Research of Capability Evaluation for Emergency Response and Risk Management on Urban Blackout Accidents

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Abstract. In order to evaluate accurately and reasonably the capability of emergency response and risk management aganist urban blackout accidents, this paper builds an evaluation model based on evaluation entropy weight method (EWM) and Pythagoras fuzzy set method. The elements of emergency response and risk management capability are analyzed on the basic of 20 blackout accidents and the evaluation indexes are selected. The EWM & Pythagoras fuzzy sets method is used to determine the index weight, and the evaluation results of emergency capacity and disposal capacity are calculated according to the expert evaluation results. A power supply company is selected as the evaluation object. The evaluation model can objectively and accurately reflect the overall capability of emergency response and risk management on urban blackout accidents. This paper provides theoretical support for improving the emergency response capacity aganist the urban blackout accidents.

Keywords: urban blackout accidnet; EWM & Pythagorean fuzzy sets method; emergency response; risk management

1 Introduction

Electricity is a fundamental energy industry for a country and plays a crucial role in urban economic development and daily life[1]. Once a power supply interruption occurs, it will have a huge impact on society, economic order, and the lives of the people[2]. In recent years, various sudden disasters have posed a huge threat to urban power supply and social public safety[3], easily triggering urban blackout accidents and disrupting normal production and social order[4-6].

As an essential part of the response process to urban blackout accidents, the risk management and emergency capabilities of the power industry are related to whether urban blackout accidents can be resolved in a timely and effective manner. Risk management and emergency capacity evaluation are conducive to identifying weak links in emergency capacity construction, and thus targeted improvement and improvement can be carried out[7]. Indicator selection is the key to emergency capability evaluation. Cai D *et al*[8] proposed an indicator system for evaluating the emergency capability of power grids, including 5 first level indicators and 13

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second level indicators; Wang D *et al*[9] split the emergency capacity of the power grid based on the temporal and spatial dimensions of emergency management, and obtained an emergency capacity evaluation index system; Liang T *et al*[10] evaluated the emergency capability of distribution network engineering from four aspects: emergency prevention, preparedness, response, and recovery. The above research can provide more accurate and reasonable evaluation results, but the selection of indicators can be further refined based on actual event response measures. The selection of calculation models is also an important part of emergency capability evaluation, and the Analytic Hierarchy Process (AHP) is widely adopted due to its simplicity and clarity [11-13]. Sun H[14], Zhang C *et al*[15], and Men Y *et al*[16] used a combination of Analytic Hierarchy Process and Fuzzy Comprehensive Evaluation to evaluate the emergency capacity of power grid enterprises. However, the Analytic Hierarchy Process (AHP) cannot effectively reflect subjective factors in the evaluation process, and it is necessary to seek appropriate methods to reduce the lack of information in the process of calculating indicator weights based on evaluation results. The impact of urban blackout accidents is wide, involving multiple departments, and the response steps are complex. It is necessary to choose a suitable calculation model to ensure the accuracy and reliability of the results. Pythagoras Fuzzy set method considers both membership and non membership, which can better solve problems such as incomplete and imprecise information in practical problems[17]. The response to urban blackout accident involves many factors, such as emergency preparedness, handling capacity, department coordination, logistics support, etc. This paper presents an evaluation model for the emergency response capability of urban blackout accidents based on entropy weight method Pythagoras Fuzzy set, which refines the response steps one by one to obtain the response elements and selects evaluation indicators accordingly. The research in this paper provides theoretical support for improving the ability of power grid enterprises to respond to urban blackout accidents.

2 Evaluation model for capability of emergency response and risk management aganist urban blackout accidents

Entropy Weight Method (EWM) is a commonly used weighting method that measures value dispersion in decision-making. The greater the degree of dispersion, the greater the degree of differentiation, and more information can be derived. Meanwhile, Pythagoras Fuzzy set is h is developed based on intuitionistic fuzzy set, which is more efficient in elaborating and disposing uncertainties in indeterminate situations. In this paper, The evaluation model for capability of emergency response and risk management aganist urban blackout accidents is built on the basic of EWM & Pythagoras Fuzzy set, as shown in Figure 1. Firstly, collect relevant information on urban blackout accidents, twenty cases of blackout events were selected and anaylzed, as shown in Table 1. Analyze the response measures for urban blackout accidents, and extract the response capability elements of each step as the basis for selecting evaluation indicators.

