Study of the Power Fiber to the Home Technologies Based on the OPLC Cable

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Abstract

The power fiber to the home (PFTTH) is a technical support of smart grid construction. It has been found that the optical fiber composite low voltage cable (OPLC) is a better medium to realize the power fiber to the home. Two types of OPLC cables with optical units of both loose tube and tight buffer structures have been designed, fabricated and tested. The test results show that the OPLC cables meet the technical specifications. According to our investigations, the OPLC cables with dry loose tube structure optical unit have better mechanical and optical performance, and thus are proposed. The OPLC cables have been used in the PFTTH pilot projects in China successfully.

Keywords: Power; fiber; cable; smart grid; voltage; loose tube; tight buffer; optical unit; PFTTH; OPLC

1. Introduction

In 2009, the State Grid Corporation of China (SGCC), the country's largest power grid carrier, unveiled a plan to build a "strong and smart grid" in three steps: through a planning and pilot phase, a comprehensive construction phase and finally, an improvement and refining phase. According to the SGCC's plan, the construction of an ultra-high voltage power grid and an urban and rural distribution network will be completed by 2020. The power fiber to the home (PFTTH) is a technical support of smart grid construction. Smart grid can be integrated with telecom networks, cable TV networks, and the internet networks through PFTTH. In order to make full use of the low voltage power cable resources, which have been connected to each family, it is necessary to develop a new type of cables, that is, the optical fiber composite low voltage cable (OPLC). The OPLC cable is a better medium to realize the power fiber to the home. . Firstly, this paper will describe the OPLC cable. Secondly, the OPLC cables with different optical unit structures will be designed, fabricated and tested. Finally, we will propose different OPLC cable designs.

2. Construction of the Communication Terminal Access Network

In 12th Five-Year Communication Plan", the SGCC mentioned the communication terminal access network firstly, which is an important part of power communication network, and the extension of the power backbone communication network [1]. The communication terminal access network will cover all levels of distribution terminal site, the user meter, indoor communication terminal, the electric vehicle charging stations and distributed energy sites etc. It consists of 10kV and 0.4kV communication terminal access networks as well as user indoor network. The layered structure of the communication terminal access network is shown in Figure 1 [2]-[3].

The 10kV communication access network is an important component of electric power communication network. It is mainly covering power distribution switching station, ring unit, pole transformer, box-type substation, power distribution rooms and so on. The 10kV communication access network provides communication support for the power distribution automation, power consumption information collection and intelligent community.

The 0.4kV communication access network is an important communication infrastructure to achieve the power information collection, two-way interactive marketing, information management for electric vehicle charging station and renewable energy access. For the smart grid development higher demands on the communication capacity and bandwidth are required. The power fiber to the home (PFTTH) is a new development technology of fiber to the home. The OPLC cable is an important part of the PFTTH systems.

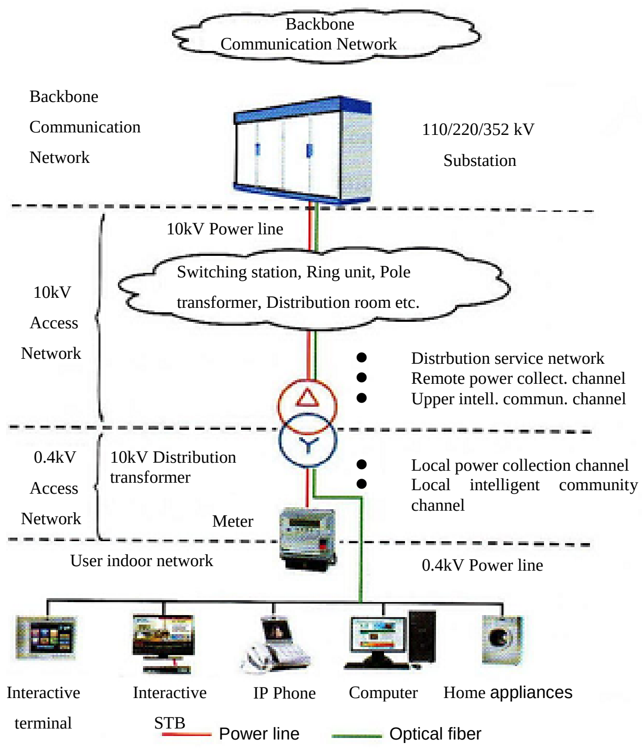


Figure 1. Layered structure of communication terminal access network

3. The OPLC Cable

3.1 Structure of the OPLC Cable

The optical fiber composite low voltage cable, referred to as OPLC, is a new type of cables, which mixes optical fiber unit in traditional low voltage power cable. The cable has double transmission abilities for both low voltage power and optical communication. It is mainly used for a voltage equal and below 0.6/1.0kV.

