YOFC_17016_WP

Electrical Properties of Optic/Electric Hybrid Cables for Access Network

Cai Jing, Lu Xingxing, He Jun, Li Mingang, Xiong Zhuang

Abstract: This paper introduces the basic principle and advantages of the application of optic/electric hybrid cables, and puts forward that attention should be paid to the electrical safety of optic/electric hybrid cables. The electrical properties of optic/electric hybrid cables for access network are discussed in combination with the resistivity of feeder, DC resistance, insulation resistance of feeder and finished cable, and dielectric strength.

Key words: Optic/electric hybrid cable, electrical properties, DC resistance, insulation resistance, dielectric strength

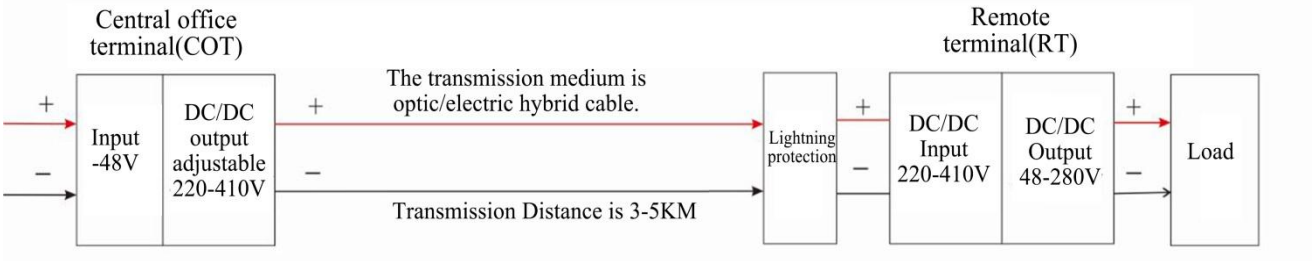
1. Introduction

With the continuous upgrading of 3G/4G network, communication optical cables and equipment continue to extend to the user side, and the equipment power supply of remote base station, communication machine room, and user access point has become a thorny issue. The optic/electric hybrid cable integrates optical unit and electrical unit, which can effectively solve the problem of power supply for communication equipment in network construction. At the same time, the optic/electric hybrid cable DC remote power supply is also conducive to the centralized construction, operation and maintenance of power supply equipment in the network, which can reduce construction, operation and maintenance costs, and can simultaneously achieve highly efficient co-cable transmission of electric energy and optical signals. However, since most of the users of the optic/electric hybrid cable are operators, their understanding about the optic/electric hybrid cable stays on the optical cable, and they attach great importance to the optical transmission performance; their attention paid to performance indicators and testing of the electrical properties need to be increased.

2. DC Remote Power Supply Solution

2.1 Basic Principle of DC Remote Power Supply

The DC remote power supply solution consists of optical line terminal, remote equipment and optic/electric hybrid cables; the optical line terminal directly transform the stable DC voltage (DC-48V) in the machine room of the nearest communication base station into suspended DC voltage (DC320V, DC350V, DC380V) through the central office terminal (PDL) of the DC remote power supply source after voltage step-up and isolation, and transmits the voltage to the



remote controller (RPC) of the DC remote power supply source through the cable or power cable of the optic/electric hybrid cables. Then the power will be connected to the remote communication equipment, achieving all-weather maintenance-free power supply for the remote communication equipment (RRU, optical fibre repeater, small macro base station, micro cellular base station, ONU, etc.) after voltage step-down.[1]

2.2 Advantages of DC Remote Power Supply

There are many kinds of power supply schemes for DC remote power supply, and different schemes can be selected according to different scenarios. DC remote power supply has the following advantages:

(1) Remote DC power supply will not be affected by interruption of mains supply.

(2) The operating costs will be lowered, the extra costs for AC power supply will be saved, and the cumbersome work in access by electric power sector and local users to main supply can be avoided.

(3) The site selection is flexible and convenient, and is not affected by the power supply line of the mains supply.

(4) The outdoor UPS will be saved and the long-term maintenance cost of power supply can be solved.

(5) The line construction is convenient: composite optical cables are used and special transmission cables will not be required, which can save line investment.

(6) Safe and reliable: The transmission line is provided with open-circuit protection, short-circuit protection, electric leakage protection, high voltage invasion protection, and lightning protection.

3. Design of Electrical Properties of Optic/Electric Hybrid Cables for Access Network

Most of the design standards for optic/electric hybrid cables for access networks follow the design standards for outdoor optical cables, and the main reference standard is *Optical and Electrical Hybrid Cables for Access Network*[2] (YD/T2159-2010). The requirements of this standard on the electrical properties of optic/electric hybrid cables are low, and the safety and reliability of optic/electric hybrid cables in long-term operation have not been considered in detail. At present, the requirements for the electrical properties of the optic/electric hybrid cables mainly include three aspects: the electrical conductivity of the feeder and the insulating property and dielectric strength of the feeder and the finished cable.

