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# New Power System Analysis and External Disaster Prevention Challenges and Prospects

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***Abstract:*** Constructing a new power system is fundamental to achieving the carbon peak and carbon neutrality targets. However, this evolving system is highly susceptible to external disasters, presenting challenges to its operational stability. An increasing number of transmission lines are passing over mountains as China's power grid gradually grows larger. These mountains are prone to large-scale wildfires, ice storms, and lightning strikes, which poses a severe danger to the to the safety and reliability of the power system. This paper examines the impact of three representative external threats to the new power system: wildfires, ice accretion, and lightning strikes. It delves into topics such as wildfire alert systems, the icing of ultra-high voltage(UHV) ground wires, and the prevention and control of lightning strikes in distribution networks. It also discusses the respective disaster mitigation strategies and anticipates the future evolutionary trajectory of the new power system, thereby offering insights and research directions for countering external disasters within the new power infrastructure.

***Keywords:*** New type power systems, external disasters, wildfire, lightning strikes

## 1. Introduction

To meet the carbon peak and carbon neutrality targets, the development of a power network capable of accommodating extensive wind and solar renewable energy sources has emerged as a pivotal national policy. [1] China is currently responsible for approximately 10 billion tons of carbon emissions annually, which constitutes roughly one-third of the worldwide carbon emissions, with the energy sector contributing to about 85% of this figure. Hence, the vigorous pursuit of new energy technologies, the establishment of a cutting-edge power system, and the low carbonation of the energy industry are imperative for advancing a clean and energy transition and fulfilling the targets of carbon peak and carbon neutrality. Countries and regions such as the United States, the United Kingdom, and the European Union have been actively pursuing energy transformations and reforming their power systems under governmental guidance, achieving notable progress in new energy generation and grid integration, power market operations, and the flexibility transformation of thermal power units. For instance, Denmark sourced over 50% of its power from new energy in 2021, while Germany and the United Kingdom derived around 40% of their electricity from renewable sources. However, there has been a surge in accidents involving power systems with a high proportion of new energy, as evidenced by incidents such as the "August 9" power outage in the UK in 2019, the power shortage in Texas, USA, in February 2021, and the power market

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shutdown in Australia in mid-June 2022. [2] As such, taccelerating the research and development of resilient new power systems is essential. Therefore, this paper analyzes three prominent external disaster problems in combination with literature, and present corresponding coping methods.

## 2. Wildfire monitoring and early warning technology

The stretch of UHV transmission corridors is extensive and frequently flanked by thick vegetation and weed growth in the vicinity. During prolonged periods of dry weather, these conditions can easily trigger wildfires. The combustion of vegetation produces charged particles and ash, which can drastically reduce the air insulation level, increasing the likelihood of UHV transmission lines experiencing trips and outages. Wildfires have emerged as one of the prominent threats to the secure and reliable functioning of power grids and the consistent delivery of electrical power. Currently, the primary strategy to mitigate the impact of wildfires on the power grid involves the use of mountain fire monitoring and early warning technologies, with a particular emphasis on satellite remote sensing techniques for controlling and preventing the spread of wildfires. UHV transmission corridors often traverse vast areas surrounded by dense vegetation, prone to wildfire risk during prolonged dry spells. Vegetation fires release charged particles and ash, which reduce air insulation, increasing the chances of UHV line faults. Currently, satellite remote sensing technology is the primary tool for wildfire monitoring in these corridors.

### 2.1. Satellite remote sensing monitoring technology

Satellite remote sensing monitoring utilizes satellites as observation platforms, offering advantages such as a broad monitoring range, brief update intervals, and swift data collection. This technology is extensively employed for monitoring wildfires in transmission line corridors. The monitoring process typically involves two principal steps: the delineation of the wildfire-affected area and the computation of the distance to the fire point. Satellites commonly utilized for wildfire detection include the NOAA series of polar orbiting meteorological satellites equipped with the Advanced Very High Resolution Radiometer (AVHRR); the EOS 'TERRA and AQUA satellites, which carry medium-resolution imaging spectrometers, the environmental satellite HJ-1B, fitted with a pair of charge-coupled device (CCD) sensors and an infrared imager, and the Fengyun No. 3 series (FY-3C and FY-3D) with medium-resolution imaging spectrometers, among others [3]. Satellite imagery captures data across visible, near-infrared, mid-infrared, and far-infrared wavelengths, enabling rapid wildfire identification.

