



Analysis and Research on Icing of OPGW Optical Cable

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Abstract. This paper analyzes the influence scope, emergency disposal, fault causes and risk characteristics of Jilin snow disaster, and discusses the means of emergency disposal. The paper summarizes the operation years and icing history of optical cables in Henan Province, excavates the causes of icing, analyzes and studies the prone to icing in west, north and central Henan from the perspective of geographical environment, analyzes the relationship between icing and optical cable aging from the perspective of operation years, and focuses on preventing 9 optical cables in the above areas. Combined with the weather change, the emergency detour scheme of icing optical cable is revised in a rolling way, and come to the conclusion of using multiplex protection to facilitate the emergency detour of channels, and increasing OTN coverage rate to facilitate the emergency detour of optical path, so as to cope with the risk of icing optical cable during Winter Peaks.

Keywords: Icing · Optical Cable Aging · Emergency Detour · Multiplex Protection Channel · OTN

1 Introduction

The recent snow disaster in other provinces interrupted communication optical cable, which affected the safety of the power grid. Henan Electric Power Company drew inferences from one instance, prepared for the rainy season, excavated the causes of icing, analyzed the OPGW optical cable of Henan 500 kV line according to the two dimensions of icing history and operation years, updated the emergency detour scheme in a rolling way, and prepare countermeasures for the optical cable icing in Winter Peaks [2].

2 Snow Disaster of Jilin Electric Power Company

On November 19, 2020, a total of 55 lines of optical cables were interrupted due to wind and snow weather in Jilin Province, including 54 ADSS optical cables and an OPGW optical cable; according to the voltage level, there are 12 220 kV optical cables and 43 66 kV optical cables. A total of 24 220 kV lines were operated with single protection.

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2.1 Emergency Measures

- 1) *Strengthen dispatching command*: Closely monitor, control the scope of disaster influence, and deal with emergencies at any time.
- 2) *Circuitous circuit rush through*: According to the emergency detour scheme, the network management configuration data is used to bypass the important business channels and restore 21 protection channels.
- 3) *On site fiber skipping*: The temporary optical path was hopped through, 32 tail fibers in the company building were completed by Information and Communication Company of Jilin, and the municipal company completed the fiber skipping of 11 220 kV stations.
- 4) *On site emergency repair of optical cables*: Overcome the difficulties on site, increase the intensity of optical cables repair, and restore more than 50 protection channels.

2.2 Cause of Failure

The ADSS fiber optical cable is the main cable for icing broken. ADSS cable has weaker load-bearing capacity than OPGW cable, and its tensile strength decreases with the increase of operation years, leading to fracture.

2.3 Risk Analysis

- 1) *Influence of power grid*: The rain and snow weather mainly affect the optical cable. There is no large-scale power failure in the primary line, but the communication system is out of operation in a wide range, which seriously affects the safety of the power grid.
- 2) *Scope of interruption scope*: The damage of optical cables is mainly concentrated in the ADSS optical cables of 220 kV and below at the municipal level, and the impact of 500 kV OPGW optical cables in the backbone network of the whole province is not significant. In recent years, OPGW is the main optical cable put into operation and has not been damaged.
- 3) *Disaster area*: The impact scope basically covers the whole territory of Jilin Province. The four areas with the largest wind and snow are at the junction of plain and mountain.

3 Analysis of Icing

3.1 Cause Analysis of Optical Cable Icing

1) *The formation of icing*: When the temperature and water vapor conditions for icing are met, the wind will continuously blow the supercooled water droplets to the line optical cable, and gradually increase after collision to form icing. When the thickness reaches a certain value, the cable will twist due to gravity, and a new windward side will appear. As the cable is twisted continuously, the icing gradually increases, and finally forms a circular or elliptical icing. When the wind direction is vertical to the optical cable or the angle is more than 45° and less than 150° the icing is serious. In addition, as the moisture content in the air increases with the increase of height, the higher the suspension height, the more serious icing.

2) *The hazards of icing*: Icing adds a thick layer of ice to thin optical cables, and increases the risk of fracture caused by their self weight. At the same time, the icing of the wire and the optical path increase the load of towers on both sides, and serious icing makes the tower unable to support the load and collapse [6].

3.2 Geographical Distribution of Icing in Henan Province

The special geographical environment is easy to produce ice and snow. Two areas in Henan Province are prone to ice and snow, namely the periphery of the Taihang Mountains and the mountainous area of central Henan, which are basically consistent with the distribution of optical cables with icing records.

