Management of Communication System in Pipeline Industry Based on OLP Technology

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Abstract

In order to effectively improve the fault self-healing ability of pipeline communication system and reduce the events of communication interruption caused by fiber break or performance degradation of optical line, this paper introduces the basic principle, system composition working mode and technical requirements of OLP technology. The OLP system is firstly introduced into the relay section of long-distance pipeline to build the standby route with the spare optical fiber as material. When the in-service route is broken or the performance of optical fiber is reduced, the OLP system can automatically switch to the standby route within 50 ms to ensure the communication transmission service be uninterrupted, and even no error code alarm. Through engineering test in pipeline industry, the operability of OLP technology applied to the pipeline communication system is verified. Using the real-time monitoring data of optical cable through OLP system, we can analyze the evolution trend of optical cable line quality, precontrol in advance, and improve the level of communication management.

Keywords: *OLP, Optical Line Protection, Technical Requirement, Long-distance Pipeline Industry, Communication Failure,*

I. Introduction

Optical fiber communication is the main way of communication system in oil and gas pipeline. Optical cable for communication is laid underground together with pipeline. Affected by aging, construction quality, termite bite and others, the fiber core inservice is often broken or the performance is reduced, which result in the interruption of communication data [1].The risk resistance of optical cable is the main factor that restricts security of transmission network. The commonly used communication optical cable has 12, 24 or 36 cores. The communication between two stations usually takes up two to four optical fibers, and the others are in. Because the optical transmission system cannot monitor the performance index of backup optical fibers in real time, there are no hot alternate route. Once the communication is interrupted, caused by optical fiber in use broken or its performance slowed down, we need consulting, reporting, testing and jumping fiber to restore communication. It will take at least 30 minutes from communication interruption to restoration. If the failure occurs at night or the maintenance staff is not skilled, the recovery time will be longer. When communication failure occurs, it is necessary to test its performance in the field, and then the communication can be restored after jumping fiber simultaneously at both stations.

OLP(Optical Fiber Line Auto Switch Protection Equipment)is based on the optical transmission layer protection, and is independent of the optical transmission system [2].OLP technology has been widely used in mobile communication and power communication systems [3-4],and even in 5G area [5].which can greatly improve the reliability of optical transmission system. There is no case of OLP in pipeline optical communication system. The spare fiber core in communication cable is used as the spare communication route. In case of core breakage or performance degradation fault in the inservice route, which affects the communication service, protection system can be switched to the standby route automatically and quickly, so as to improve the fault recovery ability of the communication system and reduce the number of communication interruption.

II. Technical analysis of OLP

2.1 Operating principle

The OLP is based on optical switching technology. The device emits a stable light source of a certain wavelength into the optical fiber. By monitoring the changes of luminous power in real-time, OLP can automatically analyze data, detect potential faults, quickly switch to spare channel, and restore communication in a very short time [6].The complete OLP scheme consists of two parts: hardware device and remote network management. The remote network management system can centrally and uniformly monitor OLP devices, and has management functions of physical resource, system routing, monitoring alarm, configuration and authority. OLP system has the following functions.

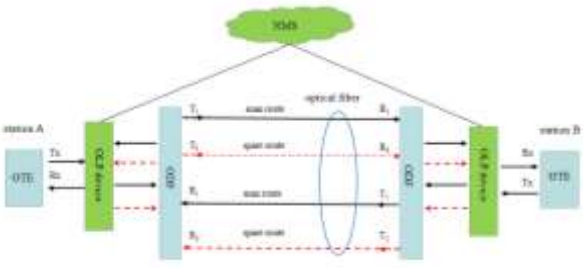
(1) Protection swap
When the main optical line fails or the optical power loss exceeds alarm threshold, the OLP firstly detects whether the device are abnormal and analyzes the setting data. If equipment is operating normally, the OLP will immediately and automatically switch to the standby line to ensure the transmission service uninterrupted. In addition to automatic switching function, this system can also be manually switched, or by remote management platform. On-site manual switching can be performed at one end, the other end will be automatically guided without doing nothing.