The OPLC cables for 0.6/1kV and below distribution network are mainly used for intelligent community or offices. The cables can be connected to the optical-electrical panel box through pipelines and tunnels or by buried way. The OPLC cables for 300/500V and below distribution network are mainly used for user access. The cable can be connected to the smart meters and other devices by vertical or horizontal layout.

According to the insulated conductors and optical unit, the typical structures of OPLC cables are shown in Figure 2.

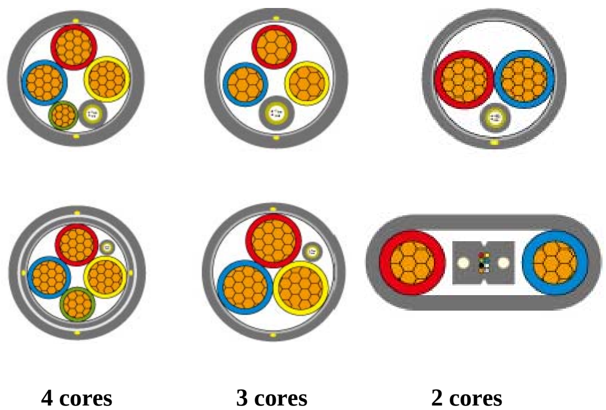


Figure 2. Typical structures of OPLC cables

3.2 OPLC Cable Design

3.2.1 Structure Design of the Optical Unit

In order to avoid electromagnetic interference and the formation of current loops, the optical unit should be non-metallic. Taking into account the dimensions of the optical unit, optical fiber excess length and cost, two kinds of optical unit structure are designed, as shown in Figure 3.

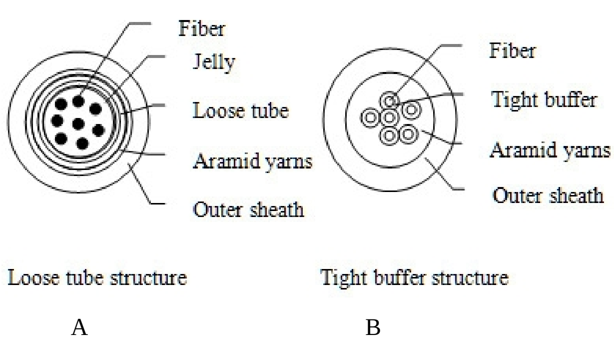


Figure 3. Structure diagrams of two optical units

Figure 3A shows the loose tube structure. The fiber excess length is controlled to 0.1–0.2% to meet the bending and tensile applications. In order to improve the optical unit performance against lateral pressure, we increase the thickness of the loose tube. A stranded layer of aramid yarn is used to enhancing the strength of the optical unit. The loose tube structure is suitable for horizontal or vertical layout in the buildings.

Figure 3B shows the tight buffer tube structure, which is a gel-free, or totally dry, stranded tube construction with high cleanliness. A stranded layer of aramid yarn is used to enhancing the strength of the optical unit. The tight buffer tube structure is suitable for horizontal or vertical layout in the buildings.

For comparison purpose, a series of mechanical tests, such as tensile, crush, impact, bending and torsion, were carried out on the OPLC samples with both loose tube and tight buffer structures. The test results show that the OPLC cables meet the technical specifications [4].

The tensile strength tests show that the OPLC cables with loose tube structure have better mechanical and optical performance than the tight buffer structure OPLC cables. The reason is that, there is almost no fiber excess length in the tight buffer tube.

The totally dry loose tube structure is a craft-friendly design allowing for faster cable preparation and less cleanup.

