c_1, Index layer $c_{21} \sim c_{23}$ to standard layer c_2 the weights are respectively:

$W = (0.17,0.33,0.33,0.17)$

$W_1 = (0.54,0.30,0.16)$

$W_2 = (0.54,0.30,0.16)$

$W_3 = (0.4,0.4,0.2)$

$W_4 = (0.62,0.24 ,0.14)$

Step 3:

According to the weight obtained in the second step, the extension correlation degree Kji between each index and each grade is obtained. See table 2

Table 2. The extension correlation degree

index	Grade	Correlation degree
Production equipment	excellent	-0.36796
	good	0.06207
	general	-029736
	poor	-0.59983
Metal structure	excellent	-0.37926
	good	-0.06396
	general	0.13654
	poor	-0.23534
Power plant building	excellent	-0.36787
	good	-0.078640
	general	0.068791
	poor	-0.3580
Security measures and management	excellent	-0.27947
	good	0.13494
	general	-0.08723
	poor	-0.57561

Step 4:

The evaluation result of the second layer is composed of the first level of relevance matrix, and then the weight of the first level indicator is used to finally obtain the extension comprehensive evaluation result of the power plant. See table 3.

Table 3. Extension evaluation results of power plant

Grade	Correlation degree
excellent	-0.2867
good	0.0786
general	-0.2434
poor	-0.5643
Evaluation results	good

Data from the table can be obtained, 0.0786>-0.2434>-0.2867>-0.5643, according to the maximum correlation criterion, the safety grade of the hydropower station has been completed well and meets the safety standards.

5. Conclusion

According to the practical experience of Extenics in the field of engineering, the matter-element theory and extension set theory of extenics theory are introduced into the safety performance evaluation system of power plants, and the corresponding classical domain matter element model and the node matter element model are established. The security level is divided into four levels: excellent, good, attention and poor. Then according to the safety index score of each hydropower plant and the evaluation grade, provide a reference for future maintenance and rectification. AHP is used to determine the weight of each index in safety evaluation, and the quantitative data needed is less. The decision method is simple and practical, and the analysis method is systematic. It can avoid the influence of subjective factors and ensure the objectivity of the whole evaluation process. This method is simple and reliable, and it is of great significance for the safety evaluation of a hydropower plant.

6. Reference

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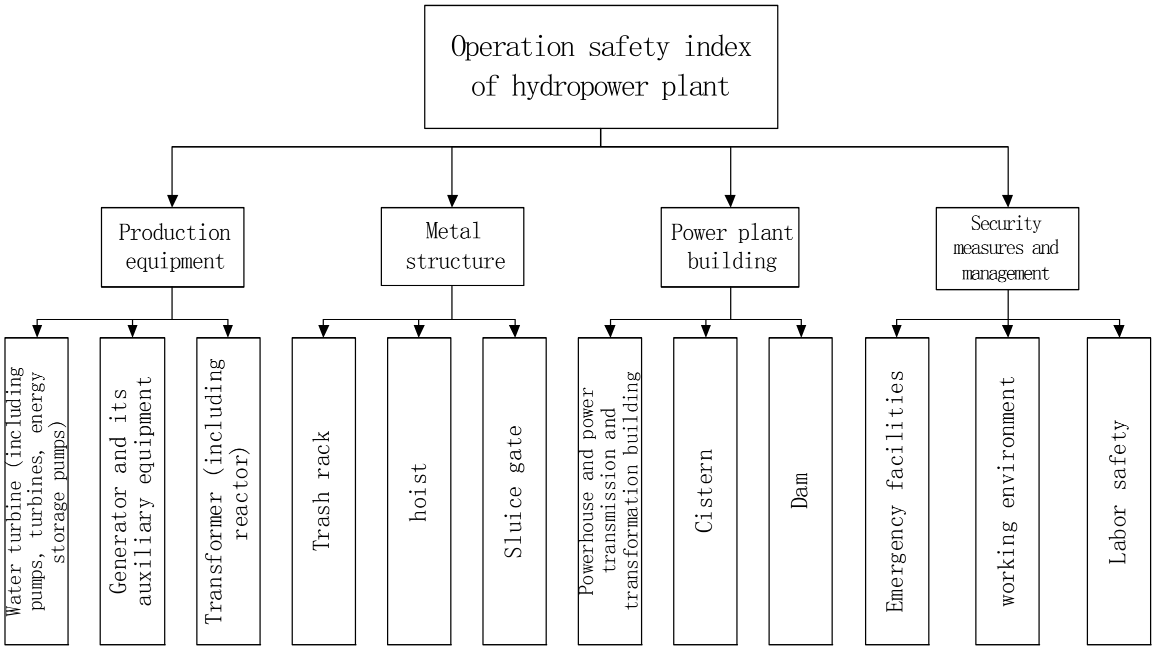

Figure 1.