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Strategies for Improving the Reliability of Differential AC Protection Transmission

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Abstract

Relay protection is the first line of defense in the power system. Its business signals have the characteristics of short allowable transmission time, low probability of channel transmission, and uncertain transmission time, which have strict requirements for the transmission performance and reliability of the channels. In addition, the "Notice of State Grid Corporation of China on Issuing the Regulations for Investigation of Safety Accidents of State Grid Corporation of China" (National Grid Safety Monitoring [2020] No. 820) was officially implemented in April 2021, which greatly increases the equipment risk probability caused by the failure of protection communication channels. Currently, the differential protection channels in the power system require strict consistency in the send-receive delay, and thus cannot set up a detour protection path, leading to a significant reduction in the reliability of the differential protection channel. It is urgent to study an innovative fiber optic communication protection technology scheme to provide multi-path protection for fiber optic communication, while meeting the constant requirement of bidirectional delay difference for protection communication bearer networks, to solve the problem of interruption of relay protection business in the case of a single channel abnormality, to ensure the stable operation of the power grid.

Keywords

List The; Keywords Covered; In Your Paper.

1. Principal Overview

Through the analysis of the characteristics of relay protection business and the current situation of power communication networks, a new fiber optic communication path protection scheme for relay devices is innovatively created while leveraging the existing SDH network, Additionally, focusing on the evolution of communication technology, research is conducted on the technical solution of protection devices based on the next generation TDM hard pipeline technology. The consistency of the existing SDH network and the future next-generation TDM hard pipeline network for current differential protection technology schemes is analyzed, and optimization suggestions are proposed for the next-generation TDM hard pipeline technology. An analysis of the fiber optic communication protection scheme for relay protection devices is comprehensively carried out domestically and internationally, taking into account the current situation of power communication networks, with the following requirements:

(1) Compatibility with the existing SDH network in the power system, ensuring overall compatibility with the network architecture.

(2) Guarantee the reliability of communication business for protection devices, avoiding complex communication interaction protocols.

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(3) The technical scheme has scalability and is compatible with the next-generation TDM hard pipeline technology.

(4) The technical scheme is decoupled from the protection device and is imperceptible to the protection device.

With the development of communication services, the previous TDM technology SDH ceased development after 2007 with ITU-T's standard G.707, which posed limitations and constraints on innovation for new features. Therefore, domestic and international standard organizations, including IEEE/CSEE/CCS, initiated a project for the new generation TDM communication technology OSU (Optical Service Unit) in 2020. The OSU technology is a TDM communication technology developed based on OTN technology framework, with a business scope and performance comparable to SDH technology, supporting a minimum payload of 2M. The line bandwidth has evolved synchronously with OTN, expanding from 10G to 100G, 200G, and 400G. The OSU business channel also supports business-level delay measurement, bringing a better experience for communication protection technology innovation for optical fiber current differential protection devices.

The technical principle is as follows:

Network element 1: The E1 optical board maps E1 to VC12 or OSU, duplicates the data into two streams, and transmits them to network element 2 via path 1 and path 2, respectively.

Path 1 is a short path with a delay of 1ms, while path 2 is a long path with a delay of 5ms.

Network element 2: Upon receiving the short path business, it buffers for 4ms. After aligning the delays of the two paths, both paths have a delay of 5ms. Upon receiving the long path, it deciphers and sends out the E1 data.

By utilizing the receiving board buffer, the delays of the two paths are completely aligned, ensuring constant delay during path switching. No protocol delivery is required during the switching process, and the local optical communication equipment can complete the switching.

As the same information is received by both paths at the same time, the business is entirely lossless and the protection is completely imperceptible after the path switch.

Using VC12 channel to carry E1 services can be compatible with the existing SDH network in the power grid.

Using OSU channel to carry E1 services, one can utilize OSU's delay measurement to automatically calculate the delay difference. In contrast, when using the VC12 channel to carry E1, manual configuration of the delay difference is required.

