Emergency Response Capability Evaluation of Power Transmission and Transformation Projects Based on Projection Pursuit Method

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Abstract

To adapt to the rapid development of power transmission and transformation projects, improve their emergency response capability level, and reduce the losses caused by accidents, the projection pursuit method was introduced into the emergency response capability evaluation of power transmission and transformation projects. The emergency response capability evaluation system of power transmission and transformation projects has been established mostly from each composition and structure of power transmission and transformation engineering systems, and highly subjective evaluation methods have been adopted to assess the models established. In this study, a total of 19 concrete indexes were selected from 4 aspects—monitoring and early warning capability, emergency control capability, emergency rescue and disposal capability, and emergency support capability—to establish an emergency response capability evaluation index system of power transmission and transformation projects. Then, an emergency response capability evaluation model for power transmission and transformation projects was constructed based on the projection pursuit model, followed by optimization using real code accelerated genetic algorithm (RAGA); for high-dimensional data, this model could directly find the structure and features of data itself, avoiding the limitations of subjective judgment and contributing to more truthful and reliable evaluation results; finally, this model was used to evaluate and analyze the emergency response capability of six power transmission and transformation projects: GZXS 500kV, JXXY500kV, QHXN 750kV, YNZT 500kV, JSNJ 500kV, and SXXA 750kV. The results show that the six power transmission and transformation projects are different in the emergency response capability level; the emergency response capability level of power transmission and transformation projects is greatly affected by the early warning personnel deployment capability, daily emergency drill capability, emergency technology implementation capability, emergency training and education capability, and risk response capability.

Keywords: Power transmission and transformation projects, emergency response capability, projection pursuit, projection direction; genetic algorithm.

Introduction

Electric power is the primary foundation of national economic and social development and an important condition to support national development strategies [1]. Electric power, which is closely related to social and economic development, has a great bearing on the robust development of the national economy, the steady improvement of people's quality of life, and the maintenance of social security and stability [2]. Under the background of China's rapid economic and social development, the growth rate of power load demand is also accelerating, it is necessary to continuously develop power grids to meet the new power demand, and ensure the high-quality development and construction of power grids is the top priority of power development [3]. As the most important link in power grid construction, power transmission and transformation projects play an indispensable role in building stable power grids and provide the most solid guarantee for economic society and residents' daily electricity consumption [4]. Meanwhile, the smooth progress of production and life is greatly influenced by the emergency response capability of power transmission and transformation projects [5]. Major hazard sources in power transmission and transformation projects mainly refer to the construction operations that may cause major safety accidents, such as mass casualties, which will have an indelible influence on the projects [6]. This paper mainly focuses on the specific analysis of the major hazard sources in the implementation of power transmission and transformation projects, the significance of emergency management, risk identification and classification, and emergency management measures, aiming to continuously elevate the risk management level of major hazard sources and the emergency management level and promote the improvement of projects' economic and social benefits. Specifically, the possible risk factors in the whole implementation process of power transmission and transformation projects were comprehensively figured out using brainstorming method and Delphi method in combination with risk management theories and project risk management practice and experience. Then, the emergency response capability of power transmission and transformation projects was comprehensively assessed based on the projection pursuit method, and a feasible evaluation system was established. Preventive measures should be taken before the occurrence of crises, which should be timely controlled upon occurrence, which can, one the one hand, reduce the unnecessary losses in the project implementation process, and on the other hand, ensure the smooth project completion as scheduled with both theoretical research significance and practical application significance.

