Research on optimization and enhancement strategy of disaster prevention and mitigation management for power grid equipment to cope with extreme weather

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Abstract. In recent years, China has experienced frequent extreme weather events such as heavy rainstorms, typhoons, and freezing temperatures, which have caused significant damage to the power grid equipment and directly impacted the safe and stable operation of the electricity network. Power grid equipment, as the essential physical components of the power grid system, possesses characteristics such as wide coverage and the ability to traverse complex environments. The majority of power equipment is directly exposed to the external environment and is greatly affected by climate change. Implementing effective disaster prevention and mitigation management for power grid equipment is of significant importance for the development of power grid companies as well as the economy and society as a whole.

Keywords: Disaster, Weather, Equipment, Management, System

1 Introduction

Currently, China's economic construction and power industry are still in a period of rapid development. The power industry has entered a stage of large-scale power grid, large-scale units, high voltage, and high automation. The national interconnected grid pattern has basically formed. The complexity of the power system has significantly increased, and the characteristics of safe operation have become increasingly complex. The evolving power system is more susceptible to damage from various disasters. China is also prone to frequent occurrence of various natural disasters, which cause significant damage to the power system. Due to their inherent characteristics, a significant portion of power grid equipment operates in remote and wilderness areas, making them vulnerable to the impact of natural disasters[1]. Once they encounter severe natural disasters such as floods, mudslides, blizzards, and earthquakes, it can easily trigger a chain reaction leading to the collapse of the power grid system, causing widespread power outages and having a significant impact on people's production and daily lives.

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2 The concept of disaster prevention and reduction in power grid enterprises

2.1 Concept of disaster prevention and mitigation of power grid enterprises

Disaster prevention and mitigation in power grid enterprises refers to the prevention of natural disasters and the adoption of measures to minimize the loss and harm to power grid facilities and equipment, ensuring the safety of national assets and the lives and properties of the people. It is an integral component of societal public safety[2].

2.2 The main aspects involved in power grid disaster prevention and reduction include

From the cases of serious power failures in domestic and international contexts in the past, it can be seen that a significant proportion of these failures were triggered by natural disasters such as floods and hailstorms. These disasters caused problems in the power system, leading to the inability to transmit electricity. According to a questionnaire survey and statistical analysis conducted by the State Grid Electric Power Research Institute on 10 provincial-level power grid companies, the main natural disasters that can cause serious damage to the power grid are typhoons, heavy rainfall, floods, lightning strikes, earthquakes, ice coating, and natural or human-caused wildfires (Shows in table 1).

Table 1. Statistics on the impact of different types of natural Disasters on China's power grid

Impact of Natural Disasters on the Power Grid	Percentage (%)						
	Heavy rainfall	Ice coating	lightnig strikes	typhoons	wildfires	floods	earthquakes
Increased occurrence of transient faults in transmission lines	20	30	80	20	40	0	20
Increased occurrence of permanent faults in transmission lines	30	70	20	40	40	20	0
Other forms of permanent faults in the lines	10	20	20	0	10	0	20
Damage to substation equipment	0	10	30	20	0	10	30
Toppling or breakage of transmission lines	0	80	10	30	0	20	20

Bulk tripping of transmission lines	20	70	40	50	20	0	30
Line section dropouts in transmission lines	0	40	10	10	0	0	20
Loss of load	20	80	10	40	30	10	20
System islanding operation	0	50	0	20	10	0	20
Full shutdown of power plants	10	40	10	20	10	10	20
Wide-scale power outage in the system	0	20	0	10	0	0	20
Disruption of SCADA/EMS operation	0	20	0	10	0	0	30
Communication infrastructure damage	10	80	40	40	10	10	20
Communication paralysis	0	10	0	0	0	0	30

3 Strategies for optimizing and enhancing disaster prevention and mitigation management in power grid enterprises.

3.1 Enhancing the intrinsic safety level of equipment

Enhancing the resilience of the power grid equipment and facilities is a fundamental measure for preventing extreme weather hazards. It is necessary to deepen the elimination of risks leading to complete shutdowns of substations, inspect historical submerged substations, repair flood-resistant walls, reinforce drainage facilities, improve the construction standards for flood protection in newly-built substations, and implement the construction of third-party power supply sources for substations[3]. Conducting stability tests of power grid equipment under extreme operating conditions to assess their capability to withstand such conditions. Installing disaster monitoring devices on critical equipment to enhance the situational awareness capability of the power grid. Accelerate the promotion of full coverage of distribution automation to achieve rapid isolation and restoration of distribution network faults.

3.2 Strengthen operations and maintenance management with meticulous precision

First, conduct inspections on key equipment. Strengthen comprehensive operational and maintenance management of equipment, conduct differentiated inspections, and focus on investigating waterlogging in urban low-lying areas, underground spaces, flood discharge areas, and embankment areas to identify and eliminate deficiencies and hidden risks in power facilities[4]. Conduct geological hazard investigation for power facilities located near hillsides, slopes, and river channels. Timely eliminate any defects or hazards identified.