1) *Taihang Mountains*. Henan is located at the intersection of the second and third steps of China's terrain, especially in the west and north of Henan, which are backed by the Taihang Mountains, facing a vast plain, and the micro topography in some areas is complex and changeable.

a) Southeast of Taihang Mountain - Hebi, Xinxiang. Hebi and Xinxiang are located in the southeast of Taihang Mountain, facing the warm and humid air flow of the Pacific Ocean. The air is easy to rise and condense, and the micro meteorology is remarkable. Historical case: On April 10, 2020, there was heavy snowfall in Hebi, which was significantly different from the spring weather in other areas, and the local temperature dropped to about 0 °C. In 2013 and April 2006, Hebi recorded heavy snowfall.

b) *South of Taihang Mountain - Sanmenxia, Luoyang*. Sanmenxia is located in the tuiyere area between Taihang Mountain and Qinling Mountain (Funiu Mountain), where cold air from the northwest can easily flow into this area. Taking the precipitation forecast map during the first cold wave in winter 2020 (November 22) as an example, Sanmenxia and the northwestern region are both snowing areas, and the frost line near Sanmenxia has moved significantly south.

Historical cases: In December 2019, a certain line and optical cable were iced, which caused the power lines to discharge and break 55#-56# optical cables.

Luoyang is located in the middle area of the above two terrains, and icing of optical cables has also occurred.

Historical cases: In January 2020, the UHV Changnan I line optical cable was covered with ice with a thickness of 3 mm and a length of 4 km.

2) *Mountainous areas in central Henan*.

a) *Jian Mountain*. Jian Mountain is located 35 km southwest of Zhengzhou, northwest of Xinmi, and belongs to the eastern part of the Songshan Mountain. The highest elevation is 1108 m. The area is densely covered with hills and the micro meteorology is remarkable.

Historical case: In February 2010 and March 2011, the cable in Jian Mountain section of an optical cable was broken twice due to icing, resulting in the interruption of all optical paths. In 2018, 2019 and 2020, the cable has been covered with ice for many times.

b) *Shizu Mountain*. Shizu Mountain is located 15 km southwest of Xinzheng, belonging to the east of Songshan Mountain, with the highest altitude of 793 m.

Historical case: In 2010 and 2020, icing appeared in the mountain section of the origin of an optical cable.

4 Statistics of 500 kV Optical Cable in Henan Electric Power Company

4.1 Icing History

In recent 10 years, there are 9 500 kV optical cables with icing danger, which are mainly concentrated in the West and north areas of Henan Province, and there are also records of icing on optical cables in mountainous areas in central Henan Province.

4.2 Analysis on the Years of Operation

The optical cable formed by rewiring is still calculated according to the operation life of the original optical cable due to its short π connection section. All cable types are OPGW [1], and the number of 24 core optical cables accounts for the largest proportion [5]. The proportion of optical cables with different operation years is analyzed, as shown in Fig. 1.

It can be seen that the optical cables that have been put into operation for 14 years or more account for the largest proportion, which is basically the initial network frame after Henan electric power communication network enters the optical fiber communication stage, and the optical cables formed by gradual rewiring.

The cable with long service life has the risk of material aging and bearing capacity attenuation. Ice coating interacts with cable aging. According to the dispatching operation records, there are mainly two kinds of faults as follows:

- 1) *Aging of optical cables caused by ice coating.* In December 2019, an optical cable in Sanmenxia suffered severe strand breakage, which was supposed to be caused by the wire discharging to the ice-coated OPGW optical cable. A power cut on the next day was applied. Urgent repairs for communication system were conducted, by reinforcing the optical cables with pre-twisted wire.
- 2) *Weakening of the ice-coated bearing capacity caused by optical cable aging.* In March 2020, a certain optical cable in Hebi was broken, which was supposed to be due to lightning strikes. After applying for an emergency repair form for the communication

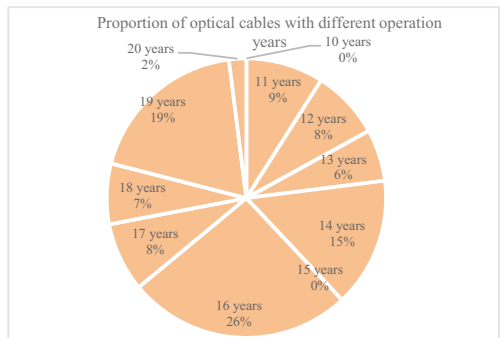


Fig. 1. Proportion of optical cables with different operation years.

system, the reinforcement of optical cable strand was immediately carried out to restore the cable's carrying capacity.

4.3 Optical Cable with Icing Risk

In summary, the nine 500 kV optical cables in the western, northern and central mountainous areas of Henan have been put into operation for a long time. Meanwhile, there is a history of icing, which may lead to level 6 and level 7 risks, which requires enhanced monitoring and roll-out emergency plans.

When an optical cable is in danger, on the one hand, it is necessary to detour important services such as protection and security control to other normal optical paths through network management detours, OTN docking detours, and SDH docking detours to ensure that the number of affected protections is less than 8 sets. On the other hand, it is necessary to repair the optical cable as soon as possible on site.

