Design of an 8X8 Optical Matrix Protection Device based on Electric Power Communication Network

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Abstract. In order to realize the fast establishment of power fiber circuitous channels, the reliability of power communication optical cable network is guaranteed. An optical matrix 8X8 protection device is designed by using all-optical switcher. The test results show that at the end of each input light path, any 8 paths can be switched, it can achieve 1:8 protection switch, realized the arbitrary switching of three modes and has the function of remote fiber route scheduling.

Keywords: Power fiber optic communication, Artificial fiber jumping, optical matrix protection device, Optical fiber scheduling.

1. Introduction
As a key component of power communication system, power fiber is responsible for information transmission between terminal equipment. If the fault of the power fiber channel causes the interruption of power communication, it may lead to the failure of coordination between the access equipment in the power system and bring huge economic losses to the power sector. It goes without saying that this will be the common challenge faced by all aspects of operation and maintenance of power grid. The traditional fiber channel fault repair method requires the repairman to arrive at the scene and perform fiber hop operation one by one at each station [1]. Due to the large number of geographical locations of substation distribution, wide area, distance. This working mode, no doubt, in the fault repair, greatly prolong the time of fault recovery, increase the operation and maintenance cost of power production [2].

The structure of the article consists of four chapters. The first chapter expounds that the traditional optical fiber interrupt operation and maintenance method is manual fiber hop. The second chapter describes the design principle of optical fiber protection device. The third chapter is the performance test of the optical matrix protection device. The last chapter is the conclusion of this paper.

2. Principles of optical matrix protection device
According to the actual demand function of power communication optical path switching, optical matrix protection device includes three parts: optical path real-time monitoring, optical path automatic switching protection and optical matrix protection software. Optical path real-time monitoring is to use OTDR to complete the rotation test of power communication optical fiber, including optical fiber transmission parameters such as optical cable distance, interruption fault point, optical fiber attenuation value, and optical path automatic switching protection. It is the core component of the optical matrix.
device to complete the automatic switching of standby routes. Optical matrix protection software can realize the functions of fast establishment of optical path and remote scheduling.

2.1. Principle of real-time monitoring of optical path

The principle of optical path real-time monitoring is shown in Fig. 1, when the fiber core optical path is tested, the pulse generated by the pulse generator drives the LD to generate optical pulse, which is injected into the optical fiber to be tested through the directional coupler. The light pulse injected into the optical fiber is scattered by impurities and bubbles inside the fiber. Part of the backscattering is called back scattering light [3] Together with the Fresnel reflection light generated from the uneven end face of the optical fiber, it is reflected to the coupler and injected into the photodiode and converted into electric pulse wave [4]. The reflected light is very weak, so it is repeated transmitted, collected, superimposed, amplified, averaged, and then displayed on CRT. It has the characteristics of high dynamic range, small size, and high horizontal resolution.

![Figure 1. Principle of optical path real-time monitoring.](image)

2.2. Automatic switching protection of optical path

The basic structure of the optical matrix 8X8 we designed are shown in Fig. 2, the scheme adopts the 8X8 magnetic optical switch matrix, which is composed of 64 prisms arranged in 8 rows and 8 rows. When the prism is not working, the prism is under the horizontal plane of the input and output optical paths, and the 8-channel input light cannot be coupled to the output; when a certain row of prisms rises, it reflects the incident light of the row to the residual output port, which passes through different ways The reflection sum of the ascending prism can produce different order of light path output, forming the light path switching [5]. Compared with the stepper motor drive mode, the switching speed, insertion loss and crosstalk are improved significantly.

The technical principle of optical path automatic switching is that the system automatically monitors the optical power of optical fiber. When the optical power of optical fiber line is lower than a certain set value, the system will automatically switch the communication signal to the standby optical fiber, so as to avoid the interruption of communication service caused by optical fiber failure [6]. Therefore, this system is suitable for end-to-end optical fiber line protection.

