

Application of PFTTH in Smart Grid

Liu Jianming, Wang Jiye, Fan Pengzhan, Zhuang Zichao

State Grid Information & Telecommunication Co., Ltd., No.1 Lane 2, Baiguang Road, Beijing, China 100761

jianming-liu@sgcc.com.cn, jiye_wang@sgcc.com.cn, pzf@sgcc.com.cn, zichao-zhuang@sgcc.com.cn

Abstract— As a widely used communication technology and the top choice in the construction of communication network, optical fiber communication is characterized by its high bandwidth, good anti-interference and optimal cost-efficiency. By using OPLC (Optical fiber composite Low-voltage Cable), PFTTH (Power Fiber to the Home) realizes the simultaneous transmission of energy and information. The PFTTH is the extension of the power communication network in the field of smart power consumption, which will be used to acquire power users' electric energy data, interact with customers and promote the share of the society resources. The article designs the OPLC, tests and analyzes its performance and also studies the key technologies of PFTTH and its application in the smart grid.

Keywords— Optical fiber Communication, OPLC (Optical Fiber Composite Low-voltage Cable), PFTTH (Power Fiber to the Home), Smart Grid, Smart Power Consumption

I. INTRODUCTION

With the development of constructing the smart grid, smart power consumption, as a significant stage where the interaction between the smart grid and customers is realized, is an important area that best illustrates smart grid interaction. Therefore, the construction of low-voltage power consumption communication network that links terminal users has become the key to smart grid construction. PFTTH (Power Fiber to the Home) means to lay the optical fiber together with low-voltage cable, and thus reach each electric meter at each home. Together with xPON (passive optical network) technology, PFTTH brings about electric energy data, two-way interaction in smart power consumption and 'triple play' service. As a result, PFTTH offers a final resolution for end users to access to the smart grid and large-amount power information interaction.

With the application of OPLC (Optical Fiber Composite Low-voltage Cable), PFTTH integrates the power and IT industries, so as to ensure power supply as well as the 'Last Mile' informatization in power grid. Meanwhile, the need of access to multi-information service is met, and people can avoid kinds of repetitive cabling, raise resource utilization, decrease production cost, and realize energy saving and emission reduction.

II. OPLC (OPTICAL FIBER COMPOSITE LOW-VOLTAGE CABLE) AND PERFORMANCE ANALYSIS

A. OPLC

OPLC means to integrate optical units consisting of optical fibers and beam tubes into cables in the production of low-voltage (0.4kV). It can realize both power transmission and optical-communication at the same time, and thus bring about simultaneous transmission of both energy and information.

The structure of OPLC is illustrated in Figure 1.

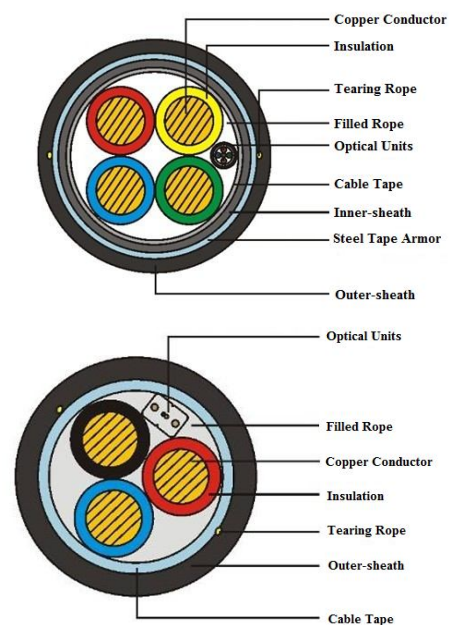


Figure 1. Structure of OPLC

B. Performance of OPLC

In the development of OPLC, attention should be paid to the influence of temperature on fiber performance in normal operation and in time of momentary short-circuit, the influence of mechanical stress on fiber performance, the influence of electromagnetic field on fiber performance, and whether the service times of fiber and cable have effect on each other.

1) Thermal Influence: Optical fiber temperature measurement, the technique currently employed in cables for power transmission and distribution based on the Brillouin Scattering Principle and the Raman Scattering Principle for Temperature. As the OPLC integrates optical units in cables, and the technique principle, fiber material and wave length used by the optical signal are different from those of optical fibers in optical fiber temperature measurement, the

performance of the optical fiber would not change due to the heat generated by the power line during the operation.

The temperature curve of all temperature measuring points of OPLC heated by constant current is shown in Figure 2.

