# Research on power fiber-to-the-home operation and maintenance technology based on fiber analysis method

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***Abstract*—FTTH (fiber-to-the-home) is a transmission method of optical fiber communication. The power fiber-to-the-home is an important part of the overall construction of power fiber-optic cable communication network. The monitoring, management and fault location of power optical fiber resources are an important aspect of operation and maintenance work. This paper combines the principles of power optical fiber sensing, engineering and system construction characteristics and other factors to make the main monitoring methods. The dimensional platform provides an integration idea.**

***Keywords—Power Optical Fiber to Home; OPLC; Operation and Maintenance Platform***

## I. INTRODUCTION

FTTH (fiber-to-the-home) is to directly connect the optical fiber to the user's home (where the user need) [1]. In the low-voltage communication access network, the optical fiber composite low-voltage cable (OPLC) is used, and the optical fiber is laid with the low-voltage power line to realize the meter-to-household[2] network integration and other services. Fiber-to-the-home (FTTH) power solves the problem of terminal access of the information highway, and can meet the requirements of informatization, automation and interaction with the power consumption of smart grids[3]. While providing electric power, it realizes the same network signal transmission of telecommunication network, radio and television network and the Internet, providing users with a more convenient and modern way of life[3]. Fiber-to-the-home can realize the co-construction and sharing of network infrastructure, greatly reduce the implementation cost of the "triple play", improve the comprehensive operational efficiency of the network, and have obvious advantages in energy saving and environmental protection.

## II. ANALYSIS OF KEY TECHNOLOGIES OF POWER FIBER-TO-THE-HOME OPERATION AND MAINTENANCE PLATFORM

With large-scale construction of fiber-to-the-home projects, the optical fiber operation and maintenance management system have become particularly important. The main purpose of the construction of the optical fiber operation and maintenance system is to provide a visual and operable management platform for the optical network, including equipment network elements and lines. management. Compared with the traditional optical fiber operation and maintenance management system, the fiber-to-the-home operation and maintenance platform are based on the optical fiber operation and maintenance management system platform, focusing on the management and monitoring of the access network optical fiber lines and related PON equipment. Compared with the operator's fiber-to-the-home management platform, the power fiber-to-the-home operation and maintenance platform adds the management of power services in the system, including data collection of water, electricity, and gas, as well as the information collection channel for smart home appliance information in the later stage.

The purpose of construction of the power fiber-to-the-home operation and maintenance platform is to organically integrate the management, operation and maintenance methods of power fiber-to-the-home cables and optical communication equipment. So as to realize real-time monitoring of equipment status, resource management, continuation, line inspection, automatic monitoring, fault warning and fault location of optical cable[4]. It provides a unified platform for the operation and maintenance of the optical cable network under the smart grid, which is convenient for the project implementation and the maintenance of the optical network system. While improving the availability and maintenance efficiency of the optical cable network, it also reduces the costs of operation and maintenance[5].

Platform construction includes the platform equipment management system, the optical fiber line management system and the integrated management system of the power fiber-to-the-home operation and maintenance platform. To ensure the efficient and reliable operation of large power fiber users, the network management function should be able to quickly open various services, support the rapid deployment of multi-service access, and be able to monitor faults in real time, quickly and accurately locate various faults, and compress the duration of faults loss, and can carry on the statistical analysis of the network equipment operation condition, in order to adjust the

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equipment configuration reasonably, optimize the network security, maximize the equipment utilization rate.

On the premise of ensuring the quality of network communication, the maintenance efficiency is improved and the maintenance cost is reduced. Functionally, the network management system should have five basic functions: event reporting, configuration management, performance management, fault management and security management[6]. Divided from the structure, the network management system should include network element layer network management and network layer network management, respectively manage network element layer and network layer objects[7]. According to different requirements, the network element layer and network layer network management can be deployed centrally or distributed[3]. Unified management of different devices, and remote management of client devices[8].