According to the analysis in Chapter 1, when the optical path interruption is detected by the optical fiber real-time monitoring system, the fault alarm information will be used as the excitation signal of
PD at the output end of automatic switching protection of optical path, and the PD in Fig. 2 will be started immediately to test the optical power value, and the optical fiber channel corresponding to the optical pair can be determined [7]. Assuming that the channel corresponding to the optical fiber is normal, its state value is set as 1; when the fiber channel is interrupted, its state value is set to 0, then the optical path $x_i$ of the i input port in the 8X8 optical matrix satisfies the following relationship:

$$x_i \in \{0,1\}, \ i \in \{1, 2, 3, ..., 8\}$$  \hspace{1cm} (1)

It can be concluded that all optical path states $X_i$ of the i input port are as follows:

$$X_i = [x_{i1}, x_{i2}, ..., x_{i8}]$$  \hspace{1cm} (2)

In the same way, we can deduce that the optical path $y_j$ of the j output port of the 8X8 optical matrix and all the optical path states $Y_j$ of the j output port satisfy the following relations 3 and 4 respectively:

$$y_j \in \{0,1\}, \ j \in \{1, 2, 3, ..., 8\}$$  \hspace{1cm} (3)

$$Y_j = [y_{j1}, y_{j2}, ..., y_{j8}]$$  \hspace{1cm} (4)

According to the above analysis, we get the 8 input port states X and 8 input port States y of the 8X8 optical matrix, which can be expressed as Formula 5.

$$\begin{align*}
X & = \begin{bmatrix}
X_1 \\
X_2 \\
\vdots \\
X_8
\end{bmatrix} \\
Y & = \begin{bmatrix}
Y_1 \\
Y_2 \\
\vdots \\
Y_8
\end{bmatrix}
\end{align*}$$  \hspace{1cm} (5)

Therefore, the key content of this paper is to establish the relationship between the input end X and the output end y of the matrix 8x8. Once the relationship is established, it will provide a remote routing scheduling strategy for power communication optical fiber failure interruption, and realize the automatic and orderly optical path hopping in the optical matrix, so as to avoid the impact of optical path jumping disorder on the optical fiber carrying power grid services when the optical fiber is interrupted. Considering the large number of optical fibers in power communication and the complexity of backup routes, we design the simplest and effective method based on the rule of matrix transformation. The internal optical path hopping mode of the optical matrix is shown in Fig. 2.
In addition, the automatic switching protection of optical fiber is the protection of OSI transmission layer, which realizes the monitoring and switching of optical fiber, and does not affect the work of transmission equipment. This technology has the following advantages: it is suitable for all kinds of network structures, does not have any impact on services, and has high switching speed, low cost and high reliability.

### 2.3. Optical matrix 8X8 protection software system

Optical matrix 8X8 protection system supports manual pre-configuration of optical circuit switching and manual routing configuration switching, realizes the routing guide and transformation of power optical communication, and realizes fast routing switch and transformation.

The system mainly supports the functions of optical circuit real-time monitoring, optical circuit automatic and manual switching, also optical cable network operation fault alarm.
Its working principle is quoted at present, optical switch, WDM wavelength, optical monitoring technology, realize the automatic or manual change business transmission fiber core physical link, full matrix switch can be solved by the artificial light to the scene jumper routing routing connections to the automatic remote control, especially in some remote unattended station, by remote control switch routing through the fiber core business, to provide cable link opened routing and link failure recovery time, reduce and human resources.

The platform performs optical route switching through manual routing configuration, and realizes alternate route switching through real-time communication and guiding and changing of intelligent optical route switching, thus completing the rapid establishment of alternate optical route.

Through big data technology, the platform makes statistics of optical fiber losses in different regions. Based on historical data, it can intelligently predict optical power losses of different optical fibers in different regions and under different environmental conditions, and strengthen automatic inspection and manual dispatching of optical fibers in frequent fault regions to reduce fault incidence.

3. Performance test of Optical matrix 8X8 protection system

The scientific research project pilot choose A, B, C three substation room, in A, B, C three deployment of three sets of intelligent substation room ODF light path wiring unit and intelligent optical path of 8 by 8 switch matrix switching unit, to occupy the ODF terminals and connection routing chart generated automatically and real-time remote monitoring, and combined with intelligent matrix switching equipment, realize remote routing routing fails, opening, and business of automatic backup routing policy set by the user according to the rearrangement of the spare line (also can be artificial fiber core routing) related to remote switch to, safeguard normal business communication.