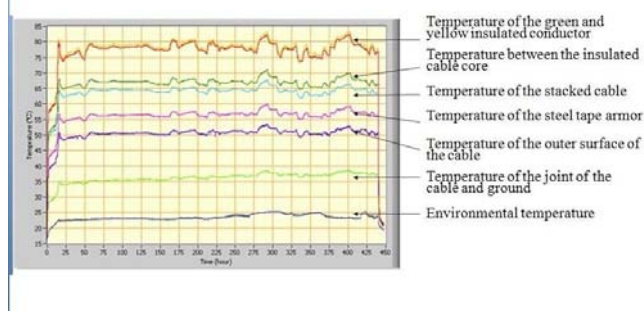


Figure 2. Temperature Curve of All Temperature Measuring Points Heated by Constant Current

The added damping curve of OPLC heat generated by constant current is shown in Figure 3.

Figure 3 shows that the changing scope's magnitude of the optical fiber's added damping is less than 0.14dB/km during the whole course.

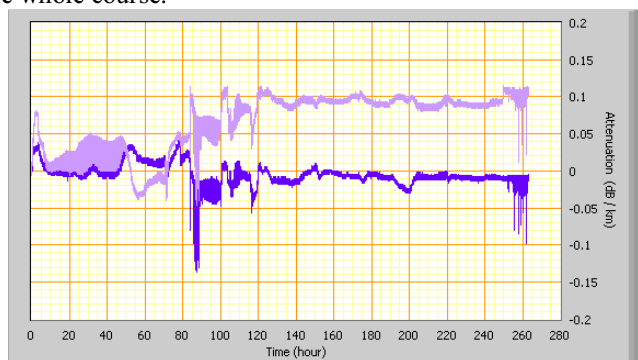


Figure 3. Added Damping Curve of OPLC Heated by Constant Current

It is required in [1] that the working temperature of optical cables is among $-30^{\circ}\text{C} \sim +70^{\circ}\text{C}$, while the working temperature of the low-voltage cables is $-15^{\circ}\text{C} \sim +70^{\circ}\text{C}$ as required in [2], the highest temperature being the same. When the “trickle current” detection is conducted in allusion to the operating environment, performance and temperature of optical cables in product test, it is found that there is no trickle current within constant 24 hours in an environment of 70°C .

2) Mechanical Stress Influence: The mechanical influences on the optical fibers include stretching, flattening, striking, repeated bending, twisting, winding, circumnutating, etc.

The optical cables that pass mechanical test should meet the following requirements:

- All optical fibers will not fracture; the sheath has no flaw that can be seen by eyes;
- Electric conduction should be kept in metal units within the optical cable;
- No damage should be seen by eyes in all units within the cable core wrapped by sheath;

- No residue added damping should be found after the experiment with optical fibers.

The stretching and flattening ability of optical cables should meet:

- Under the stipulated long-term tension, no obvious added damping should be seen in optical fibers with zero fiber strain;
- Under the stipulated short-term tension, the added damping should be less than 0.10dB, and the fiber strain should be no more than 0.1%;
- Under stipulated long-term flattening pressure, there should be no obvious added damping in optical fibers;
- Under short-term flattening pressure, the added damping should be less than 0.10dB.

The mechanical stress experiment on added damping curve of optical fibers is shown in the following figures (figure 4 - figure 8).

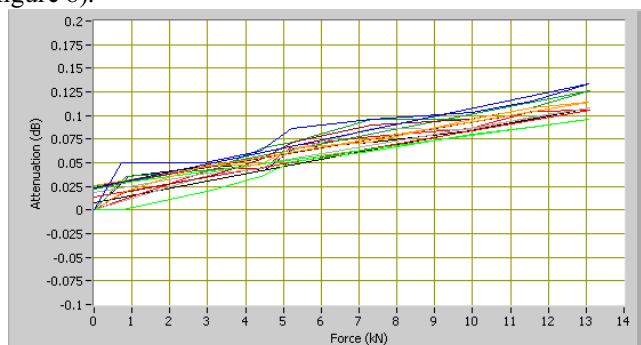


Figure 4. Added Damping Curves of Optical Fibers in Stretching Experiment

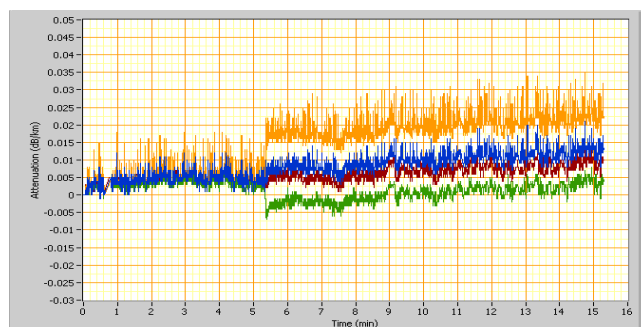


Figure 5. Added Damping Curve of Optical Fibers in Striking Experiment (with a height of 0.5M)