## III. DESIGN OF DISTRIBUTED POWER OPTICAL FIBER LINE MANAGEMENT SYSTEM

At present, the monitoring of the optical cable is to realize the indirect monitoring of the entire optical cable by monitoring a specified optical fiber or several optical fibers in the optical cable. The monitoring of the power optical cable network mainly adopts the Optical Time Domain Reflector meter (OTDR) to effectively identify and locate the fault of the optical fiber communication line [9]. The multi-parameter distributed optical fiber sensing mechanism and measurement control technology are studied from the actual needs of the state monitoring of the power optical cable network, and the distributed optical fiber Rayleigh scattering sensing, Brillouin scattering sensing and Raman scattering sensing, optical fiber Grating sensor technology, etc [10]. Integrate the hardware structure of the fiber optic sensor, and implement multi-parameter sensing and measurement control on the basis of the general architecture, which is compatible or expanded with feature function modules, and expands its intelligent line inspection and measurement functions. Thereby, monitoring capability of one sensing device covering almost all optical cable lines in a substation is realized, and the complexity of system deployment is reduced [11].

It has important theoretical significance and engineering practical value to provide monitoring equipment with wide area monitoring, high reliability, low cost and market promotion value for power optical cable network monitoring. Typical distributed optical fiber sensors in the power industry are shown in Table 1.

TABLE I. TYPICAL DISTRIBUTED OPTICAL FIBER SENSORS IN POWER INDUSTRY

| Sensing Mechanism | Type | Key Parameter | Application Scenario |
|---|---|---|---|
| Rayleigh scattering | OTDR | 1)measurement distance: 200km; 2)spatial resolution: 1m; 3)positioning accuracy: 1m. | Cable fault monitoring |
| | Φ-OTDR | 1)measurement distance: 50km; 2)spatial resolution: 1m; 3) Frequency response range: 1Hz to 100Hz; 4)frequency accuracy:±1Hz | Power facility anti-intrusion, anti-external break monitoring, etc. |
| | P-OTDR | 1)measurement distance: 50km; 2)spatial resolution: 10m; 3) Frequency response range: 1Hz to 1kHz; 4)frequency accuracy:±1Hz | Overhead line wind and dance monitoring, power facility anti-intrusion, anti-external break monitoring, etc. |
| Brillouin scattering | B-OTDR | 1)measurement distance: 40km; 2)spatial resolution: 1m; 3) positioning accuracy: 1m; 4) Strain accuracy:30με | Lightning strike, fire and other abnormal temperature rise monitoring, icing monitoring, etc. |
| Raman scattering | R-OTDR | 1)measurement distance: 10km; 2) spatial resolution: 1m; 3)positioning accuracy: 1m; 4)temperature accuracy: 1°C | Cable hot spot monitoring, fire warning, etc. |

### A. OTDR

OTDR is used primarily to identify and locate faults in optical fiber lines [12]. The system structure of a typical OTDR is illustrated in Figure 1. The signal control and processing unit are equipped with a clock to trigger and time the pulse generator and the analog-to-digital conversion unit. The product of the signal returning time and the speed of light in the fiber corresponds to the scattered position, so as to realize the positioning of the scattered points in each position of the fiber [9].

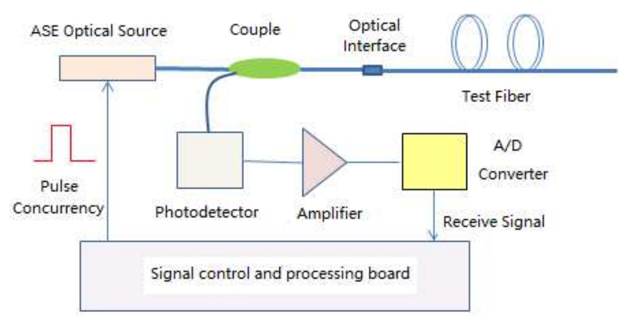



Fig. 1. Schematic diagram of OTDR

Figure 2 displays the curve measured using OTDR. When there is an event point in the tested fiber, the continuity of the detection curve will be interrupted. For example, there are usually end-face reflection peaks at the front end and the tail end of the optical fiber, and splice loss at the splice point makes the test curve after the splice position move down as a whole. At the same time, there are end-face reflection peaks and connection loss of the connector, and the back-end signal directly falls into the noisy area of the photodetector except for the end-face reflection peak at the broken position of the fiber.