Literature Review

The research on emergency management theory in China has a later starter than that in Western developed countries. At first, the research was carried out mainly at the government level, and the research field was relatively single [7]. However, the research has developed very rapidly, and there are now relatively mature emergency evaluation models and index scoring systems. Here are some research results of emergency response capability evaluation in the electric power field. Hasanipanah et al. [8] comprehensively analyzed the four stages (prevention, preparation, response, and recovery) of emergency management of electric power, and used the index decomposition method of "dynamic and static combination" to evaluate power emergencies, which played a certain reference role in the construction of emergency response capability evaluation index systems for electric power enterprises. Ansari, et al. [9] built an emergency response capability evaluation system of power enterprises, used the expert scoring method to score their emergency response capability, and finally calculated the current situation of emergency response capability of each index, which could be referenced, to some extent, in the sub-index evaluation of power enterprises. Ronco et al. [10] established a relatively complete three-level evaluation index system for the emergency response capability of power enterprises, evaluated and scored the indexes by experts through static survey and dynamic evaluation, obtained the evaluation results by using the checklist method, and finally put forward rectification suggestions. Ghose et al. [11] formulated an evaluation index system for the emergency response capability of power supply enterprises in case of large-area power failure of power grids and sudden natural disasters, conducted weight determination and index scoring for the first-level and second-level indexes by using the analytic hierarchy process (AHP) and fuzzy comprehensive evaluation method, calculated the score of the evaluation system, and completed the evaluation work based on the evaluation system. Cui et al. [12]

applied the AHP-variable entropy weight method to organize the evaluation of the emergency repair capacity of distribution networks, which eliminated the subjective factors in determining the index weight by AHP to the maximum extent, made the evaluation results more objective, and satisfied the current situation of emergency response capability more. In addition to AHP [13] as the index calculation method of risk evaluation systems, the evidence theory method [14], association rules analysis method [15], neural network method [16], and Bayesian network classifier [17] have been maturely applied in index evaluation and calculation, but most of these methods have high requirements for the quantity of data or indexes. The evaluation indexes for emergency response capability building are mostly qualitative indexes, which cannot be accurately and quantitatively extracted, resulting in a difficult application. To sum up, despite the rapid development of the evaluation work for emergency response capability building of power systems, the work has a late start in China, the evaluation work for overall emergency response capability building of power enterprises has not been carried out yet, and the emergency response capability evaluation system lacks integrality and systematicness. Hence, establishing a scientific, comprehensive, and feasible emergency response capability evaluation system to guide power supply enterprises to organize and implement the evaluation work of emergency response capability is an important research topic in the development of electric power.

At present, the gap between the evaluation research carried out by Chinese scholars on emergency response capability and that by foreign scholars has been narrowed. Guo H et al. [18] comprehensively evaluated the emergency response capability of construction projects by constructing an index system for monitoring and early warning capability, emergency control capability, emergency rescue capability, emergency support capability, and recovery capability in combination with triangular fuzzy number-based AHP, but AHP failed to consider the interdependence between elements, not conforming to the complex relationships between actual construction projects. Aiming at urban sudden electric power accidents, Zhao et al. [19] established a first-level index system (including monitoring and early warning capability, emergency prevention capability, emergency handling capability, and emergency recovery capability) through such systematic methods as AHP from the cyclic engineering angle of emergency management (prevention, preparation, response, and recovery). Huang et al. [20] used the multi-level fuzzy comprehensive evaluation method to evaluate the emergency response capability of power grid infrastructure in case of unexpected accidents by reference to foreign emergency response capability evaluation standards from four stages: prevention, preparation, response, and recovery. Ma et al. [21] evaluated the emergency management capability of enterprises based on grey clustering analysis from 6 aspects: the planning, organization, leadership, control, communication, and decision-making capabilities of enterprise emergency management. Grynbaum et al. [22] evaluated OS-ERC indexes by combining language trees, fuzzy cognitive maps, and AHP. Lan et al. [23] evaluated the emergency response capability of natural gas pipelines via the multi-level fuzzy comprehensive evaluation matrix. Mukilan et al. [24] established a comprehensive evaluation model for urban emergency response capability by analyzing the fuzzy AHP of influencing factors. Qi et al. [25] comprehensively evaluated the risks of power transmission and transformation projects using the network analysis method based on triangular fuzzy numbers.