3.1 Electrical Conductivity of Feeder: Resistivity and DC Resistance of Single Feeder

Unless there are special provisions, the conductors used in the optic/electric hybrid cables for access network are mainly copper wire and aluminum wire which are not plated with metal, and the No. 1 solid conductor and No. 5 flexible conductor specified in the standard *Conductors of Insulated Cables* (GB/T3956-2008) are usually used[3].

Conductor resistivity is a physical quantity used to indicate the resistance property of conductors. The resistance property of copper and aluminum conductors for power transmission at 20 ℃ is specified clearly in *Test of Electrical Resistivity of Metallic Materials* (GB/T3048.2-2007)[4], as shown in Table 1.

Table 1 Resistance Property of Copper and Aluminum at 20 ℃

Property / Conductor	Volume resistivity ($10^{-8}\Omega\cdot m$)	Resistance temperature	Linear expansion temperature	Density ($10^{4}g\ m^{-3}$)

		coefficient (10^{-3}/℃)	coefficient (10^{-5}/℃)	
Standard annealed copper	1.7241	3.93	1.7	8.89
Annealed aluminum wire	2.80	4.07	2.3	2.703

The DC resistance of conductor is the key factor to ensure the operation safety of optic/electric hybrid cable. If the DC resistance value is too large and the line is heated for a long time, it will lead to the rapid aging of insulating materials and short circuit of the line, which will cause safety accidents and threaten the safety of people's lives and property. Generally, according to *Conductors of Insulated Cables* (GB/T3956-2008)[3], the resistance of conductors of common specifications at 20℃ shall not exceed the maximum value specified in Table 2.

Table 2 DC Resistance of Conductor at 20℃

Nominal cross-sectional area/mm^2	Maximum conductor resistance at 20℃ (Ω/km)		
	Solid copper wire (not plated with metal)	Solid aluminum wire	Soft copper wire (not plated with metal)
1	18.1	—	19.5
1.5	12.1	—	13.3
2.5	7.41	—	7.98
4	4.61	—	4.95
6	3.08	—	3.3
8	2.27	—	2.47
10	1.83	3.08	1.91
16	1.15	1.91	1.21

3.2 Insulating Property of Feeder and Finished Cable: Insulation Resistance

Feeder insulating materials are mainly crosslinked polyethylene (XLPE), high density polyethylene (HDPE), and polyvinyl chloride (PVC). The insulating property of the feeder mainly depends on the dielectric constant of the insulating material and the thickness of the insulation layer. Dielectric constant indicates the relative capacity of the dielectric medium to store electrical energy in the electric field. For insulating materials, the smaller the relative dielectric constant is, the better the insulating property will be. PVC is easy to be polarized due to the polar side chain on its molecular chain, and its dielectric constant is larger than that of XLPE and

HDPE. However, XLPE is less susceptible to polarization than HDPE because of the reticular molecular structure formed in the crosslinking process and has the lowest dielectric constant. The relative dielectric constants of the three materials are shown in Table 3 below.

Table 3 Relative Dielectric Constants of the Three Materials [5]

Insulating Material	XLPE	HDPE	PVC
Relative dielectric constant	2.0-2.1	2.3-2.4	3.2-3.4

Under the same insulation resistance requirement, the thickness of XLPE will be the largest, followed by HDPE and PVC. In order to reduce the diameter and cost of optic/electric hybrid cable, XLPE should be used for insulation. However, XLPE has low crosslinking efficiency and high production cost at present. Taking the total cost of feeder and optic/electric hybrid cable into comprehensive consideration, HDPE is generally recommended as the insulating material for the feeder. At the same time, since PVC material has certain polarity, its oil resistance at high temperature is poor, and its filling compound compatibility in the long-term working condition of optic/electric hybrid cable is not good, if PVC is used as the insulating material for the feeder, it is recommended that the semi-dry structure be adopted for the optic/electric hybrid cable.

Comparison of insulating properties of filling compound-filled optic/electric hybrid cable and semi-dry optic/electric hybrid cable: cable filling is used to fill the void of cable core of the filling compound-filled optic/electric hybrid cable to achieve water blocking effect, and the main component of cable filling is vaseline, which is also a dielectric material and is conductive to increasing the insulation resistance of the optical cable. The semi-dry optic/electric hybrid cable uses dry water-stop for water blocking and mainly relies on air insulation; since the relative dielectric constant of air is very low, the insulating property of semi-dry optic/electric hybrid cable is slightly better than that of filling compound-filled optic/electric hybrid cable.

HDPE, MDPE and LSZH are usually used as sheathing materials of the optic/electric hybrid cables for the access network. The dielectric constants of these three materials are all small and their insulating properties are excellent.