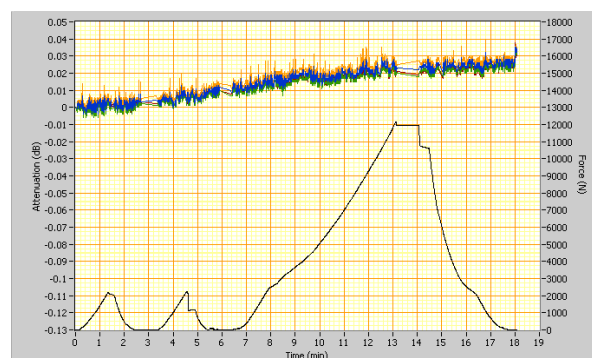


Figure 6. Figure 6. Added Damping Curves of Optical Fibers in Flattening Experiment

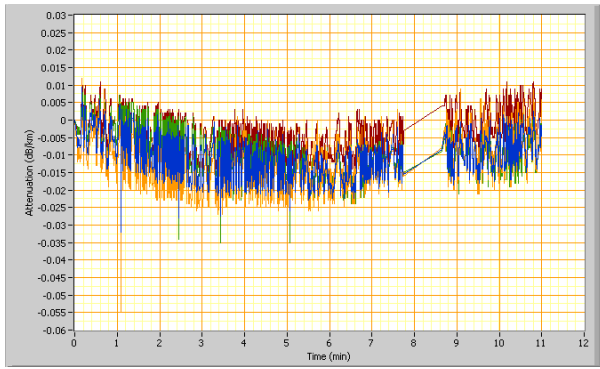


Figure 7. Added Damping Curves of Optical Fibers in Repeated Bending Experiment

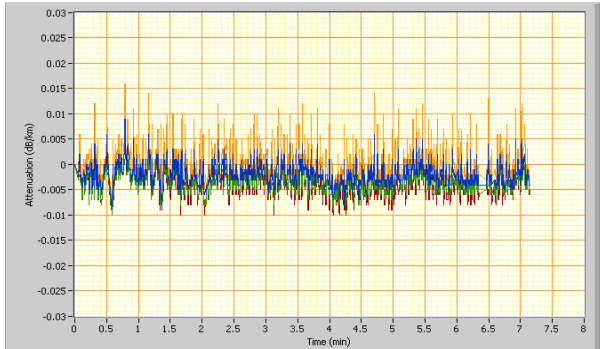


Figure 8. Added Damping Curve of Optical Fibers in Twisting Experiment ($\pm 90^\circ$)

Since the optical units are protected when the OPLC is formed, the technique and performance meet the requirement.

3) Electromagnetic Influence: Optic-electronic voltage transformers are employed to detect current in the transformer substation. Combining Optics sensing technology and fundamental principles of electronics, optic-electronic voltage transformers include active electronic current transformer and passive magneto-optical glass current transformer. Optical fibers are used to transmit light pulses.

Since the optical fiber, with quartz as its basic component, is able to transmit light but cannot conduct electricity or be affected by the electromagnetic field, the optical signal transmitted in the optical fiber will not be affected by the electromagnetic field, and we say optical fiber transmission is resistant to electromagnetic interference. Based on this feature, the optic-electronic voltage transformers apply optical fiber in transmitting light pulse signals, and the optical-communication will not be affected by the electromagnetic environment.

4) Service Time Influence: With regard to its serving time, the structure of OPLC decides the well match between cables and optical fibers in their serving time. The serving time of cables is decided by the oxidative induction time of sheath, with a designed using time of 20 years and a much longer service time in reality. The designed using time of on-land-cable is also over 20 years. The factors influencing serving time include:

- Existence and expansion of microcrack on the surface of optical fibers;

- Erosion on the surface of optical fibers caused by water and steam molecules in the air;
- Long-term stress caused by irrational allocation of optical fibers.

In OPLC, the optical fibers are protected in sheath, which is filled by a special factice that can avoid the water, moisture, harmful gas and heat affections. Meanwhile, the OPLC is firm enough to confined external forces and the optical fibers would not be influenced. As a result, the serving time of optical fibers in OPLC can be ensured.

III.NETWORK OF PFTTH

Integrating cables and optical fibers into a whole, OPLC transmits power and information simultaneously so as to realize the double-function of power supply to end users and information transmission. The low-voltage distribution net should be taken into consideration in the design of PFTTH.

A. Network Composition of PFTTH

The smart grid communication network includes the core network and access network, with PFTTH as the access network. PFTTH is the access method to employ the optical medium in OPLC to link communication station end and end users. A PFTTH system is composed of xPON master, optical cable distribution point, user access point and xPON terminal, as is illustrated in Figure 9.