By looking up the existing literature, it has been found that abundant research results have been achieved regarding the risk evaluation of power transmission and transformation projects, but their emergency response capability management has been less investigated. Therefore, the emergency response capability evaluation of power transmission and transformation projects was further explored. In the field of engineering projects, the research methods for emergency management capability mainly include particle swarm optimization and artificial neural network [26], entropy-TOPSIS [27], the combination of AHP and fuzzy comprehensive evaluation [28], and network analysis (ANP) [29]. However, when analyzing the safety evaluation models of power transmission and transformation projects, the above methods have not fully considered the index establishment in large-scale complicated engineering projects and the uncertain factors in evaluation. ANP compares every two factors based on "comparison between A and B relative to A" to obtain the weight phasor, but it does not consider the time factor in the independent submatrix, and it will be easily subjected to arbitrary and wrong weight assignment in terms of element set weighting. The evaluation study on emergency management capability has been increasingly mature, while the emergency response capability of power transmission and transformation projects has been insufficiently evaluated. Given this, the projection pursuit method was introduced in this study as the basis for evaluating the emergency response capability of power transmission and transformation projects according to their characteristics. The projection pursuit method, which has developed in recent years, is considered an important theory and method of studying the complex relations between indexes. Considering the fuzziness in the expert-based evaluation of a project, the projection pursuit method was introduced to implement the fuzzy evaluation of emergency response capability so that the evaluation results could be more objective, reasonable, and effective. Furthermore, a projection pursuit method-based emergency response capability evaluation model was established and applied to power transmission and transformation projects, expecting to provide a reference for the future emergency management of power transmission and transformation projects.

Methodology

First of all, the goals of constructing the evaluation index system for the emergency response capability of power transmission and transformation projects were introduced, i.e., implementing the requirements of laws and regulations, finding out the problems and deficiencies in emergency management and emergency technology of power supply enterprises in time, and taking preventive control measures in advance to improve the emergency management capability of power supply enterprises; based on the established evaluation index system, then, an emergency response capability evaluation model based on the projection pursuit model for urban power transmission and transformation projects was established and optimally solved using the accelerated genetic algorithm.

Establishment of the evaluation index system

The emergency evaluation indexes of power transmission and transformation projects are based on the occurrence process of accidents. According to the general theory of emergency management, prevention and preparation should be made before the occurrence of accidents with the moment of occurrence as the center; active response should be made upon the occurrence; efforts should be put into recovery after the occurrence. Emergency management is largely divided into 3 stages: pre-, in-process, and post- (post-treatment is no longer considered since it is under the jurisdiction of companies instead of project departments). In this study, the pre-part was divided into A1 (monitoring and early warning capability) and A2 (emergency control capability); the in-process part was divided into A3 (emergency rescue and disposal capability); the post-part was divided into A4 (emergency support capability). Monitoring and early warning capability: monitoring and early warning are the precondition for the stable implementation of power transmission and transformation projects. Once this occurs, accidents will bring great harm to power transmission and transformation projects. To avoid enormous economic and personnel losses, a monitoring and early warning system must be established to perform real-time dynamic monitoring of power transmission and transformation projects. The monitoring and early warning capability is directly associated with the hazard degree brought by accidents. Monitoring and early warning capability indexes include risk factor prediction capability, hazard source monitoring capability, early warning facility capacity, and communication and liaison capability. Emergency readiness capability: The corresponding preparatory work, if made before the occurrence of accidents, will greatly help reduce the hazard degree of accidents. Hence, sufficient preparations should be made to provide a basis for executing emergency rescue tasks. Emergency control capability indexes include decision-making capability, emergency training and education capability, and daily emergency drill capability. Emergency rescue and disposal capability: Upon the occurrence of accidents is a golden stage for carrying out the rescue work in case of emergencies. In the face of accidents in power transmission and transformation projects, relevant departments should actively organize response and rescue activities, which will be of crucial importance for reducing property losses and casualties and is the key to curbing the further intensification of the event, so the emergency rescue and disposal capability must be strengthened. The emergency rescue and disposal capability indexes include organization and coordination capability, response and action capability, emergency rescue capability, and emergency evacuation capability. Emergency support and control capability: this aspect not only includes emergency personnel but also includes the support of materials and equipment, and the rescue work can be smoothly carried out only when such support is given appropriately. In addition, efforts should also be made to prevent the further intensification of the event and avoid the transmission of false information by news media, or otherwise, negative impacts will be imposed on companies. Emergency support capability indexes include emergency equipment rescue capability, emergency rescue personnel assignment capability, emergency supplies support capability, emergency technology implementation capability, and external publicity and PR capability. Based on the above analysis and through expert survey and looking up relevant literature as well as the field investigation on the characteristics of power transmission and transformation projects, an evaluation index system (including 4 first-level indexes and 19 second-level indexes) for the emergency response capability of power transmission and transformation projects was established, specifically as seen in Table 1.