According to the shape characteristics of the signal at the discontinuity of the OTDR curve, the event information in the optical fiber line can be inferred. In the power field, OTDRs are often used to measure the attenuation coefficient of optical fibers and to find fault points (breaks) in optical fiber communication lines. In order to obtain a larger measurement dynamic range, ASE light sources are often used in OTDRs, and laser light sources, such as 1625nm lasers, can also be used for power fiber line monitoring.

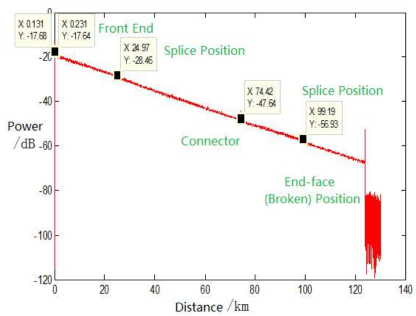
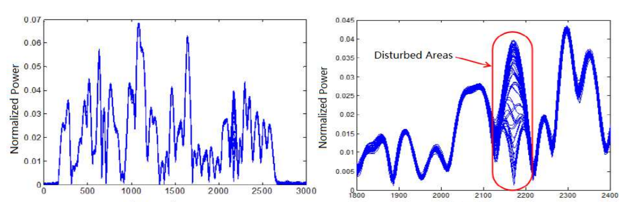



Fig. 2. OTDR trace and the characteristics of typical events in it

## B. *ϕ-OTDR*

Like the OTDR hardware structure, the phase-sensitive OTDR (φ-OTDR) uses a high-coherence laser, in which the laser linewidth is generally less than 1kHz, and the phase noise is extremely low)[13]. The high-coherence laser can convert the perturbation information sensed by the fiber under test into the phase change of the sensing light signal and then make the scattered light signal power change accordingly.

Figure 3(a) shows the OTDR curve without averaging the signal in a normal state, and the optical signal intensity at each position changes slowly and randomly. Figure 3(b) displays the regular change of the signal power at the disturbed position (2070±30 meters). By removing the time-domain signals at different consecutive moments near the position and performing Fourier transform, the frequency or spectral characteristics of the disturbance can be obtained. According to the measured disturbance frequency or spectrum characteristics, disturbance events can be reversed, such as excavators, construction locomotives, etc.




(a) (b)

Fig. 3. OTDR trace without disturbing and signal variation at the position being disturbed

## C. *P-OTDR*

Polarization OTDR (P-OTDR) mainly uses the disturbed position to cause regular changes in the optical polarization state of the optical signal in the fiber under test. The change in the optical polarization state will cause the detected scattered light signal intensity to change[14]. Compared with the structure of OTDR, the P-OTDR introduces a polarizing device or laser to output polarization-maintaining laser in the optical signal transmitting end, and introduces a new device at the scattered light signal receiving end: Polarization detection device or a polarization beam splitter. Thereby ensuring the accuracy of polarization detection. Compared with the phase-sensitive OTDR, the curve measured by the P-OTDR also changes drastically and randomly after the disturbance position, as showed in Figure 4, so it is difficult to monitor multiple points at the same time.

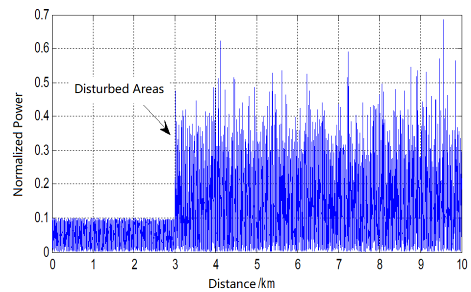



Fig. 4. The OTDR trace with polarization disturbing

## D. *R-OTDR*

R-OTDR is the most widely used in the field of electricity. The data acquisition card generates triggering electrical pulses to drive the pulsed laser to generate optical pulses, and the optical pulses enter the wavelength division multiplexer and connect to the optical switch, thereby entering the fiber channel under test. Following consideration of the temperature measurement distance, the tested fiber is usually 62.5/125 micron multimode fiber[15].