2. Technical Research

2.1 Research on Non-intrusive Switching Technology

This project requires the optical fiber current differential protection device to ensure constant bidirectional delay difference during the switching process of the optical fiber communication path. The existing technology mainly guarantees strict consistency in both directions during or after the switching of the primary and backup paths to ensure constant bidirectional delay difference. The innovative technology of this project directly analyzes the essence of the business, aligns the delay of the primary and backup paths in advance, so that the path delay remains unchanged during and after the switch, thereby ensuring the constant bidirectional path delay difference. Because the delay of the primary and backup paths is completely aligned, it theoretically achieves lossless business during the switching process. Achieving lossless in the switching process possesses technical difficulties, such as perceiving faults and completing path switching within an extremely short (microsecond-level) time. At the same time, switching needs to occur at a fixed position within the communication frame to achieve lossless business.

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2.2 Research on Compatibility Technology

This project requires compatibility of the new generation TDM hard channel OSU technology with the SDH equipment, achieving technical compatibility before and after, with a simple technical solution to reduce reliance on protection equipment and existing communication devices, and to decouple protection and communication devices.

(1) On the new transmission equipment, a single board for carrying protection E1 light interfaces is developed. The board simultaneously supports SDH technology and the new generation TDM hard channel OSU technology. The VC12/OSU channels carrying E1 light implement a 3:1 lossless path switch.

(2) If using the SDH plane for carrying, it can be compatible with the existing SDH network in the power grid, and only new equipment needs to be added at the end to complete the project deployment.

(3) If using the new OSU technology for carrying, the reliability of carrying protection services with the new OSU technology is verified, while also verifying the 3:1 lossless path switch.

3. Functional Testing

Performance verification should include protection function testing and delay testing. Protection function testing includes 2M optical service protection testing and E1 electrical service protection testing. Delay testing includes testing the delay difference in the path of sending and receiving services, as well as delay testing before and after lossless protection switchover. To verify performance, the environment is set up as shown in Figure 1.

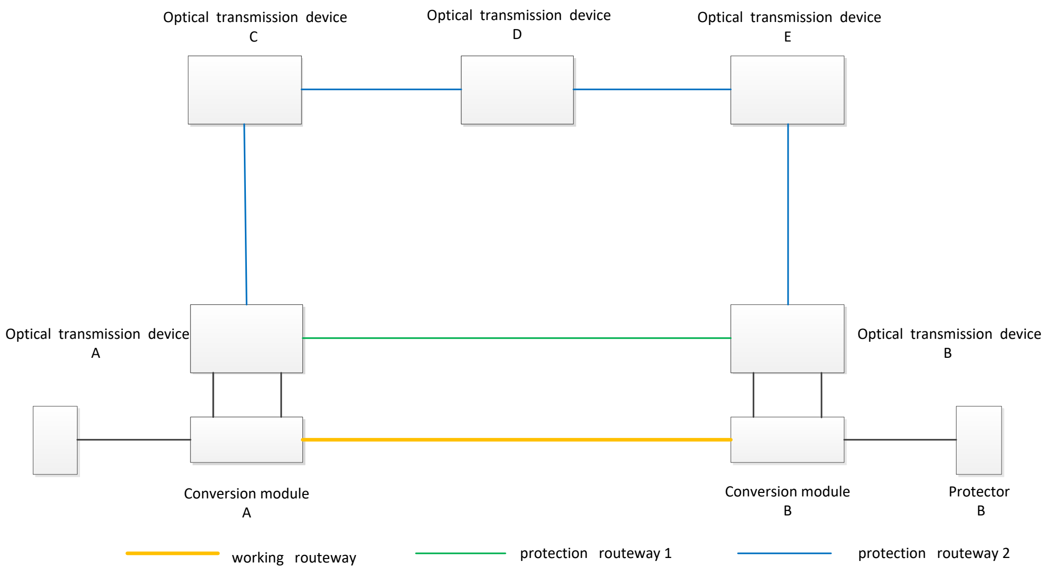

Figure 1. Schematic diagram of test environment construction

3.1 Protection Function Testing

3.1.1 2M Optical Service Protection Testing

(1) 2M optical tps protection function testing

Test steps:

1) Set up the test environment.