![Intelligent optical path 8X8 matrix switching principal connection diagram.](image)

In this project, three stations were selected for intelligent optical switching and intelligent ODF system trial operation. The network management system was installed in the headquarters, and the internal network management communicated with the trial-produced products of the 3 stations. See the following figure for details shown in Fig. 5.
Figure 5. Network design of 8X8 Optical Matrix switching device in substation.

This system successfully realizes the remote and arbitrary switching of optical fiber cores for business routes, completes the switching of alternate routing cores for multiple services, and automatically switches to the set threshold value by monitoring the changes of optical power at the protection switching end, so as to ensure the normal business transmission and the rationality of resource utilization.

All-optical switching unit refers to the light switch, WDM wavelength, optical monitoring technology, realize the automatic or manual change business transmission fiber core physical link, full matrix switch can be solved by the artificial light to the scene jumper routing routing connections to the automatic remote control, particularly in some remote unattended station, by remote control switch business route through the fiber core, provide fiber optic link opened routing and link failure recovery time, reduce the manpower.

The 8X8 matrix switch of the intelligent optical circuit of the three stations is set to automatic working mode. When the optical fiber fails, it will automatically switch to the backup fiber, and when the backup fiber fails, it can automatically switch to other lines to continue to ensure data transmission. When the main and backup fibers joining station A to Station B are physically damaged, and the communication cannot be restored by switching between the main and backup fibers, the equipment will automatically switch the route of Station A through Station C and then through station B, namely the original A-B, and adjust it to A-C-B.

3.1. Protection Switching Mode 1
A - B double the business one and two, Shared backup routing and standby routing 2, when the business is A main route fiber disruption, priority strategy according to the preset sequence automatically in 1 seconds to switch to the alternate routing, again interrupted business two masters with routing optical fiber, strategy according to the preset sequence should be automatically switch to the alternate routing A priority, but alternate routing has been used by A business, business 2 automatic priority automatically switch to the alternate route 2, safeguard normal business communication, rearrangement of chaos will not occur.
3.2. Protection Switching Mode 2
A-B point Business 1: Presets two alternate routes 1 and 2 according to the policy. When the primary route and alternate route 1 of business 1 interrupt the optical fiber, the intelligent optical switching equipment will switch to alternate route 2 automatically, so as to ensure the normal communication of business and avoid the chaos of switching.
3.3. Protection Switching Mode 3
A-B point business 1: Two alternate routes 1 and 2 are preset according to the policy. When the primary route of business 1 is interrupted, and the standby C-B segment and the standby A-C fiber are also interrupted, task switching can be carried out through human network management or field equipment to ensure the normal communication of the business link.

![Protection Switching Mode 3 schematic.](image)

According to the switching of the three modes, we can draw some important conclusions that the optical matrix 8x8 protection device designed in this paper can realize the automatic selection of 8 different paths of each input optical path, and realize the protection strategy of 1:8: for each optical path.

4. Conclusion
The application of optical matrix 8X8 protection device will fundamentally change the backward operation and maintenance mode completely relying on manual operation and realize the new operation and maintenance mode of "one-stop" management of the whole network optical fiber state. A new spatio-temporal response operation and maintenance mechanism is formed: instantaneous alarm in time and quick switch of backup fiber core in case of failure ensure normal communication service; Daily monitoring can realize early warning of optical fiber performance deterioration, and realize full digital management of resources in space.

1. Accurately control the utilization rate of fiber core resources, automatically record and statistics the ODF terminal occupancy of each machine room and fiber node and the jump connection of fiber core of each fiber segment
2. In case of line failure, automatic line switch is realized to ensure normal business, and the fiber core is connected to the transmission route between each fiber segment by remote jumper.
(3) Realize the supervision and management of daily inspection and maintenance of optical fiber lines, supervise the inspection of managers at different levels of optical fiber line work, realize the supervision and management function of multi-level joint inspection, and reduce the incidence of optical fiber line obstacles to the minimum.

(4) In power communication, the system can be used for seamless switching protection of important business, avoiding the time-consuming and low efficiency problems of manual maintenance mode.

(5) The system shall be used for automatic switching protection. The design of standby fiber and standby route shall be done in advance, and the switching route sequence in case of optical fiber failure shall be considered in advance.

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