(2) Graded warning
The OLP system can monitor both main fiber and standby fiber, and display the fiber performance indexes synchronously through a LED display of the field equipment and the remote network. The measurement accuracy will be high .Fiber optic fault alarm can be classified processing: no light alarm, primaryt alarm, secondary alarm and tertiary alarm. The switch panel would display alarms with four diferent colors of lights: Green (normal), Yellow (secondary alarm), Red (primary or no light alarm), Colorless (idle or no equipment).The alarm value can be setted by network platform.

(3) Lightless lock
OLP system always deploys passive optical device with power-off protection. When the OLP device power down, the system will automatically lock to power down or on the circuit, no switching action, to ensure that communication service is still at work.

2.2. System components and its functions

The OLP system is mainly composed of OLP protection plate, optical cable backup fiber core, and terminal network management system, as shown in Fig.1.The device unit generally has 6 light ports:Rx,Tx,T_1,T_2,R_1,R_2.The Rx/Tx are connected to the local terminal device. The T_1/R_1 are connected to main optical cable tails. The T_2/R_2 are connected to spare optical cable tails. The number of light port can be customized according to actual needs.



OTE(optical transmission equipment)
NMS(network management system)

ODF(optical Distribution Frame)
Figure 1： Structure diagram of OLP

OLP protection plate is an important part of optical circuit protection system, which includs laser, monitoring unit, control unit, optical switch and other components. The laser provides a stable test source with a fixed wavelength. The monitoring unit receives the optical signal of the test light source to monitor the line performance index in real time. When the main and secondary fibers are used for real-time monitoring. It will be a stable test light source in each switching protection module, and adopts the way of sending test. The device adopts the method of sending test, that is, A sends test light to B.B switches the protection module for light power monitoring, and the opposite direction is the same. The control unit is used to protect the inversion judgment and give control instructions. The light switch is used to execute the protection reversal command to select the primary or alternate route. The optical switch is the core component of the whole protection switching system. With the rapid development of communication technology, MEMS (Micro-Electro-Mechanic Systems) optical switch based on the core of microelectronic technology and semiconductor manufacturing technology has gradually replaced the traditional mechanical optical switch. Compared with the traditional 1×N mechanical optical switch, MEMS optical switch has the advantages of small size, low power consumption, long life, stable operation, better performance, less insertion loss and so on [7-8].

The backup fiber core provides the physical channel for the optical line protection system. When the main route fails, the system automatically reverses to the standby route to ensure uninterrupted communication. What is worth mentioning is that the OLP system can monitor the light loss of the spare core in real time and send an alarm by setting a threshold value to keep the spare core in a hot backup state.

The network management system can realize the dynamic centralized and unified management of OLP devices. The system is run in B/S browser mode, which has the functions of remote viewing equipment state and line optical power information, modifying threshold value and alarm value, automatically generating the history curve of optical power of optical fiber, inquiring and statistical duration alarm and so on [9].

2.3 Operating Mode

The operating mode of OLP system mainly includes 1+1 concurrent selection and receiving mode and 1:1 selective transmission and receiving mode.

The 1+1 OLP system adopts single-ended switching. When the optical signal sent by the transmission device passes through the OLP device, it is divided into two equal parts by the splitter, one half as the service optical signal and the other half as the test optical signal. When the primary route fails and the reversal condition is reached, the sender of the OLP device does not act and the receiver automatically reverses to the alternate route. The signal of 1+1 OLP system is not the same route.