2) Create VC cross-carrier 2M optical service.

3) Create a TPS protection group on the 2M optical board of the conversion module.

4) Adjust the A and B protection equipment ports and channels to be carried by the conversion module.

5) Remove the working board, trigger the TPS protection switchover, and record the switchover time.

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6) Restore the working board and ask for the service switchover time.

Test Results: The switchover time is less than 50ms.

(2) 2M optical lossless protection function testing

Test steps:

1) Set up the test environment.

2) Create a lossless protection group between the conversion modules at site A and site B, carrying 2M optical service, and set the working channel, protection channel 1, and protection channel 2.

3) Adjust the A and B station protection equipment ports and channels to be carried by the conversion module.

Single-fiber removal testing:

4) Interrupt the receiving end fiber of the working channel, trigger the lossless protection switchover, and ask for the switchover time.

5) Interrupt the transmitting end fiber of the working channel, trigger the lossless protection switchover, and ask for the switchover time.

6) Interrupt the receiving end fiber of protection channel 1, trigger the lossless protection switchover, and ask for the switchover time.

7) Interrupt the transmitting end fiber of protection channel 1, trigger the lossless protection switchover, and ask for the switchover time.

8) Restore the removed fiber, and after the restoration time ends, the service automatically switches back to the working channel. Ask for the service switchover time.

Dual-fiber removal testing:

9) Simultaneously interrupt the receiving and transmitting end fibers of the working channel, trigger the lossless protection switchover, and ask for the switchover time.

10) Simultaneously interrupt the receiving and transmitting end fibers of protection channel 1, trigger the lossless protection switchover, and ask for the switchover time.

11) Restore the removed fiber, and after the restoration time ends, the service automatically switches back to the working channel. Ask for the service switchover time.

Test Results: The single-fiber and dual-fiber service switchover are both lossless.

3.1.2 E1 Electric Service Protection Test

(1) E1 electric tps protection function

Test steps:

1) Set up the test environment.

2) Create a VC cross-carriage 2M electric service between the conversion modules at stations A and B.

3) Create a TPS protection group on the 2M electric board in the conversion module.

4) Adjust the relay protection device ports and channels at stations A and B to be carried on the conversion module equipment.

5) Remove the working board, trigger the TPS protection switchover, and ask for the switchover time.

6) Restore the working board and ask for the service switchover time.

Test Result: The switchover time is less than 50ms in both cases.

(2) E1 Electric lossless protection function test

Test steps:

1) Set up the test environment according to Figure 3.(Where?)

2) Create a lossless protection group carrying 2M electric service between the conversion modules at stations A and B, setting the working channel, protection channel 1, and protection channel 2.

3) Adjust the relay protection device ports and channels at stations A and B to be carried on the conversion module equipment.

Single fiber testing:

4) Interrupt the receiving end fiber of the working channel, trigger the lossless protection switchover, and ask for the switchover time.

5) Interrupt the transmitting end fiber of the working channel, trigger the lossless protection switchover, and ask for the switchover time.

6) Interrupt the receiving end fiber of protection channel 1, trigger the lossless protection switchover, and ask for the switchover time.

7) Interrupt the transmitting end fiber of protection channel 1, trigger the lossless protection switchover, and ask for the switchover time.

8) Restore the removed fiber, wait for the restoration time to end, and the service automatically switchover to the working channel. Ask for the service switchover time.

Dual fiber testing:

9) Simultaneously interrupt the receiving and transmitting end fibers of the working channel, trigger the lossless protection switchover, and ask for the switchover time.

10) Simultaneously interrupt the receiving and transmitting end fibers of protection channel 1, trigger the lossless protection switchover, and ask for the switchover time.

11) Restore the removed fibers, wait for the restoration time to end, and the service automatically switchover to the working channel. Ask for the service switchover time.

Test Result: Both single and dual fiber services are switched losslessly.

3.2 Delay Test

3.2.1 One-way Delay Test for Service Transmission Path

(1) One-way delay test for 2M optical service

Test steps:

1) Set up the test environment.