Table 1: Indexes influencing emergency response capability of power transmission and transformation projects

First-level index	Second-level index
Monitoring and early warning capability	Risk factor early warning capability
	Hazard source monitoring capability
	Early warning personnel assignment capability
	Early warning equipment deployment capability
	Communication and liaison capability
Emergency readiness capability	Decision-making capability
	Emergency training and education capability
	Daily emergency drill capability
Emergency rescue and disposal capability	Organization and coordination capability
	Response and action capability

	Emergency rescue capability
	Emergency evacuation capability
	Hazard response capability
	Emergency rescue whole-process management
Emergency support and control capability	Emergency equipment rescue capability
	Emergency personnel assignment capability
	Emergency supplies support capability
	Emergency technology implementation capability
	External publicity and PR capability

Establishment of the evaluation model based on the projection pursuit method

Based on the established evaluation index system for the emergency response capability of power transmission and transformation projects, a corresponding evaluation model for the emergency response capability of urban power transmission and transformation projects based on the projection pursuit model was established and optimally solved through the accelerated genetic algorithm. This mainly included 4 main aspects of content: standardization of evaluation indexes, construction of project index functions, determination of the optimal projection direction, and calculation, clustering, and ranking of emergency response capability evaluation values.

(1) Index standardization

The initially established evaluation index dataset is set as $\left\{x_{ij}\left|i=1,2,\cdots,n;j=1,2,\cdots,p\right.\right\}$, where x_{ij} is the *j*-th index value of the *i*-th city. To eliminate the deviation brought by different dimensions of index data to the calculation result, the data was normalized as follows in Formula (1):

$$x_{ij}^{*}=\begin{cases}\dfrac{x_{ij}-x_{jmin}}{x_{jmax}-x_{jmin}}, & \textit{Positive indicator}\\[2ex] \dfrac{x_{jmax}-x_{ij}}{x_{jmax}-x_{jmin}}, & \textit{Negative indicator}\end{cases} \quad (1)$$

Where x_{jmax} and x_{jmin} stand for the maximum and minimum values of the *j*-th index, respectively; x_{ij}^{*} is the normalized data of index values.

(2) Construction of projection index functions

The projection pursuit method refers to projecting high-dimensional data into a low-dimensional subspace so that the original data is dispersed into a projection with a meaningful structure, i.e., studying and solving high-dimensional problems by introducing them into low-dimensional space. This method can overcome the defects of traditional research methods, namely, the poor robustness in high-dimensional space, and the original data in actual life can be directly used to seek their internal laws. A projection index function $T(a)$ is constructed, namely, the 27-dimensional data in the established emergency response capability evaluation index system of power transmission and transformation projects are projected along the projection direction of $a=\{a(1),a(2),\cdots,a(j),\cdots,a(p)\}$ to obtain one-dimensional projection values, thus acquiring the needed evaluation value Z_i for the emergency response capability, as seen in Formula (2):

$$Z_i = \sum_{j=1}^{p} a(j) \cdot x_{ij}^*, i = 1, 2, \cdots, n \quad (2)$$

So that the solved projection values Z_i present a locally dense but overall dispersed distribution, S_Z is set as the standard deviation of the projection value Z_i and D_Z as the local density of Z_i, and thus $T(a)$ can be expressed as follows:

$$T(a) = S_Z \cdot D_Z \quad (3)$$

$$S_Z = \sqrt{\sum_{i=1}^{n} (z_i - E_z)^2 / (n-1)} \quad (4)$$

$$D_Z = \sum_{i=1}^{n} \sum_{k=1}^{n} (R - r_{ik}) \cdot U(R - r_{ik}) \quad (5)$$

Where E_z is the average projection value of the sequence $\{Z_i \quad i = 1, 2, 3, \cdots, n\}$; R stands for the window radius of local density, generally taken as $0.1S_Z$; $r_{ik} = Z_i - Z_k$ is the distance between samples; $U(R - r_{ik})$ represents the unit step function.