#### 2.1.1. Fire point region extraction algorithm

The MODIS contextual model algorithm developed by Flannigan and Flasse [4,5] addresses detection errors common to older algorithms. Building on this, Giglio et al. [6] created a MODIS fire identification algorithm that successfully reduces false alarms from deforestation and minimizes large fires' concealment under heavy smoke. Zhou et al. [7] later proposed a fire point identification method which can enhance the precision of fire point identification and offer a novel approach for monitoring mountain fires in transmission line corridors by taking into account various threshold-influencing factors, including solar altitude angle, non-vegetation pixels, and cloud pixels.

#### 2.1.2. Calculation of fire point distance algorithm

Using remote sensing imagery to identify fire-affected areas allows for calculating the distance between fire points and transmission towers, thereby determining the high-risk zones along transmission lines and providing the power grid system with effective safety alerts. Lu et al. [8]

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conducted extensive researches in this area and proposed three methods: the circular buffer method, the near grid method, and the regional block search method. Comparative analysis confirmed that the regional block search method was the most expedient. Considering the numerous poles and towers along transmission lines and the computational time required for exhaustive calculations, the team proposed an optimized algorithm that leverages a database engine and grid indexing to calculate the nearest pole and tower distance from the fire point, further enhancing computational efficiency.

To monitor the dynamics of wildfires along transmission lines in real-time, some researchers have integrated Geographic Information Systems (GIS) with remote sensing technology. Mazzeo et al. [9] in Italy proposed an integrated satellite system using GIS technology to comprehensively analyze data from sensors like MODIS, AVHRR, and SEVIRI, thereby prioritizing fire risks and optimizing fire suppression resource allocation.

## 3. Ground ice melting prevention technology

UHV transmission lines serve as a critical conduit for the conveyance of electricity from large-scale renewable energy bases, and they are subjected to more severe impacts from disasters than traditional power grids. Due to their high transmission capacities and extended lengths, UHV lines are often routed through high-altitude, mountainous areas prone to significant ice formation, which can result in tripping and line fractures, posing a serious threat to the integrity and safety of the power grid. Therefore, monitoring ground ice along transmission lines is of paramount importance, and the deployment of ground ice melting equipment is essential for reducing these risks.

### 3.1. Manual ground ice melting wiring device

Ground ice melting involves using the ground wire as a load, where two phases of the three-phase wire are connected to form a loop. A DC ice melting device installed at the station then applies current to the ground wire, generating heat to melt the snow and ice accumulated on it. However, the trial operation of this device revealed several operational deficiencies. First of all, operators must climb towers during icy conditions to operate the device, posing a high risk of falls and other accidents. Additionally, the complexity and time consumption associated with the wiring process. Additionally, the wiring process is complex and time-consuming, often taking at least 3 hours. This is largely due to the substantial distance between the wire and the ground wire at the high voltage level, complicating the connection with the chuck and the drainage copper rod. Connecting the device manually at tension corner towers—particularly at inner angles—is especially challenging or sometimes impossible due to the corner angle constraints. Moreover, inadequate protective measures of the device, with the over-flowing copper rod being directly exposed, making it susceptible to icing,, compromise its functionality. To address these issues, Southern Power Grid Company and Nanjing Electric Power Fittings Design and Research Institute Co., Ltd. collaborated to develop an automated ground ice melting wiring device to streamline the process and improve safety and reliability[10]

### 3.2. Automatic ground ice melting wiring device

The automatic ground ice melting wiring device functions analogously to a rotary knife switch, employing mechanisms to execute closing and opening actions in order to establish and sever the connection between the wire and the ground. When ice melting is required, the operator transports the control box and power supply to the tower. The process begins by routing the control line and power line down the tower to connect with the relevant components mounted on the tower. Subsequently, the operator performs the protection lock opening and locking procedure, followed by the opening and closing of the conductor to connect the ground and wire. This action initiates the

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ice melting process at the substation. Once the ice melting operation is completed, the conductor is switched and closed in a sequential manner, and the protective locking and locking action is carried out to revert the device to its per-ice melting state. After ensuring that the device is properly secured, the operator disconnects the control box and power supply, and returns them to the substation for safe storage, completing the entire ice melting operation safely and efficiently [10].

### 3.3. Remote control system for automatic ground ice melting wiring device

Although the automatic wiring device has mitigated the need for manual tower boarding to perform wiring tasks, operators still need to be present at the tower base to control the operation. Each ice melting section requires the installation of a wiring device at both the head and tail ends, and since a single ground line can have multiple ice melting sections, the installation spread is extensive. Consequently, winter ground ice melting operations demand the deployment of multiple teams to each installation point, consuming a significant amount of manpower and material resources. Moreover, towers are often situated in remote areas with poor road conditions and extreme weather, posing substantial risks to personnel. Furthermore, the ice melting operation involves repetitive work ticket procedures and requires regular reporting to the power station on the implementation status, which is not only time-consuming but also prone to errors.