3.2.2 Location of the Optical Unit

In order to investigate influence of the optical unit location in cable on fiber attenuation, two types of OPLC cables with different optical unit locations were designed and fabricated, as shown in Figure 4. In Figure 4A the optical unit is placed in the center of the cable. In Figure 4B the optical unit is placed at an eccentric position and is stranded together with insulated conductors.

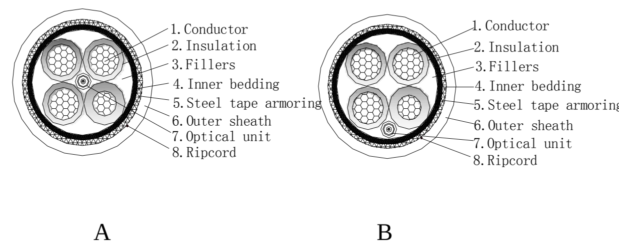


Figure 4. Location of the optical unit

For comparison purpose, tests of tensile, crush and impact were carried out on the OPLC cables of both Figure 4A and Figure 4B.

The crush test results show that the OPLC cables with optical unit in the cable center (Figure 4A) do not meet the technical specifications [4]. We speculated that there was possible following reason for this failure. During the crush test, the conductors moved to the cable center, and thus exerted a greater pressure on the optical unit.

Considering the better mechanical performance and easier stripping of optical unit, it is appropriate to place the optical unit at an eccentric position of the cable.

3.2.3 Stranding Tension Control

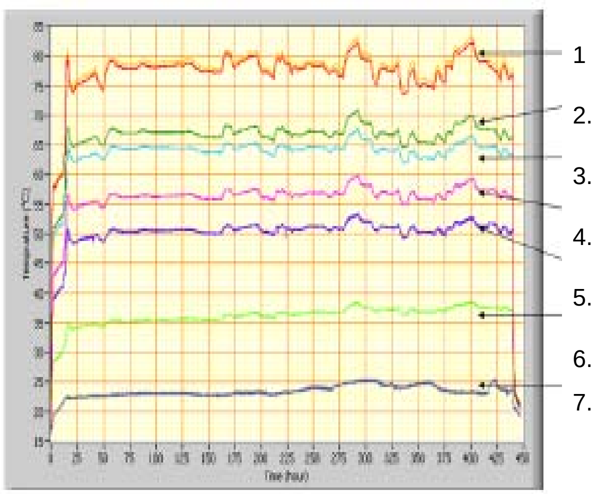
The stranding tension control is key technology for producing OPLC cable. Too much tension will cause fiber stress, consume fiber excess length, therefore, will result in an increase in optical attenuation. If the tension is too small, the optical unit is easy to bend that will also cause deterioration of optical performance. In the development of OPLC cable, we refer to the stranding tension control process for producing the submarine optical fiber composite power cable. By monitoring tension, stress and strain of optical unit during production, we can determine the suitable stranding tension for the OPLC cable. In the production process, we use active pay-off tension control technology. By taking these measures, we are able to produce the OPLC cable with excellent mechanical and optical performance.

3.2.4 Study on the Heat Resistance

Taking into account a long operational lifetime of OPLC, users and manufacturers are very concerned about compatibility of the optical unit with the long-term working temperature of the power cable. The purpose of heat resistance test is to determine temperature range of the optical unit and effect of temperature on optical performance, when the insulated conductors are in normal working temperature.

In order to measure temperature of conductors, optical unit etc., a set of on-line temperature measuring system has been developed. During the test, we let a continuous current through conductor to increase the conductor surface temperature to about 75~80℃ over a long period of time (20 days). During this time, both surface temperatures of individual cable components and optical attenuation are monitored

Figure 5 shows the measured temperature curves of conductors, insulation, sheath and optical unit. From Figure 5, we can see that the surface temperature of the optical unit, that is the temperature between conductors, is less than 70℃ when the conductor surface temperature is less than 80℃. [3].