Secondly, for the evaluation index system, based on the relevant theories of emergency management[18] and the emergency response process for urban blackout accidents, this paper selects the first level indicators as emergency prevention, emergency preparedness, emergency response, and post recovery. The second and third level indicators are determined based on the response elements for urban blackout accidents. The selection of evaluation indicators should follow the principles of representativeness, independence, evaluability, and differentiation[19] to ensure that the evaluation indicators can objectively reflect the emergency response capacity of urban blackout accidents.

The impact of each evaluation index on the response ability to urban blackout accidents is different. First, the entropy weight method Pythagoras Fuzzy set method is used to determine the weight of each index on the basis of expert evaluation. Finally, for the emergency capability of urban blackout accidents, the evaluation grade is fuzzified, experts are invited to score each three-level index item, and the evaluation result is obtained by using the fuzzy calculation method. Finally, the fuzzy result is de fuzzified to obtain the final accurate result.

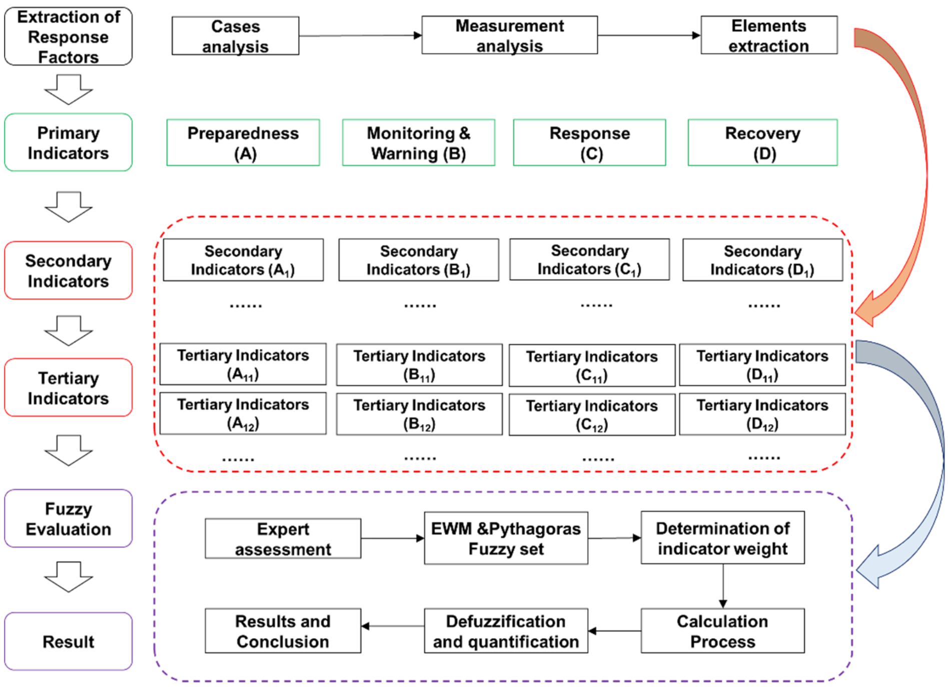

Fig.1. Evaluation model for emergency response capability based on EWM & Pythagorean fuzzy sets

Table 1. Case list of urban blackout accident

	Blackout location	People affected (million)	Year
1	Southern Brazil	97	1999
2	India	230	2001
3	Luzon	35	2001
4	Luzon	40	2002
5	Italy	56	2003
6	Java–Bali	100	2005
7	Southern China	100	2008
8	Brazil and Paraguay	60	2009
9	India	620	2012
10	Bangladesh	150	2014
11	Pakistan	140	2015