The 1: 1 OLP system only sends one signal, and only receives one signal. When a fault occurs, it is necessary to synchronize the replacement at both ends, and both ends have a handshake protocol [10].All the optical signals sent by the optical terminal are transmitted through the main route. The OLP device carries a laser that independently instills a steady light source signal to the alternate route. When the primary route fails and the inversion condition is reached, the OLP system reverses both the receiving and the originator routes to the alternate route, and the primary alternate route detection light source is focused on the primary route through a 2x2 optical switch to monitor the performance index of the primary alternate route in real time.

Both 1+1 and 1:1 OLP systems have their advantages and disadvantages [11-12].1:1 OLP system comes with synchronous protection switching protocol. The whole reversal judgment process does not need network management system intervention. The OLP equipment is built in the control chip to complete independently, only

based on line performance indicators. The reversal judgment is more rigorous than the 1+1 OLP. The 1+1 OLP may be misjudged when the optical power of the transmitting device changes. It needs the network management system software to analyze the data in real time, assist the decision, and issue the change instruction. Insertion losse of 1+1 OLP is generally bigger than 1:1 OLP [13].

2.4 points for attention

Pipeline communication system requires high quality of optical circuits. In order to improve the overall stability of the system, high quality optical devices should be selected when OLP equipment is configured [14].Although OLP device has its own lightless locking capability, a redundant backup power supply mechanism is recommended. Theroute of OLP device can be swapped in four modes: automatic do not return, automatic return, manual, and forced. It is generally recommended to use automatic return or automatic do not return mode. When in automatic return mode, the alternate route is used only as a temporary channel. When the primary route fails, the OLP device reverts back to the primary route. When in automatic non-return mode, the device is switched to the standby route after the primary route fails. The current route is maintained to work when both primary and standby routes are normal

The introduction of OLP equipment will increase the intervention loss to a certain extent. In order not to affect the normal operation of the wave division system, the maximum allowable attenuation margin of the optical fiber line should be fully considered before the network entry, which should be greater than the intervention loss of the protection system [15].It is necessary to add Erbium-doped Fiber Amplifier (EDFA) or Fiber Raman Amplifier (FRA) to amplify the optical power If it is true that the loss value of optical circuit is too large to accept the interference loss of OLP equipment [16].

There is little difference in fiber length due to the different fibers in the same cable in route and standby route. The 100G wave division system adopts DSP technology and has a large dispersion tolerance. There is no need to compensate for the dispersion of the standby circuit during the implementation of OLP, which greatly simplifies the structure of OLP optical line protection system [17-18].In order to ensure reliable operation of the equipment, detailed maintenance plans should be formulated according to the equipment performance parameters, the key parts should be regularly maintained and the hidden defects of the equipment should be eliminated in a timely manner [19].When the main and standby route fails at the same time, the communication interruption fault will still occur, because they are in the same communication cable. We can try to incorporate all the spare fiber cores into OLP system to improve the integrity of communication system. An automatic switching device with multiple optical lines can be explored to improve the fault self-healing ability of optical lines with broken core. When optical circuit has broken fiber and large loss and other safety risks, we should take timely engineering measures to control [20].

III. Application of OLP system

3.1 Profile of Pipeline Optical Cable

The total length of optical cable for communication between Station A and Station B of a natural gas pipeline is 52.9 km, which uses 36-core G652 communication cable. The main communication data is transmitted by four optical fibers in the cable. Using single mode one-way transmission mode, a single fiber carries multiple transmission services at the same time. Sending and receiving services each take up 2 fiber cores. The other two fiber cores are used for the communication between the station and the valve room, and one is used for the data communication of cathodic protection. There are 29 fiber cores cold standby in this section of optical cable. The optical cable lines were tested on the ODF frame of Station A with OTDR, and the loss was shown in Table 1.