1. Insulated conductor temperature, 2. Temperature between conductors

3. Temperature of the cable stacks, 4. Temperature of armored steel tape

5. Cable surface temperature, 6. Temperature at cable grounding point

7. Environment temperature

Figure 5. The measured temperature curves

Figure 6 shows the measured attenuation changes of optical fibers. From Figure 6, it can be seen that the increases in optical attenuation are less than 0.5dB/km [3].

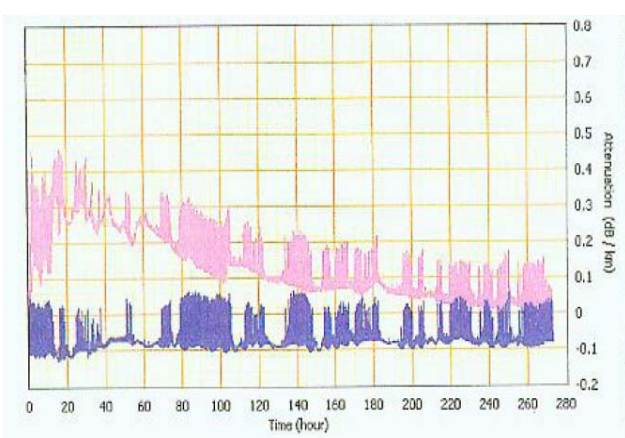


Figure 6. The measured attenuation changes

3.3 Advantages of the OPLC Cable and its Application

In comparison with the layout of a separate low-voltage power cable and optical cable, the OPLC cable has the following advantages:

1. Function combination: In the OPLC cable, optical fiber cable and low-voltage power cable are combined into one, so the OPLC cable has double transmission abilities for both low voltage power and optical communication.

2. Business combination: Using OPLC cables, together with the corresponding optical equipments and devices, the XPON networks can be constructed. On one transmission line we can engage in a variety of businesses, such as IPTV, Internet access, multimedia phones, power consumption information collection, intelligent community service etc. This means that the electric service, information service and community service are integrated as a whole.

3. Channel combination: Through the PFTTH, the smart grid is integrated with telecommunication, cable TV and internet networks. In this way, we are able to avoid duplicate constructions, thus save a lot of resources, such as pipes, metal, plastic. The cost of user network construction can be effectively reduced.

4. Construction combination: For transmission of both low voltage power and optical communication, only one laying construction is required. Thereby the second laying work is not necessary. The laying construction cost can be reduced.

PFTTH system is formed by the OPLC cable and XPON technologies. It is a new technology. PFTTH system is comprised of power private network and public network. The power private network is used for electricity consumption information collection, electric vehicle charging, electric power distribution automation and self-service payment business. The public network is used for a complement to three networks, that is, telecommunication networks, cable TV networks, and internet networks.

The PFTTH Pilot projects began last year and will extend through mid-year 2011. The pilot projects have involved 37,000 households in 20 cities from 14 provinces in China, and will use 1,800 OPLC cable kilometers. The PFTTH program will be extended this year to include 62,000 households and 10,000 OPLC cable km. The PFTTH technology has broad prospects, with an outlook of 2.8 million households and 200,000 OPLC cable km by 2015.

4. Conclusions

The power fiber to the home (PFTTH) is a new development technology. It is a technical support of smart grid construction. Through PFTTH the electric-services are integrated with telecom, video, and internet services.

The OPLC cable is a new type of cables that combines power and fiber applications [4]. The OPLC cable is a better medium to realize the power fiber to the home. This cable offers a cost savings of about 40% compared with traditional methods that have separate low-voltage and optical communication cables.

The experiment study indicates that the OPLC cables with dry loose tube structure optical unit have better mechanical and optical performance, and thus are proposed.

Considering the better mechanical performance and easier stripping of optical unit, it is appropriate to place the optical unit at an eccentric position of cable.

The stranding tension control of optical unit is key technology for producing OPLC cable. In the development of OPLC cable, we refer to the stranding tension control process for producing the submarine optical fiber composite power cable.

For study on the heat resistance, a set of on-line temperature measuring system has been developed. The measured results show that when the conductor surface temperature is less than 80℃, the surface temperatures of optical unit and increase in optical attenuation are less than 70℃ and 0.5dB/km, respectively.

Since 2010, the OPLC cables have been used in the PFTTH pilot projects in China successfully.

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