Discussion on The Application of Overhead Power Communication Optical Cable

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Abstract. Overhead optical cable is an important framework for the power communication network. The common types of optical cables erected with power lines of 35 kV and above include optical fiber composite ground wire (OPGW), non-metallic self-supporting optical cable (ADSS) and optical fiber composite phase wire (OPPC), different types of optical cables have their own characteristics, and are suitable for different situations. This article starts with the structure of the optical cable, analyzes the characteristics of different types of optical cables, and further analyzes and compares from the perspective of electrical, economic, and maintenance. For the problems encountered during the use of different types of optical cables, the safety, The technical regulations are more comprehensively explained. This article is for operation and designer reference.

1. Introduction

The power communication network is an important infrastructure supporting the construction of a strong smart grid and the modern management of enterprises, and an important basic platform for carrying the production and operation of the power grid and the operation and management of enterprises. Overhead optical cable is an important skeleton of the power communication network. At present, the common types of optical cables erected on power lines of 35 kV and above are optical fiber composite ground wire (OPGW), non-metallic self-supporting optical cable (ADSS) and optical fiber composite phase wire (OPPC). The selection of overhead optical cable is affected by the voltage level of the power line and the type of the tower. For different power lines, the appropriate type of optical cable should be selected.

With the increasing public demand for the quality of power supply, the safety of communication networks as power information transmission is becoming more and more important, and the management department has increased its assessment in this regard. Due to equipment failures and the interruption of communication optical cables, the dispatching telephone and dispatching services of the power dispatching control center at the provincial level and above and more than 10% of direct dispatching stations were interrupted[1].Communication system failures are classified as level 5 to level 8 equipment events according to different degrees[2].Therefore, it is particularly important to choose the appropriate type of communication cable in the power system to ensure safe operation.
2. Characteristics of different optical cables

2.1. OPGW optical cable
The outer layer of the OPGW optical cable structure is an aluminum alloy conductor, the middle is an aluminum-clad steel wire, and the inner layer is an optical fiber protected by a stainless steel tube.

The advantage of OPGW optical cable is that it is suitable for being erected on a newly built line. It has high strength and relatively safe and reliable operation. The disadvantage is that when it is applied in areas with high thunderstorm days, there is a risk of strand breaking and wire breakage due to lightning strikes. The strength calculation of the tower needs to be carried out when erecting the old lines, especially the transmission line before the 2008 ice disaster. Reinforcement and reinforcement, and even the need to replace the tower, will cause increased costs.

OPGW optical cable has both line lightning protection and communication functions. It needs to meet the distance requirements between the ground wire and the conductor in the design regulations. The outer aluminum clad steel monofilament diameter cannot be less than 2.8mm at 110kV, and not less than 3.0mm at 220kV[3].

When it is matched with another lightning protection wire (shunt line) of different materials, the shunt calculation is required, and the calculation result needs to meet the thermal stability requirements.

2.2. ADSS optical cable
In recent years, the domestic layer 35-110 kV line commonly used layer twisted type ADSS optical cable, its structure is shown below.

The ADSS optical cable has the characteristics of light weight and little impact on the tower. It is generally erected on the tower body. After the tower body (pulling wire) is reinforced and reinforced, it can basically meet the additional conditions, so it is suitable for erecting 35-110 kV On the old line.

When it is erected on a 220 kV line, it is prone to electrical corrosion. The mechanism of ADSS optical cable electrical corrosion is that the optical cable is in a high potential field and there is a potential difference on the surface, which means that there is an electric field strength along the surface of the optical cable. The value of the electric field strength at the exit of the optical cable hanging point or near the metal member of the tower is relatively greater. The electric field strength drives the current on the surface of the optical cable under humid conditions, and the current causes the surface of the optical cable to heat up and evaporate the water, forming a dry belt. The dry belt is subjected to a potential difference, which may form an arc and cause discharge. After long-term operation, the hydrophobicity of the ADSS cable jacket decreases. Which in turn causes disconnection and disconnection[4].

At present, it is found that the ADSS optical cable erected on the 220 kV overhead line has electrical corrosion and even disconnection. For example, in 2019, Henan Electric Power Company organized various units to carry out a special investigation of ADSS optical cable for 220 kV overhead lines, conducted a special study on the observation technology of ADSS optical cable electrical corrosion, and finally selected "Bird Watching Mirror + "Mobile phone + Bluetooth + camera frame" observation method can clearly take pictures to check the electrical corrosion of ADSS optical cable. In order to further prevent the occurrence of the disconnection of the 220 kV overhead line ADSS optical cable, after combing and investigation, the company has a total of 61 220 kV overhead line ADSS optical cables. After operation evaluation, there are 49 ADSS optical cables that can be used continuously, and 12 ADSS optical cables that need to be returned and removed[5].