Second, ensure the protection of power facilities. Identify trees, buildings, structures, and temporary facilities that may pose risks to the safety of power facilities. Report the inspection results to the local government's electricity management department promptly and coordinate with relevant government departments to carry out necessary rectification measures[5].

Third, implement disaster prevention and mitigation organization and mobilization. Prepare contingency plans, reserve necessary supplies, maintain comprehensive records and documentation, conduct emergency drills, and ensure communication support. Strengthen the management of emergency systems and conduct comprehensive self-inspections on disaster prevention and mitigation efforts. Address any identified issues within the specified timeframe.

3.3 Enhance disaster prevention and mitigation efforts assurance

First, enhance the guarantee of the disaster prevention and mitigation personnel team. The State Grid should follow the principle of "combining peace and war, quick response" to establish and improve the repair personnel team, ensuring that they are professional, skilled, well-equipped, and able to respond quickly. It is also important to strengthen the collaborative contact mechanism with social repair resources and improve the emergency handling capabilities during disasters. Make full use of the emergency rescue teams in power transmission and transformation and maintenance companies, and establish emergency repair teams in various cities. These teams can be further divided into several sub-teams, such as transformer emergency repair teams, transmission emergency repair teams, and distribution emergency repair teams, to ensure prompt equipment and facility repairs and quickly restore power grid operations and electricity supply. Meanwhile, during normal times, organize teams to conduct comprehensive exercises and specialized drills based on the principles of "real operation, real effectiveness," comprehensively test the command and disposal capabilities, information transmission, and on-site coordination of the emergency command system at all levels, improve the practical combat level, and achieve the goal of practicing through exercises and improving combat capabilities. Further improve the expert team, establish emergency expert teams composed of headquarters, provincial companies, electric power research institutes, economic research institutes, etc., and improve the expert work mechanism to leverage expert support.

Second, increase targeted funding for disaster prevention and mitigation. In order to enhance the disaster prevention and mitigation capabilities of equipment and facilities, implement various disaster prevention and mitigation measures, ensure power grid safety, and minimize property losses, environmental damage, and social impacts, it is necessary to increase funding in relevant areas. Regarding equipment upgrades and renovations, with a focus on improving the standards and capabilities of equipment and facility disaster prevention, it is important to break the cycle of constant repairs and replacements through increased dedicated investments. Allocating funds specifically for improving the disaster prevention and mitigation capabilities of equipment is essential in order to identify areas that require improvement, conduct comprehensive assessments, and carry out necessary transformations to significantly enhance disaster prevention and mitigation abilities. For new construction projects, it is important to conduct differentiated designs based on the analysis of different regions and climates, increase initial investments, improve the quality of equipment installation, and strengthen capabilities to respond to extreme weather conditions. Increasing funding for emergency equipment is also crucial, including electrical specialty equipment such as general tools, specialized installation and maintenance tools, and testing equipment, as well as transportation and lifting equipment such as repair vehicles, transport vehicles, and cranes, large-scale drainage equipment, and power generation and lighting equipment. This will help teams efficiently and rapidly repair damaged facilities, restore power supply, and ensure that emergency-related funding is properly allocated to support regular emergency training, drills, and overall improvement of team skills and professional capabilities.

Third, handle public opinion in disaster prevention and mitigation effectively. The fundamental role of power grid enterprises in the national economy and social life, as well as the inherent natural monopoly of their products and services, necessitate the management of complex public relationships and public opinion supervision. Before and after a disaster, each department must accurately assess the warning information related to the disaster based on their responsibilities, propose warning suggestions, have them approved by the company, and then release warning notices of different levels through the relevant departments. The work of warning actions should be conducted in accordance with the principle of graded responsibilities, including consultations, analysis, and evaluations. It is important to cooperate in news publicity and public opinion guidance. Additionally, based on the development and handling of the disaster, timely suggestions for adjusting the warning levels should be provided until the warnings are lifted. Simultaneously, in the event of a disaster, monitoring and early warning for external public opinion should be coordinated, and cooperation with external affairs departments should be carried out to respond effectively. For measures that may cause significant changes in public opinion, timely and accurate information should be provided. When public opinion arises, it is necessary to support the analysis of relevant public opinion events, evaluate the level of impact, trends, and progress of the events, and provide appropriate recommendations.

4 Conclusion

Adequate disaster prevention and mitigation measures for equipment are essential for the sustainable development of the power grid. It not only enhances the power grid's ability to withstand interferences and maintains its stability but also supports the company in achieving good economic benefits. Disaster prevention and mitigation work is a long-term and challenging task that involves multiple disciplines and units, both internally and externally. It requires strengthening internal collaboration within the company and enhancing communication and coordination with government departments to establish a comprehensive disaster prevention system throughout society.

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