(3) Determination of the optimal projection direction

Finding the best projection direction is the key to solving practical problems by projection pursuit, and the best projection direction can be solved by maximizing the projection index function, namely:

$$\max Q(a) = S_z \cdot D_z \quad (6)$$

$$s.t. \sum_{j=1}^{p} a(j)^2 = 1 \quad (7)$$

It is extremely difficult to solve the optimal projection direction, and genetic algorithm applies to mathematical models with multiple complex constraints. In this study, the best projection direction was optimally solved via genetic algorithm. Since the accuracy of the standard genetic algorithm will be restricted by the string length, higher accuracy can only be achieved by increasing the string length, and premature convergence may occur. As for the accelerated genetic algorithm, the genetic operations are parallelly implemented in the solving process, which can greatly shorten the evolution time, and the search space can be continuously optimized by keeping outstanding individuals so that the search scope is more comprehensive. Furthermore, better solutions can be chosen to harvest global optimization and solve the optimal projection direction a^*.

(4) Calculation, clustering, and ranking of emergency response capability evaluation values of power transmission and transformation projects

Based on the solved optimal projection direction a^* and normalized data, the optimal projection value Z_i of the emergency response capability of each power transmission and transformation project is solved through Formula (2), which is rightly the final evaluation value of the emergency response capability. Then, the hierarchical clustering analysis was implemented according to the obtained Z_i, and the difference between power transmission and transformation projects in the emergency response capability level was predicted using Euclidean distance and the sum of squares of deviations. Therein, the Euclidean distance represents the actual distance between two points in 2D and 3D spaces, d_{ij} indicates the distance between the *i*-th sample and *j*-th sample, and then the Euclidean distance is expressed by Formula (8):

$$d_{ij} = \left[\sum_{k=1}^{p} (x_{ik} - x_{jk})^2 \right]^{\frac{1}{2}} \quad (8)$$

The algorithms used to solve the local optimum problem are mature, among which a classical one is the Ward sum of squares of deviations. *N* samples are *k* classes $G_1, G_2, \cdots, G_t, \cdots, G_k$, x_{it} denotes the *i*-th sample in class G_t, n_t represents the number of samples in class G_t, x_t stands for the gravity of class G_t, and the sum of squares of deviations L_t of samples in class G_t is calculated as follows:

$$L_t = \sum_{i=1}^{n_t} (x_{it} - \bar{x}_t)^{'} (x_{it} - \bar{x}_t) \quad (9)$$

The quadratic sum L within the whole class is:

$$L = \sum_{i=1}^{k} \sum_{i=1}^{n_t} (x_{it} - \bar{x}_t)^{'} (x_{it} - \bar{x}_t) \quad (10)$$

If classes G_p and G_q are merged into G_r, the recursive formula for the distance between G_k and new class G_r is:

$$D_w^2(k,r) = \frac{n_p + n_k}{n_r + n_k} D_w^2(k,p) + \frac{n_q + n_q}{n_r + n_k} D_w^2(k,p) - \frac{n_k}{n_r + n_k} D_w^2(p,q) \quad (11)$$

The Euclidean distance and the sum of squares of deviations were used to classify the emergency response capability level of power transmission and transformation projects. Moreover, Z_i of each sample was compared via SPSS software, and the closer the values, the higher the tendency for the samples to be classified into one class.

Result Analysis and Discussion

Research objects and data sources

The objects of this study were GZXS 500kV, JXXY500kV, QHXN 750kV, YNZT 500kV, JSNJ 500kV, and SXXA 750kV power transmission and transformation projects. In this study, the emergency response capability of the 500 kV-750 kV high-voltage power transmission and transformation projects during construction and operation was evaluated, and the composition of the comprehensive emergency response capability evaluation index system of power transmission and transformation projects and the relationships manifested therein were studied. Next, the comprehensive emergency response capability of the power transmission and transformation projects was reasonably evaluated, and their advantages and disadvantages in the response to emergencies were figured out. In this way, the corresponding measures can be taken, which is very important for strengthening the sustainable development strategies for China's power transmission and transformation cause.