Raman Stokes scattered light and the anti-Stokes scattered light of the light pulse in the fiber under test are returned and separated by their respective channels in the wavelength division multiplexer. Separated Raman Stokes scattered light and anti-Stokes scattered light is respectively connected to the corresponding port on the avalanche photodetector, and the electrical signals output by the avalanche photodetector is collected and processed by the dual-channel data acquisition card respectively.

Figure 5 shows the time-domain curves of Raman Stokes and anti-Stokes signals measured by R-OTDR. When performing temperature demodulation, a length of temperature calibration fiber of 200 to 300 meters is usually set at the front end of the fiber. After obtaining the power values of the Raman Stokes signal and the anti-Stokes signal at the $T_0$ temperature, the power information of the entire fiber at each position of the $T_0$ temperature is calculated by the attenuation supplement: Raman Stokes signal; Anti-Stokes signal power. Therefore, the temperature information along the entire fiber can be estimated by using the temperature demodulation formula. The temperature demodulation formula is as follows [16]:

$$\frac{1}{T(L)} = \frac{1}{T_0} - \frac{k_B}{h\Delta\nu} \ln\left(\frac{V_{as}(T,L)/V_s(T,L)}{V_{as}(T_0,L)/V_s(T_0,L)}\right) \qquad (1)$$

In the formula, $T(L)$ is the temperature at the $L$ position, $T_0$ is the calibrated temperature, $k_B$ is Boltzmann's constant, $h$ is Planck's constant, $\Delta\nu$ is the Raman scattering frequency shift, while $V_{as}(T,L)$ and $V_s(T,L)$ are the anti-Stokes signal and the Stokes signal voltage when the temperature is $T$, $V_{as}(T_0,L)$ and $V_s(T_0,L)$ the anti-Stokes signal and the Stokes signal voltage when the temperature is $T_0$.

Temperature distribution along the fiber after demodulation is shown in Figure 6.

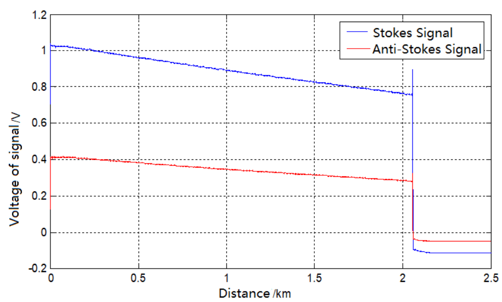



Fig. 5. OTDR traces of Raman Stokes and Anti-Stokes signals

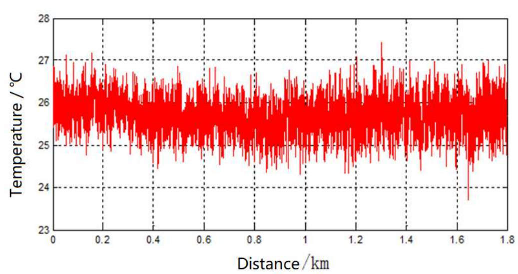



Fig. 6. The demodulated temperature distribution along the fiber

## E. B-OTDR

Figure 7 shows a typical system structure of a Brillouin OTDR (B-OTDR)[17]. After the laser emits laser light through the coupler, it is divided into two paths. One way into the electro-optic (intensity) modulator is modulated into optical pulses, which are injected into the fiber under test through the circulator. The other way is directly connected to coupler 2 and used as local oscillator light[18]. The back scattered light signal of the optical pulse in the fiber under test is connected to the other input end of the coupler 2 after passing through the circulator. In the coupler 2, the difference frequency envelope produced by the coherence between the scattered light signal and the local oscillator light is converted into a corresponding radio frequency signal by the photodetector and output. Since the Brillouin scattering (radio frequency) signal is around 11 GHz and the frequency spectrum is generally above 300 MHz, it is necessary to extract the Brillouin signal point by point in a wide frequency range by means of microwave frequency sweeping[18].