2) Create VC cross-carrier 2M optical service transmission between conversion modules at site A and site B, with the service path selected as the direct path through the conversion module.

3) Adjust the relay protection device ports and channels at site A and site B to be carried by the conversion module equipment.

4) Test the delay from site A to site B and from site B to site A, and calculate the delay difference.

5) Create VC cross-carrier 2M optical service transmission between conversion modules at site A and site B, with the service path selected as: A station conversion module - A station 3500 - B station 3500 - B station conversion module.

6) Test the delay from site A to site B and from site B to site A, and calculate the delay difference.

7) Create VC cross-carrier 2M optical service transmission between conversion modules at site A and site B, with the longest external loop path selected.

8) Test the delay from site A to site B and from site B to site A, and calculate the delay difference.

Test results: the one-way delay difference is less than 200us.

(2) One-way delay test for e1 electrical service

Test steps:

1) Set up the test environment.

2) Create VC cross-carrier 2M optical service transmission between conversion modules at site A and site B, with the service path selected as the direct path through the conversion module.

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3) Adjust the relay protection device ports and channels at site A and site B to be carried by the conversion module equipment.

4) Test the delay from site A to site B and from site B to site A, and calculate the delay difference.

5) Create VC cross-carrier 2M optical service transmission between conversion modules at site A and site B, with the service path selected as: A station conversion module - A station 3500 - B station 3500 - B station conversion module.

6) Test the delay from site A to site B and from site B to site A, and calculate the delay difference.

7) Create VC cross-carrier 2M optical service transmission between conversion modules at site A and site B, with the longest external loop path selected.

8) Test the delay from site A to site B and from site B to site A, and calculate the delay difference.

Test Result: One-way delay difference is less than 200us.

3.2.2 Time Delay Test before and after Lossless Protection Switching

(1) Time delay change test of 2M optical lossless protection before and after switching.

Test steps:

1) Set up the test environment.

2) Create a lossless protection group between the conversion modules at station A and station B, carrying a 2M optical service, and set up the working channel, protection channel 1, and protection channel 2.

3) Redirect the relay protection equipment ports and channels from stations A and B to the conversion module equipment for carrying.

4) Test the current service delay.

5) Interrupt the transmission and reception fiber of the working channel, trigger the service switchover to protection channel 1, query the protection group status, and test the current service delay.

6) Interrupt the transmission and reception fiber of protection channel 1, trigger the service switchover to protection channel 2, query the protection group status, and test the current service delay.

7) Restore the interrupted fiber, wait for the recovery time to elapse, and the service will automatically switchover to the working channel. Query the protection group status and test the current service delay. Compare the delay difference during the protection switchover process.

Test Result: Delay difference of ±10us.

(2) Time delay change test of E1 electrical lossless protection before and after switching.

Test steps:

1) Set up the test environment.

2) Create a lossless protection group between the conversion modules at station A and station B, carrying 2M electrical service, and set up the working channel, protection channel 1, and protection channel 2.

3) Redirect the relay protection equipment ports and channels from stations A and B to the conversion module equipment for carrying.

4) Test the current service delay.

5) Interrupt the transmission and reception fiber of the working channel, trigger the service switchover to protection channel 1, query the protection group status, and test the current service delay.

6) Interrupt the transmission and reception fiber of protection channel 1, trigger the service switchover to protection channel 2, query the protection group status, and test the current service delay.

7) Restore the interrupted fiber, wait for the recovery time to elapse, and the service will automatically switchover to the working channel. Query the protection group status and test the current service delay.

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8) Compare the delay difference during the protection switchover process.

Test Result: Delay difference of ±10us.

4. Conclusion

This technology can greatly improve the reliability of alternating current differential protection channels, provide multiple path protection for optical fiber communication, meet the constant dual-way delay requirement for relay protection on communication bearer network, solve the interruption problem in relay protection service in the event of a single channel abnormality, improve the fault recovery capability of communication networks, reduce the operational pressure on maintenance personnel, ensure the stable operation of the power grid, improves production efficiency, and saves manpower and maintenance costs.

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