12	Turkey	70	2015
13	Sri Lanka blackout	21	2016
14	Java	120	2019
15	Argentina, Paraguay and Uruguay	48	2019
16	Venezuelan blackouts	30	2019
17	Sri Lankan blackouts	21	2020
18	Pakistan	200	2021
19	Bangladesh	140	2022
20	Pakistan	230	2023

3 Result and Discussion

In this paper, a city in south-east China was taken as an example, the capability evaluation for emergency response and risk management aganist urban blackout accident were carried out. Based on relevant documents such as emergency plans, emergency drill records, and accident handling records, the response measures of the power industry after a blackout event were refined. Then, response elements were extracted. Overall, response measures are divided into preparedness, monitoring & warning, response and recovery. Element of response measures were analyzed. As an example, the elements of measures within monitoring & warning are shown in Table 2. The measures are divided into risk monitoring and assessment, early warning release, and early warning actions. The measures are refined into various response steps, as shown in columns 2 and 3 of Table 2.

Based on the analysis of elements, 4 primary indicators, 12 secondary indicators and 45 tertiary indicators were obtained, as shown in Table 3. The emergency response team, material preparedness, information submission, and relevant plan revisions, work mechanisms, and recovery measures in each response step are all reflected in the " Preparedness (A) " and " Recovery (D)" series of indicators, and are no longer listed in the " Monitoring & Warning (B)" and "Response (C)".

Table 2. Analysis of response steps and elements (monitoring & warning)

Measures	Elements
(1) Monitor and analyze the status of operating equipment	(1) Accuracy of equipment risk monitoring
(2) Monitoring and risk assessment of electricity consumption risks for important users	(2) Accurate monitoring of electricity risk for important users
(3.1) Arrange the operation mode of power grid, conduct risk assessment of power grid operation, monitoring of special operation modes, and professional management of power grid security control (3.2) Balance power grid load, timely grasp the power production and supply situation, and analyze the impact on substations and lines	(3) Accuracy of power grid operation risk monitoring
(4.1) Conduct targeted equipment inspections; Organize the emergency team to gather the repair team in advance and be on standby to ensure that they can depart within 1 hour after receiving the repair instructions.	(4.1) Duty system

Measures	Elements
(4.2) Properly allocate emergency equipment for power supply, and maintain spare parts, communication and communication tools, and accident handling tools related to various emergency repairs in good condition.	(4.2) Allocation of power emergency equipment, special inspection and protection of key support equipment
(5.1) Check that the backup scheduling system is operating normally; Check whether the remote control function of the control duty site is intact and available, and notify the automation duty personnel to do a good job in system security work; Check the configuration of emergency communication means such as Satellite phone.	(5.1) Operation of backup power grid dispatch system and communication system
(5.2) Collect information on power grid operation, power generation, and coal supply, and promptly report to the company's large-scale power outage emergency leading group. At the same time, report to the leaders in charge and try to postpone the planned power outage maintenance work in the relevant areas as much as possible, ensuring the full connection and protection operation of the power grid as much as possible	(5.2) Timely update of power grid operation plan
(6) Sort out and count potential lifeline engineering users, important and key support users, and large and medium-sized residential areas that may be affected.	(6) Important users information
(7.1) Verify emergency material inventory information	(7.1) Emergency supplies preparation
(7.2) Prepare in advance for emergency support, catering, accommodation, and medical preparations for the repair of electricity and logistics	(7.2) Emergency support catering, accommodation, and medical preparation

Table 3 Evaluation index and weight

Primary Indicators	Weight	Secondary Indicators	Weight	Tertiary Indicators	Weight
Preparedness (A)	0.145	Emergency plan (A_1)	0.253	Special plan, departmental support plan, and onsite handling plan (A_{11})	0.333
				Mechanism related to emergency (A_{12})	0.322
				Training and Exercise (A_{13})	0.345
		Emergency team (A_2)	0.255	Team Organization (A_{21})	0.425
				Skills and Rapid Response Ability (A_{22})	0.575
		Emergency supplies (A_3)	0.258	Allocation of emergency power car (A_{31})	0.323
				Reserve, transportation, and management of emergency equipment and spare parts (A_{32})	0.366
				Reserve, transport and management of transportation vehicles, medical supplies, daily necessities (A_{33})	0.311
		Communication (A_4)	0.234	Timeliness and completeness of information submission (a_{41})	0.505