In response to these challenges, Southern Power Grid Company issued the "Three-year Action Plan for Anti-icing and Deicing" in 2018[11], which prioritized the research and promotion of intelligent anti-icing and deicing technologies. This action plan specifically suggests the implementation of remote control and operation for the automatic ground ice melting wiring device to enhance the efficiency and safety of ice melting operations. To date, a set of remote control system with comprehensive functionality has been developed and put into application. The hardware of this remote control system is primarily distributed between the tower side and the substation side. Upon receiving an ice melting execution command, the power station operator sends a closing or opening action command from the control host to the ground ice melting remote control cabinet, thereby enabling remote ice melting operations.

## 4. Lightning strike prevention technology for distribution network lines

Throughout the development of electric power enterprises, the impact of lightning on power transmission has been a significant concern in the industry. Direct and inductive lightning strikes often result in high rates of trip faults, insufficient insulation coordination, and elevated grounding resistance issues. In response to these challenges, various measures have been implemented to prevent lightning strikes and to mitigate the damage caused by lightning to distribution network lines thereby enhancing the resilience and reliability of the power distribution system in the face of lightning-related disruptions [12].

### 4.1. Lightning positioning system

The system is designed to precisely record and annotate the location of lightning strikes, along with pertinent details such as the time of occurrence and the intensity of the strike. The lightning location system has been monitoring and compiling data over the years, which is then archived and managed for future reference. These data encompass specifics such as the geographical coordinates of strikes, their frequency, and intensity, which is then displayed on a single-line diagram of the distribution network. This visualization provides a comprehensive overview of the frequency and distribution pattern of lightning activity within the network. By aggregating all marked lightning locations, a comprehensive lightning location map is created. This map serves as a valuable tool for analysts, enabling them to rapidly grasp the spatial distribution and identify areas with a high incidence of lightning events. This information is instrumental in planning future protective measures, including the placement and coverage area of various types of lightning arrester within the lightning rod system, as well as determining the optimal locations for grounding systems and assessing the grounding resistance values of distribution network facilities [13].

### 4.2. Lightning detection system

Routine inspections of lightning rods are essential to ensure they remain undamaged and free of corrosion, thus maintaining their efficiency in directing lightning to the ground. Traditional tip-based lightning rod systems rely on the optimization of tip geometry and materials to facilitate lightning discharge. These systems protect equipment by utilizing the principle of discharge blasting, which involves the release of lightning through a combination of high voltage and gas mixed discharge. Real-time lightning monitoring leverages sensors and GPS technology to track the location and strength of strikes, allowing for remote monitoring via the internet. The integration of the traditional lightning rod system, lightning protection lines, and the new intelligent lightning monitoring system creates a multi-layered and multi-dimensional lightning protection framework. This comprehensive approach enhances the overall effectiveness of lightning protection, providing robust defense against potential lightning-related damage.[12]

## 5. Conclusion

At present, the new power system external disaster prevention measures are not mature, through the analysis of three typical natural disaster prevention measures, mountain fire, ice cover, lightning strike and the corresponding prospect. Through the technology of mountain fire monitoring and early warning and satellite remote sensing monitoring, the prevention and control measures of mountain fire disasters can be implemented comprehensively. Through the manual wiring device of ground ice melting and the more safe and convenient remote implementation method, the prevention and control measures of wire icing disaster can be effectively carried out. Lightning location can be predicted quickly and control measures can be implemented through lightning protection technology and lightning location system. But there are still great difficulties to be improved such as satellite monitoring small area of mountain fire identification problem, the integration technology of ground ice melting wiring device and artificial intelligence and the anti-aging problem of insulators needed for lightning protection of distribution network.

Currently, disaster prevention measures for new power systems remain in early stages of development. This review has examined prevention technologies for three typical natural disaster scenarios: wildfires, ice accumulation, and lightning strikes, along with prospective advancements in each area. For wildfire prevention, satellite remote sensing and early warning systems enable more comprehensive monitoring and control of mountain fires. In the context of ice accumulation on wires, the deployment of ground ice melting devices, including manual wiring tools and safer, remotely operated systems, allows for effective disaster management. For lightning protection, rapid detection and response are achieved through lightning positioning systems and protection technology.

Despite these advancements, several technical challenges remain. For instance, satellite-based monitoring systems still face difficulties in accurately identifying small-scale wildfires, while the integration of ground ice melting technology with AI requires further development. Additionally, addressing the anti-aging properties of insulators is crucial for enhancing lightning protection in distribution networks. Continued innovation in these areas will be essential for improving disaster resilience in new power systems.

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