5 Emergency Safeguard Measures

5.1 Strengthen Linkage and Prepare for Emergency

In icy and snowy weather, strengthen cross-professional coordination and linkage, provincial communications dispatching must strengthen the monitoring of the above-mentioned optical cables in a targeted manner, implement the daily zero report and real-time reporting system, strengthen the risk prevention and control of related optical cables and sites, and increase network management optical equipment alarms and engineering Condition monitoring patrol video frequency, and timely issuing risk warning orders to optical cable operation and maintenance units in risk areas. The Provincial Information Transportation Inspection Center must be on duty, and spare parts for related brand and model light boards are ready to be in place to ensure that the emergency circuitous light path is connected in time. The line operation and maintenance unit strengthens the patrol video frequency according to the service life classification and risk section, focuses on the long service life line, prepares for emergency repairs, counts backup cables, and repairs vehicles are on standby for 24 h to ensure that optical cable inspections are in place and repairs are timely [3].

5.2 Update Emergency Plans and Improve the Speed of Emergency Repairs

In the case of fiber optic cable failure, if not all the fiber cores are interrupted, priority will be given to adjusting the affected optical path to the standby fiber core operation. If all the fiber cores are interrupted or the spare fiber core does not meet the conditions, the affected optical path needs to be connected to the provincial network OTN for a detour. Important business channels are given priority to use the network management of this network to directly bypass, which would be the most efficient. If the channel detour conditions are not available, then consider the optical path detour, and use the provincial network OTN detour, which requires on-site optical path connection, which would be the second most efficient. However, due to the limitation of the grid structure, some protection and security control services may not meet the "triple double" requirements after emergency detours.



Fig. 2. Visual line monitoring platform.

5.3 Carry Out Actual Combat Drills to Deal with Rain, Snow and Ice Disasters

It is planned to carry out an ice-coated communication on-site emergency drill in December, to strengthen the coordination and linkage of relevant units and departments, pursue the practicability and authenticity of the disposal process, test the accuracy of the emergency circuitous plan, refine the operation steps to on-site wiring and improve the all-weather actual combat capability and major response Disaster handling capacity [4]. Strictly monitor the mechanism during the exercise, clarify the person responsible for the exercise control, and analyze the advantages and disadvantages in a timely manner after the exercise, so that the emergency awareness of the participants is continuously improved, and the effect of the scriptless exercise is continuously enhanced. The exercise process should be controllable and the safety of the exercise site should be guaranteed.

5.4 Strengthen Technical Defense Measures to Assist Early Warning and Pre-control

Use new technology to improve the safety of line optical cables, respond to severe weather, monitor and warn in advance, prevent failures, and reduce the pressure of manual monitoring and repair. Line operation and maintenance units have installed visual monitoring platforms on several lines, with a certain degree of intelligent auxiliary early warning, and can cooperate with communication scheduling to strengthen ice coating monitoring during ice and snow weather and reduce the workload of manual line inspection (Fig. 2).

6 Conclusions

6.1 The Optical Fiber Protection Channel Adopts Multiplexing Mode to Facilitate the Roundabout

Optical fiber protection channels generally use fiber core channels and multiplexing channels. When the optical cable is interrupted, the multiplexing channel can quickly configure data on the NMS, and use the existing communication transmission network and other routing resources to restore operation in a circuitous way, which has the

advantages of fast and convenient. The fiber core channel needs to send people to the site to patch the fiber, and each site on the new fiber optic cable path needs to be manually patched. Each segment of the fiber cable must meet the requirements of attenuation and the number of spare cores. The original protection communication optical module must be able to supporting the total distance of the new optical cable path is time-consuming and laborious and may not be able to be opened.

At present, the 500 kV line in Henan has basically adopted multiplex protection channels, but the 220 kV line still uses a large number of fiber core protection channels. When the optical cable is iced or other interrupted failures, it is not conducive to channel recovery.

6.2 Increase the Coverage of OTN Equipment in the Provincial Backbone Network to Facilitate the Roundabout of Optical Path

500 kV optical cables carry a large number of SDH optical paths of level 1, 2 and 3. When the optical cable fails, there will be a massive interruption of optical paths. The effective method is to use the provincial network OTN equipment at the stations on both sides of the optical cable section to connect and detour the interrupted SDH optical path. At present, the provincial network OTN equipment does not cover all 500 kV stations. When this kind of optical cable fails, the detour recovery work optical paths can only be done through other SDH detours (insufficient bandwidth, and only a small number of detours), or through other 220 kV optical cable paths (due to the increase of attenuation and jump contacts, it is time-consuming and laborious, and may not function well). Therefore, it is recommended to speed up the construction of the provincial network OTN equipment and achieve 100% coverage of 500 kV stations. Although the OTN transmission network does not carry the most important services like SDH, such as protection and security control, and is mainly based on automation and information wide bandwidth, it can play a key role that SDH cannot replace when the optical cable is faulty or overhauled.

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