Best projection direction

The best projection direction was solved by programming in MATLAB2014B according to the model established in this study, the maximum projection index value was 4.13 (the maximum value solved by the objective function), and the projection direction in this case was rightly the best projection direction, which could reflect the structural features of high-dimensional data to the greatest extent. In addition, the weight of each index was the square of the components corresponding to the best projection direction, as seen in Table 2. It is known from Table 2 that the best projection direction of monitoring and early warning capability, emergency readiness capability, emergency rescue and disposal capability, and emergency support and control capability was 0.9503, 0.7315, 1.2025, and 1.2457, respectively, and their weights were 0.2301, 0.1771, 0.2912, and 0.3016, respectively. From the best projection directions and their weights, it could be seen that the emergency support and control capability had the greatest influence on the resilience of urban waterlogging disasters, and the emergency readiness capability had the least influence. The emergency rescue and disposal capability played a key role in improving the emergency response capability of power transmission and transformation projects. The minimum weight of emergency readiness capability revealed the insufficient emergency response capability of power transmission and transformation projects, and efforts should be made to enhance the risk resistance capacity of power transmission and transformation projects concerning the improvement of emergency readiness capability. Given this, it is more necessary to grasp key points, improve weak links, and strengthen the monitoring and early warning capability, and emergency readiness capability of power transmission and transformation projects. The best projection direction could embody the relative importance of each evaluation index to the finally evaluated resilience value, and this rule prevailed for both positive and negative indexes. Among the 19 evaluation indexes, those ranking top 5 were early warning personnel assignment capability, daily emergency drill capability, emergency technology implementation technology, emergency training and education capability, and risk response capability.

Table 2: Best projection direction and weight of indicators

First-level index	Second-level index	Best projection direction	weight
Monitoring and early warning capability	Risk factor early warning capability	0.2511	0.0631
	Hazard source monitoring capability	0.2035	0.0414
	Early warning personnel assignment capability	0.3304	0.1092
	Early warning equipment deployment capability	0.0919	0.0084
	Communication and liaison capability	0.0733	0.0054
Emergency readiness capability	Decision-making capability	0.1169	0.0137
	Emergency training and education capability	0.2973	0.0884
	Daily emergency drill capability	0.3172	0.1006
Emergency rescue and disposal capability	Organization and coordination capability	0.1883	0.0355
	Response and action capability	0.1589	0.0253
	Emergency rescue capability	0.1968	0.0387
	Emergency evacuation capability	0.2055	0.0423
	Hazard response capability	0.2744	0.0753
	Emergency rescue whole-process management	0.1786	0.0319
Emergency support and control capability	Emergency equipment rescue capability	0.2604	0.0678
	Emergency personnel assignment capability	0.2685	0.0721
	Emergency supplies support capability	0.1623	0.0263
	Emergency technology implementation capability	0.2992	0.0895
	External publicity and PR capability	0.2553	0.0652

The evaluation value for the emergency response capability of each power transmission and transformation project could be acquired by substituting the solved best projection direction a^* into Formula (2). This evaluation value reflects the emergency response capability of power transmission and transformation projects in resisting emergency risks. The emergency response capability evaluation can efficiently position the weak regions and weak links influencing the emergency response capability of power transmission and transformation projects to design pertinent improvement strategies. The calculation results are listed in Table 3.

Table 3: Evaluation results for emergency response capability of power transmission and transformation projects

Power transmission and transformation project	Monitoring and early warning capability	Ranking	Emergency readiness capability	Ranking	Emergency rescue and disposal capability	Ranking	Emergency support and control capability	Ranking
GZXS	0.4462	3	0.4987	1	0.4661	1	0.2765	5
JXXY	0.5549	2	0.4721	3	0.4613	3	0.4509	3
QHXN	0.2207	5	0.3244	5	0.4648	2	0.5035	2
YNZT	0.1948	6	0.2102	6	0.3812	4	0.0909	6
JSNJ	0.2897	4	0.4983	2	0.3462	5	0.5474	1
SXXA	0.5678	1	0.3617	4	0.2980	6	0.3985	4