In order to avoid the electrical corrosion of the ADSS optical cable, the potential and electric field strength of the ADSS hanging point and the position of the optical cable under different operating conditions should be calculated before laying the high-voltage overhead line. It should be ensured that the potential is less than 12kV (common type Optical cable), 25kV (corrosion-resistant optical cable), and the electric field strength is less than 10kV/m[4].
ADSS optical cable can not be erected in the section across high-speed railways, highways, and important transmission channels to prevent public safety and power grid safety incidents[3][6].

2.3. OPPC optical cable
OPPC optical cable is similar to OPGW in structure. It is an optical cable that combines optical fiber units in the phase line. It has the dual functions of power supply and communication. It is generally used for voltage levels below 110kV, and is also used on 220kV lines.

The advantage of OPPC optical cable is that during the transformation of the old line communication, the OPPC optical cable can be used to directly replace a conductor of the original line without additional load on the tower. Compared with OPGW, there is no risk of lightning strike, and compared with ADSS, there is no need to strengthen the tower. The disadvantage is that there is photoelectric separation, and operation and maintenance are not convenient.

When the OPPC optical cable is selected, the mechanical electrical properties such as the diameter, weight, and cross-sectional area of the same loop wire should be basically consistent, so as to maintain the same current carrying capacity and consistent wire sag.

3. Analysis of electrical, economic and operation maintenance
The following author uses the previously designed 24-core optical cable as an example to further explain the sag characteristics and economy of different types of optical cables.

3.1. Optical cable sag characteristics
The mechanical parameters of the three different types of optical cables are shown in Table 1, and the sag characteristics are shown in Tables 2 and 4, respectively. The design calculation conditions are the highest temperature of 40°C, the lowest temperature of -20°C, the annual average temperature of 15°C, the maximum wind of the reference height of 27m/s, and the thickness of ice coating of 10mm.

| Table 1. Optical cable mechanical parameter table |  |
|-----------------------------------------------|---|
| model                                        | OPGW | ADSS | OPPC-185/30 |
| Cross-sectional area mm²                     | 97.60 | 138  | 210.50      |
| Diameter mm                                  | 13.20 | 12.90| 18.88       |
| Weight kg/km                                 | 479.00| 137.00| 732.60      |
| Breaking breaking force N                    | 60000 | 29200| 64320       |
| Coefficient of elasticity N/mm²              | 109000| 14100| 76000       |
| Linear expansion coefficient10⁻⁶ 1/℃         | 15.50 | 5.20 | 18.90       |
| Annual average operating stress N/mm²        | 116.80| 33.86| 72.57       |
| Safety factor                                | 3.5   | 3.6  | 2.7         |

| Table 2. OPGW-100 optical cable sag characteristics table |  |
|----------------------------------------------------------|---|
| Range m                                                  | Lowest temperature | Annual average temperature | Iced | Maximum temperature |
| 100                                                      | 0.41             | 0.52                        | 0.42 | 0.73               |
| 150                                                      | 0.94             | 1.16                        | 0.95 | 1.54               |
| 200                                                      | 1.71             | 2.06                        | 1.74 | 2.60               |
| 250                                                      | 2.74             | 3.22                        | 2.78 | 3.89               |
| 300                                                      | 4.04             | 4.64                        | 4.09 | 5.42               |
| 350                                                      | 5.62             | 6.31                        | 5.68 | 7.19               |
| 400                                                      | 7.48             | 8.25                        | 7.54 | 9.2                |
Table 3. SASS characteristics of ADSS optical cable

| Range m | Sag m | Lowest temperature | Annual average temperature | Iced | Maximum temperature |
|---------|-------|---------------------|-----------------------------|------|---------------------|
| 100     | 0.36  | 0.36                | 1.68                        | 0.38 |                     |
| 150     | 0.75  | 0.81                | 3.25                        | 0.85 |                     |
| 200     | 1.35  | 1.44                | 5.14                        | 1.51 |                     |
| 250     | 2.84  | 3.05                | 7.95                        | 3.21 |                     |
| 300     | 5.75  | 6.07                | 11.46                       | 6.30 |                     |
| 350     | 9.84  | 10.17               | 15.60                       | 10.41|                     |
| 400     | 14.68 | 15.01               | 20.40                       | 15.25|                     |

Table 4 OPPC-185/30 optical cable sag characteristics table

| Range m | Sag m | Lowest temperature | Annual average temperature | Iced | Maximum temperature |
|---------|-------|---------------------|-----------------------------|------|---------------------|
| 100     | 0.44  | 0.60                | 0.86                        | 0.94 |                     |
| 150     | 1.13  | 1.48                | 1.94                        | 2.05 |                     |
| 200     | 2.30  | 2.85                | 3.44                        | 3.58 |                     |
| 250     | 4.02  | 4.70                | 5.38                        | 5.53 |                     |
| 300     | 6.28  | 7.02                | 7.75                        | 7.91 |                     |
| 350     | 9.02  | 9.79                | 10.55                       | 10.72|                     |
| 400     | 12.21 | 13.01               | 13.79                       | 13.96|                     |

The elasticity coefficient and linear expansion coefficient of the ADSS optical cable are relatively small. It can be seen from the table that the arc sag changes more with the increase of the gear distance. The arc sag under the ice coating condition is larger than the high temperature condition. The design of the ADSS optical cable erection It is generally used to verify various distances with ice coating conditions.