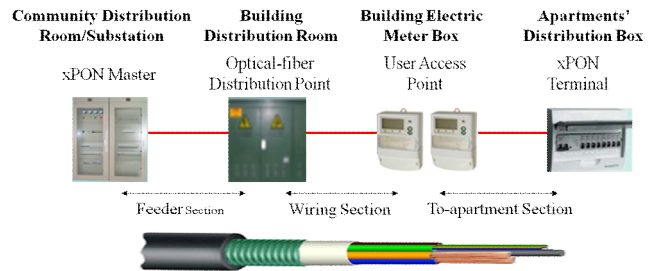


Figure 9. Network Composition of PFTTH

In the application of PFTTH, the xPON master is usually set in the 10 kV community distribution room or the 110kV substation, the optical cable distribution point are set in the building distribution room, the user access point are set within the building electric meter box, and the xPON terminal is located in the apartments' distribution box.

B. Network Structure of PFTTH

The network structure of PFTTH is shown in Figure 10.

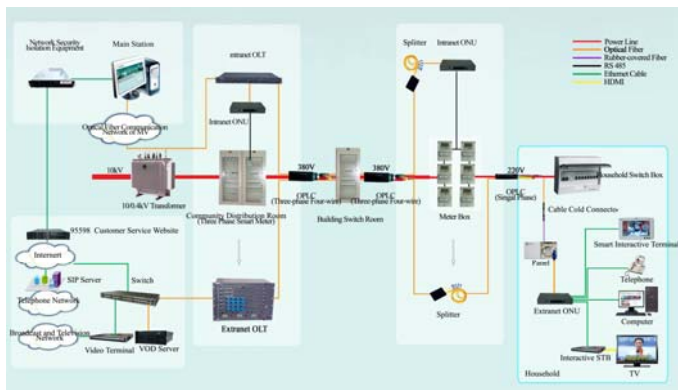


Figure 10. Network structure of PFTTH

It can be seen from the figure that three-phase four-wire OPLC is introduced from the 10/0.4kV low-voltage side (xPON master) of the transformer; and through the building distribution room (optical cable distribution points), the single-phase OPLC is introduced to the electric meter box (access points of users) and finally to the apartments' distribution box (xPON terminal). The network supports both energy and information at the same time.

IV. APPLICATION OF PFTTH IN PILOT COMMUNITIES

By laying optical fibers along with low-voltage cable, PFTTH constructs a local communication network for smart power consumption in communities, provides high-speed and reliable broadband access. Together with other means of communication, PFTTH can provide customers with smart power consumption interactive service.

The business types of PFTTH are power-system-related services and extended services. Power-system-related services include AMI system, Distributed Resources Management, and Electric Vehicle Orderly Charging. The extended services consist of smart home-based services, IP data service, voice service, video service and general information service.

Figure 11 illustrates a typical smart power consumption community, including the main station of Electric Energy Data Acquisition, the property management centre, Two-way smart meter, photovoltaic power generation equipment, charging equipment for electric vehicle, smart interactive terminal, smart socket, and equipments offering security service in families.

Ever since 2009, the State Grid Corporation of China (SGCC) explores PFTTH pilot areas in Beijing, Shanghai, Zhejiang, etc. Currently, 23,000 families have access to PFTTH, and the operation effect has reached the designed requirement.

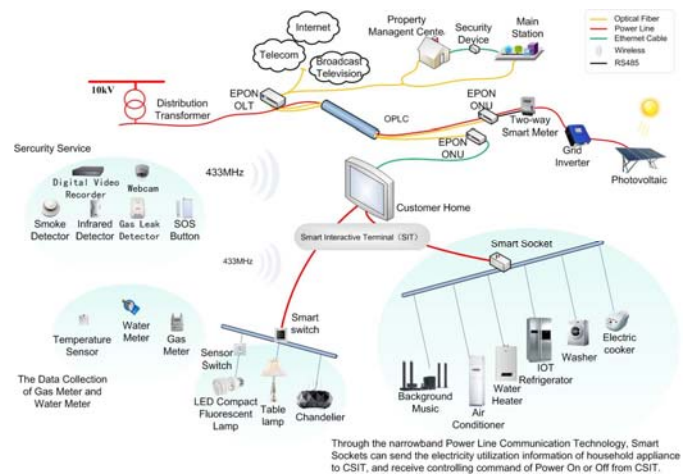


Figure 11. Applications of PFTTH in Smart Power Consumption

V. CONCLUSION

Through application of PFTTH, the simultaneous transmission of both energy and information is achieved, so as to promote resource sharing, decrease comprehensive cost, save space, meet customers' need for information when providing electric service, and offer a more convenient and modern life style. The developing strategy of building the strong and smart grid and the rapidly increasing need for information and communication have brought forth huge market opportunity for the development and application of PFTTH.

REFERENCES

- [1] *Optical Cable Specification*, GB/T 7424-2003
- [2] *Code for Design of Cables of Electric Engineering*, GB 50217-2007