Primary Indicators	Weight	Secondary Indicators	Weight	Tertiary Indicators	Weight
				Information submission channels and methods (A_{42})	0.495
Monitoring & Warning (B)	0.325	Risk Monitoring and Analysis (B_1)	0.357	Accuracy of equipment risk monitoring (B_{11})	0.333
				Accuracy of electricity risk Monitoring for important users (B_{12})	0.333
				Accuracy of power grid operation Risk Monitoring (B_{13})	0.334
		Warning Release (B_2)	0272	Communication system reliability (B_{21})	1.000
		Measures (B_3)	0.371	Emergency duty system and inventory update (B_{31})	0.008
				Implementation and supervision of risk warning and control measures for power grid operation (B_{32})	0.014
				Special inspection and protection of key support equipment (B_{33})	0.016
				Operation status of backup dispatch system and communication system (B_{34})	0.012
				Power grid operation plan updated in time (B_{35})	0.014
				Important Users Information (B_{36})	0.009
				Important Users Communication (B_{37})	0.010
				Public opinion monitoring and information release preparation (B_{38})	0.008
				Mechanism of Liaison and Consultation (B_{39})	0.009
Response (C)	0.395	Early disposal (C_1)	0.335	Establish an emergency command center to organize and carry out emergency rescue (C_{11})	0.241
				Collection of user electricity demand and sensitive demands (C_{12})	0.243
				Organize experts to guide on-site work (C_{13})	0.255
				Adjustment of power grid operation mode & ensure power supply for users (C_{14})	0.261
		Emergency repair (C_2)	0.374	Safety supervision (C_{21})	0.011
				Equipment inspection and on-site repair (C_{22})	0.015
				Emergency Electricity and	0.014

Primary Indicators	Weight	Secondary Indicators	Weight	Tertiary Indicators	Weight
				Lighting (C_{23})	
				Maintenance follow-up and important user comfort (C_{24})	0.010
				Fault Equipment Isolation (C_{25})	0.012
				Organize parallel resumption of power transmission work between the main and regional power grids (C_{26})	0.012
				Main and backup dispatchers on synchronous duty, switching if necessary (C_{27})	0.012
				Logistics support work at each emergency repair station (C_{28})	0.014
		Linkage and collaboration (C_3)	0.291	Collaborates with other emergency forces (C_{31})	0.255
				Information exchange and communication (C_{32})	0.248
				Materials supply (C_{33})	0.252
				News Promotion (C_{34})	0.244
Recovery (D)	0.135	Accident Investigation (D_1)	0.482	Accident Investigation Procedure (D_{11})	1.000
		Aftermath and recovery (D_2)	0.518	Emergency Response Summary and Evaluation (D_{21})	0.487
				Rectification and improvement (D_{22})	0.513

4 Conclusion Remarks

This paper proposes an evaluation model for the emergency capability of urban blackout accidents, which establishes an evaluation index system from the perspectives of emergency preparedness, monitoring & warning, response, and recovery. Measures for urban blackout accidents are analyzed, the elements are extracted, and evaluation indicators are determined. EWM & Pythagoras Fuzzy set method is introduced to determine the weight of indicators, which improves the tolerance for uncertain information and makes the evaluation more objective and comprehensive. In urban blackout accidents, the power industry, as a part of event handling, undertakes the task of power restoration in risk managment and social emergency rescue. Otherwise, this paper has not further refined the specific steps of government enterprise linkage and departmental collaboration. In future research, it is necessary to analyze the coordination and cooperation between the power industry and social emergency forces, study the steps and elements of response measures, and evaluate the emergency response capacity for urban blackout accidents more comprehensively, reasonably, and accurately.

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