Table 1: Loss of optical cable line

serial	Loss	serial	Loss	serial	Loss	serial	Loss	value

number	value /dB	number	value /dB	number	value /dB	number	/dB
1	13.63	**10**	14.09	**19**	14.34	**28**	Valve chest
2	13.27	**11**	13.19	**20**	13.31	**29**	Cathodic protection
3	14.49	**12**	14.12	**21**	13.49	**30**	14.13
4	14.02	**13**	13.67	**22**	14.58	**31**	14.53
5	14.06	**14**	14.82	**23**	13.40	**32**	16.04
6	14.88	**15**	14.30	**24**	16.08	**33**	14.45
7	13.71	**16**	14.20	**25**	14.13	**34**	12.74
8	13.51	**17**	14.21	**26**	14.11	**35**	14.40
9	14.51	**18**	14.61	**27**	阀室	**36**	14.43

The 2nd, 4th, 17th and 20th optical fibers are in use. The 28th and 29th optical fibers are used for communication of valve chest. The rest of the fiber cores are cold standby. According to the line test results, the average loss of optical fiber line is 14 dB. The minimum loss is the second core. The loss value is 13.27 dB. The maximum loss is the 24th core, whose loss value is 16.08dB.The overall performance of optical fiber is excellent.

3.2 Projectinstruction

The automatic protection is not considered in communication service between station and valve room and cathodic protection service.1:1 OLP system can be selected. The specific performance parameters were shown in Table 2.The system swap wait time is set to 0 ms (Reversion waiting time is the waiting time before the switching action, which should be executed when the receiving power value exceeds the switching threshold).The switching time is less than 35ms, which meets the requirement of uninterrupted communication. The threshold value of wave division system is 28dB.The total interventional loss of equipment shall not be greater than 3dB.The introduction of OLP equipment will not affect the performance of the wave division system, according to the optical fiber line. The reversal threshold was set at 27dB.When the total loss is detected to be equal to or more than 27dB, the route in use is automatically switched to the alternate route. The OLP system is based on the line loss value to deal with the optical fiber fault alarm classification. The total loss value below 22dB is normal, and the green light indicates. If the total loss reaches 24dB,it is the second level alarm. The yellow light indicates that the total loss reaches 26dB,and the red light indicates. The indicator light goes off when he total loss reaches 28dB.

Table 2: Main parameters of OLP

serial number	parameter specification
1	The replacement time: less than 35m
2	Wavelength of test ligh: 1550mm
3	Detect optical power accuracy: ±0.25dB
4	Input optical power range: -50dBm ~ +23dBm
5	insertionloss: 3dB

In order to realize a effective protection to transmission system, it is necessary to ensure that the parameters, such as line decay and chroma dispersion of the standby line are consistent with the main line. Firstly, install an OLP device at both sites. The four fiber cores of No. 21, 5, 23 and 16, which have similar loss to the route in use, are selected as the standby route of No. 2, 4, 17 and 20 in turn. By adjusting the tailings to connect the OLP device to the internal network, the transformation can be completed. The eight-fiber bi-directional route between the equipment and the station constitutes a set of automatic switching protection subsystem.

We can simulate the performance of OLP system only by a backbuckle operation on the tailpipe. Selected in the optical fiber, a gradual increase in style of playing back button tail fiber bending degree, line loss increases gradually, until the light line fails, the device between the main and backup routing has realized automatic rearrangement of function, set the light line loss of network management system software grading alarm function effectively, transmission equipment did not send error alarm, The feasibility of OLP equipment used in pipeline communication system is verified.

IV.Conclusion

OLP system based on transmission layer is an economical and effective way to protect optical fiber transmission line. It can ensure that the communication business is not interrupted, improve the communication security and line fault recovery ability, and reduce the number of communication interruption events when OLP system is used. According to the real-time monitoring data of main and standby routes, the evolution trend of optical cable line quality can be analyzed, and the level of communication management can be improved by pre-controlling in advance. The optical communication operation and monitoring data of different relay segments can be collected into a unified remote network management server. A pipeline communication system management platform based on OLP technology can be build which can solve the problems such as too many terminal equipment, decentralized management, inconvenient operation and difficult maintenance.

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