Therefore, the radio frequency local oscillator and Brillouin signal generated by the microwave source are mixed in the mixer, and then the signal power near the local oscillator frequency band is filtered out by the low-pass filter and extracted by the acquisition and processing board. By scanning the microwave source point by point, the three-dimensional Brillouin spectrum illustrated in figure 8 is finally obtained. By judging the Brillouin frequency shift at each position, as showed in Figure 9.

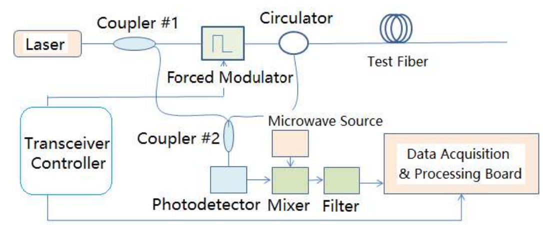



Fig. 7. Schematic diagram of Brillouin OTDR

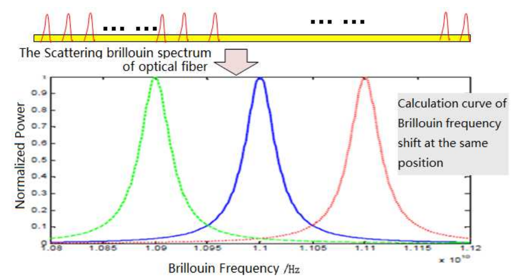



Fig. 8. The Brillouin spectra and the frequency shift at each position along the fiber

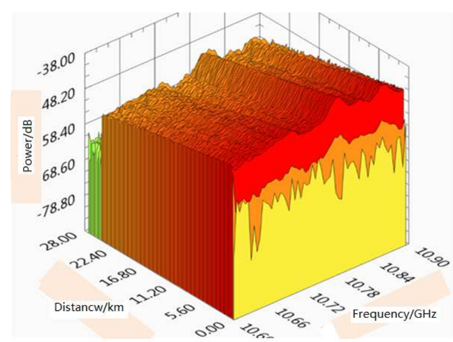



Fig. 9. The 3D Brillouin spectra

## IV. INTEGRATED OPERATION AND MAINTENANCE PLATFORM FOR POWER FIBER-TO-THE-HOME

The bottleneck of OPLC promotion and application lies in the intersection of electrical and optical communication in construction, operation and maintenance. Equipment management and optical fiber line management system in the system are introduced into the whole process of design, and the simulation technology is used to optimize the architectural and structural design. At present, the disconnection between project construction and later operation and maintenance is one of the main factors that make it difficult to improve the level of various platform management industries in China. The auxiliary technology of important components in the integrated system can be used to manage the information of the main system throughout its life cycle, which is a very effective means to break through this information gap.

About the characteristics of optoelectronic composite in OPLC, through a variety of OTDR-based detection methods and test principles, change data of optical parameters such as light reflection and refraction under different thermal, electrical, and stress fields are fully collected[19]. Simulation verification and other methods can reflect the real-time change of light on the side of the operation status of the overall power fiber-to-the-home project system, so that the information can be transmitted completely and accurately, and applied to the whole process of building operation and maintenance. Realize the application of early-stage data to later-stage operation and maintenance management, and view the system operation status conveniently and efficiently through 3D visualization, allowing operation and maintenance personnel to quickly familiarize themselves with the system, reduce operating costs, and get rid of the dependence on human experience to a greater extent.

## V. Conclusion

In this paper, the principle of power fiber optic sensing, the characteristics of engineering and system construction and other factors are given, the main monitoring methods are given, and the integration idea of the power fiber-to-the-home operation and maintenance platform is given.

With the gradual promotion and vigorous development of smart cities and digital cities, further research and expansion of fiber-to-the-home operation and maintenance technology for power will greatly solve the engineering technology of difficult communication guarantee, energy monitoring, and fault diagnosis and analysis in complex environments question. Further improve and perfect the real-time sensing systems of the power operation and maintenance platform, so that the operation status of the entire optical path and monitoring transmission line can be fed back to the front-line technicians more intuitively and effectively, and it will also provide all-round support for the promotion and optimization of the power fiber-to-the-home project.

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