During the long-term operation of the optic/electric hybrid cable, the feeder will be heated with current flow, and its working temperature is generally below 70℃. As a result, in actual production, the insulation resistance of the feeder at 70℃ will be controlled to be not less than the value shown in Table 4 below. The insulation resistance of finished cable is controlled to be no less than 10000MΩ·KM at room temperature. For use in high voltage areas, higher values of insulation resistance should be considered.

Table 4 Minimum Insulation Resistance of Copper Wire at 70℃

Wire \ Insulating material	HDPE	PVC
	Minimum insulation resistance at	Minimum insulation resistance at

	70 ℃	70 ℃
1.00	0.0100	0.0100
1.50	0.0100	0.0100
2.00	0.0098	0.0098
2.50	0.0090	0.0090
3.50	0.0085	0.0085
4.00	0.0070	0.0070
5.00	0.0068	0.0068
6.00	0.0060	0.0060
8.00	0.0058	0.0058
10.00	0.0056	0.0056

3.3 Dielectric Strength of Feeder and Finished Cable: Voltage and Arc Resistance

Feeders and finished cables shall have sufficient dielectric strength to avoid the occurrence of dielectric breakdown during the use of optic/electric hybrid cables. Dielectric breakdown is the phenomenon that with the continuous increase of the voltage to a certain limit value, the resistivity decreases to a certain value, the current increases, and the polymer loses its insulating property due to local conductivity. There are three main forms of dielectric breakdown: intrinsic breakdown, thermal breakdown and discharge-induced breakdown [5]. The optic/electric hybrid cable for access network works in the power-up state for a long time, and the heat is generated by the conduction of the feeder. As the time goes on, when the insulating material is aged to a certain extent, thermal breakdown and discharge-induced breakdown will be caused. In order to ensure the use safety and service life of the optic/electric hybrid cable, the use of the insulating materials for the feeder must be paid attention to. The insulating materials must be new materials with high performance; recycled materials and environmentally friendly materials must not be used. In addition, the thickness of the insulation layer and the concentricity of the insulation must be ensured in the process of insulation extrusion.

The dielectric strength of the feeder and the finished cable is measured by means of voltage resistance test and arc resistance test. In the voltage resistance test, the voltage will be rapidly increased to the voltage specified in the standard and kept for the specified time. It will be observed that whether the insulation layer and sheath are broken down or not. *Optical and Electrical Hybrid Cables for Access Network* (YD/T2159-2010) [2] specifies that the test temperature shall be 20 ± 5 ℃, the standard voltage shall be 2KV, and the time for keeping the voltage shall be 5min. This standard can meet the requirements for the general use of optic/electric hybrid cables. However, since the State Grid Corporation also began to introduce the use of optic/electric hybrid cable, considering the service environment, the standards for the voltage resistance test should be more stringent.

In the arc resistance test, the gas between the two polarities is broken down to generate arc and spark under a certain high voltage electric field, which

results in the formation of conducting layer on the surface of the sheath material. The resistance of the polymer to arc and spark is usually expressed by the length of the time required. At present, arc resistance test has not been introduced in the standards for optic/electric hybrid cables. With the expansion of the application scope of optic/electric hybrid cables and the increased complexity of the service environment, it is necessary to test the arc resistance of optic/electric hybrid cables.

5. Conclusion

The optic/electric hybrid cable integrates the optical unit and the electrical unit, and solves the difficulty of the power supply for distributed base stations with excellent comprehensive performance. It has been used more and more widely in Inner Mongolia, Liaoning and other areas where the power supply is difficult. With the gradual expansion of the application scope and the increase of the service environment, the electrical safety of the optic/electric hybrid cables becomes increasingly prominent. In the structural design and production control, the optical transmission performance and electrical transmission performance should be considered at the same time, and the DC resistance, insulation resistance and dielectric property should be controlled.

Smart Link Better Life.

Bibliography

[1] Shi Huiping, Tan Guohua, Fu Kai. Development and Applications of Electrical Wire and Optical Fibre Composite Cable. Study on Optical Communications. 2011 (3): 32-36.

[2] Optical and Electrical Hybrid Cables for Access Network. Communications Industry Standard of the People's Republic of China. YD/T2159-2010.

[3] Conductors of Insulated Cables. National Standard of the People's Republic of China. GB/T3956-2008.

[4] Test Methods for Electrical Properties of Electric Cables and Wires -Part 2: Test of Electrical Resistivity of Metallic Materials. National Standard of the People's Republic of China. GB/T3048.2-2007.

[5] He Manjun, Chen Weixiao, Dong Xixia. Polymer Physics. Fudan University Press, 2001.

长飞光纤光缆股份有限公司
Yangtze Optical Fibre and Cable Joint Stock Limited Company
地址：武汉市光谷大道9号（430073）
ADD：No.9 Optics Valley Avenue, Wuhan, Hubei, China(P.C.: 430073)
电话(Tel)：+86 400-991-6698
邮箱(Email)：marketing@yofc.com
www.yofc.com