3.2. Economic characteristics of optical cable

OPGW optical cable is generally suitable for the construction of 35 kV and above grounded lines or the old lines with grounding that meet the strength after reinforcement.

ADSS optical cable is generally suitable for 35 kV ungrounded pole tower lines or 35-110 kV old lines that can be queried for design data and can be reinforced by pole towers.

OPPC optical cable is generally suitable for 35-110 kV lines. In recent years, some 220 kV lines in China have also been erected. It is especially suitable for pole lines without ground lines or old lines that cannot be queried due to design data and cannot be reinforced.

The following uses the 110 kV old line as an example to compare the cost per kilometer of three different types of optical cables. See Table 5 for the cost per kilometer of different types of optical cables.

Table 5. Single-kilometer cost table of 24-core optical cable

| Serial number | Optical cable model | Tower tower reinforcement costs | Optical cable body costs | Subtotal |
|---------------|---------------------|-------------------------------|--------------------------|----------|
| 1             | OPGW                | 2.0                           | 1.27                     | 3.27     |
| 2             | ADSS                | 0.8                           | 1.39                     | 2.19     |
| 3             | OPPC                | 0                             | 2.30                     | 2.30     |

Description:
Cost unit in the table: ten thousand yuan (RMB)
The construction costs of different optical cables in the table are all considered the same.
The 110 kV line pole tower is based on 4 bases/km, the old line's reinforcement fee for installing OPGW optical cable is 5,000 yuan/base, and the old line's reinforcement fee for installing ADSS optical cable is 2,000 yuan/base.

The price of optical cable comes from the information price of power grid engineering equipment materials in the first quarter of 2020 (total 31st period).

The above table shows that the old line adopts the ADSS and OPPC schemes from the economic point of view, which are similar to those of the OPGW scheme.

Because OPGW and ADSS schemes should consider pole tower reinforcement, OPGW scheme should reinforce pole tower ground support and tower body, ADSS scheme should strengthen pole tower tower body, OPGW scheme has a longer construction period, OPPC scheme does not need to consider pole tower reinforcement, Therefore, the construction period is the shortest.

3.3. Operation and maintenance analysis

The operation and communication department recommends that the OPGW optical cable should be preferred. Even for the old line communication reconstruction project, it is best to use the OPGW optical cable close to the original line parameters, followed by the ADSS optical cable, and finally the OPPC optical cable. The reason is that the OPPC optical cable has photoelectric separation in the process of operation, due to the quality of the connection, the terminal box often fails. The construction unit and the optical cable manufacturer often blame it. The technical strength of the emergency repair of the operation and communication department is too weak. The emergency repair depends too much on the optical cable manufacturer, resulting in a long communication interruption time. The risks are high.

In addition, after a broken wire fault occurs in the middle of the OPPC optical cable line, the conventional treatment method is to use a crimping tube to connect the wire through the crimping method to ensure the restoration of power transmission. After the optical cable material is purchased in place, the power is turned off again and the two fault points are replaced. The entire optical cable between the connector boxes (generally more than 1000m in length), which causes problems such as long communication interruption, repeated power outages on the line, difficulty in rush repairs, and high costs. The power supply service is more stringent in the evaluation of power outages, and the same line is repeated It is difficult to get an application for power outage.

Some provinces in China no longer consider using OPPC optical cable in the 14th Five-Year Plan of the communication network. For example, Document 7 stipulates: Overhead line optical cable should be mainly composed of optical fiber composite ground wire (OPGW), supplemented by non-metallic self-supporting optical cable (ADSS). Pipeline optical cable and incoming guide cable should use non-metallic flame retardant optical cable. OPPC optical cable is excluded.

If according to Document 7, there will be many old steel pipe pole lines in the Pingdingshan power supply area. The operation time is about 20 years. Some pole tower design information is incomplete, and some tower tower information is complete, but because the structural characteristics of the steel pipe pole cannot be strengthened, more It is not possible to dismantle and rebuild normal operating lines that are less than the end of life due to the addition of communication optical cables, so these old lines cannot be erected in the short term.

The author believes that the current OPPC optical cable technology continues to mature, we should continue to summarize the experience of operation and maintenance, can not easily deny this technology. According to the engineering experience introduced in Document 8, after the OPPC optical cable is broken, the cores of the two breakpoints are passed through the ordinary wire crimping tube, the core is welded, and then put back into the crimping tube, then insert a few aluminum wires into the crimping tube, then crimp the OPPC optical cable, and finally add a reinforced pre-twisted wire to the crimping tube for reinforcement. In this way, the simultaneous repair of the wire and the optical fiber not only ensures the power transmission of the line, but also ensures the rapid recovery of the communication line, and the cost is low.
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