It could be observed from Table 3 that among the six power transmission and transformation projects (GZXS, JXXY, QHXN, YNZT, JSNJ, and SXXA), the SXXA power transmission and transformation project reached the highest evaluation value of monitoring and early warning capability. The emergency readiness capability and emergency rescue and disposal capability of the GZXS power transmission and transformation project ranked first, its monitoring and early warning capability ranked third, and the emergency response capability level of GZXS was the highest. JSNJ achieved the highest evaluation value of emergency support and control capability, and the emergency readiness capability of JSNJ ranked second, with a high overall evaluation level; YNZT ranked the lowest in monitoring and early warning capability, emergency readiness capability and emergency support and control capability, and ranked the fourth in emergency rescue and disposal capability. Therefore, YNZT exhibited the lowest emergency response capability level, which was ascribed to its low monitoring and early warning capability, emergency readiness capability, emergency rescue and disposal capability, and emergency support and control capability. And YNZT project is located in the southwest of China, with plateaus and mountains as dominant terrains, relatively incomplete infrastructure, and relatively slow economic development, which led to its relatively low emergency response capability. Given this, the emergency response capability of this power transmission and transformation project may be improved by appropriately increasing the equipment input, enhancing the risk awareness of managerial staff, and perfecting the infrastructure construction.

Result analysis

According to the analysis results, it could be seen that the priority of the evaluation indexes for the emergency response capability of power transmission and transformation projects was as follows: early warning personnel assignment capability, daily emergency drill capability, emergency technology implementation capability, emergency training and education capability, emergency response capability, emergency personnel assignment capability, emergency equipment rescue capability, external publicity and PR capability, risk factor early warning capability, emergency evacuation capability, hazard source monitoring capability, emergency rescue capability, organization and coordination capability, emergency rescue whole-process management capability, emergency supplies support capability, response and action capability, decision-making capability, early warning equipment deployment capability, and communication and liaison capability. After evaluating the emergency response capability of the six power transmission and transformation projects (GZXS 500kV, JXXY500kV, QHXN 750kV, YNZT 500kV, JSNJ 500kV, and SXXA 750kV), it was known that GZXS and JXXY projects obtained the highest scores, belonging to an outstanding level, but there were still weak deficiencies; QHXN and JSNJ projects obtained moderate scores, belonging to a medium level; YNZT and SXXA projects obtained relatively low scores, belonging to a relatively poor level; according to the projection pursuit method, the emergency response capability evaluation indexes showed interdependency and mutual influence, so the whole evaluation plan for emergency response capability should be mastered in addition to the establishment of single indexes. In this way, crises can be responded to calmly, lowering the hazard to the lowest level. Of course, the advantages of the emergency response capability evaluation indexes for power transmission and transformation projects were discussed using the projection pursuit method only from an overall perspective, while no contingency plans specific to crises were proposed. During the construction and operation of power transmission and transformation projects, special emergency management teams should be established to strengthen management, continuously perfect the management system, strengthen the mutual coordination and cooperation between departments, and ensure the smooth implementation of power transmission and transformation projects. Specific to the abovementioned possible crises, detailed contingency plans should be made and updated in a real-time fashion, avoiding change in the situation of the event, which will result in unpreparedness. Daily emergency training and education, assessment, and drills should be done well and the reliability of emergency equipment should be checked regularly. The contingency plans can be further improved on the premise of sufficient preparations.

Conclusion

In this study, the projection pursuit method was introduced into the emergency response capability evaluation of power transmission and transformation projects, an emergency response capability evaluation index system for such projects was constructed, and a new projection pursuit model was introduced and optimally solved using real code accelerated genetic algorithm (RAGA). Then, an emergency response capability evaluation model of power transmission and transformation projects based on the projection pursuit method was established. This model can study and solve high-dimensional problems by introducing them into low-dimensional space according to the most original index data, avoiding the limitations of subjective judgment, contributing to more objective and reliable evaluation results, and providing a new idea for the emergency response capability evaluation of power transmission and transformation projects with high-dimensional data. Furthermore, the main factors influencing the emergency response capability of power transmission and transformation projects were figured out, the emphasis was laid on the indexes with high degrees of membership, and their mutual relations were strengthened. This study can be referenced for future similar power transmission and transformation projects to make emergency preparations and improve their emergency management level.

The best projection directions were solved according to the general emergency theories and the actual situation of each power transmission and transformation project. Moreover, the generalized structure of projection pursuit and the weight calculation method were made full use of, proving its feasibility in the evaluation of power transmission and transformation projects. It is concluded that the emergency response capability of power transmission and transformation projects can be improved by strengthening their early warning personnel assignment capability, daily emergency drill capability, emergency technology implementation capability, emergency training and education capability, and risk response capability.

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