Self-healing Model Construction and Simulation of Power SDH Transmission Network

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Abstract. With the rapid development of Synchronous Digital Hierarchy (SDH) technology, it has been more and more widely used in power communication networks. The power communication network has high requirements on the reliability of data transmission, and the self-healing ring has the advantages of automatic fault recovery, high reliability, flexible networking, and simple implementation, thus becoming an indispensable part of the construction of power communication SDH networks. How to effectively evaluate the self-healing ability of SDH and improve the performance of the transmitted services has become an urgent problem to be solved. In the actual operation of the network, the self-healing capability of SDH cannot be accurately and effectively evaluated. Therefore, on the Exata simulation platform, the SDH transmission network equipment, network, services and other resources and self-healing behavior are modeled to achieve the SDH. Transmission network "fault occurrence - fault detection - fault recovery" this self-healing process simulation. Finally, a comparative evaluation of the availability of access networks and backbone networks was carried out for a protection network in a certain area, verifying that the channel protection function of SDH self-healing rings can effectively improve the security and reliability of the power grid.

Key words: SDH transmission network, self-healing model, simulation implementation.

INTRODUCTION

In recent years, as SDH transmission networks have become more and more widely used in power communication networks, it has become increasingly important to improve the survivability of transmission networks. Therefore, the self-healing function evaluation of SDH networks has also become more and more concerned [1]-[2]. The actual measurement and evaluation of the self-healing ability in the SDH power communication network are prone to several problems, such as the impact of the greater network security and the lack of support of the available real network, so the use of simulation techniques and methods, combined with the actual power the self-healing process of the communication network analyzes the self-healing ability of the SDH network and its impact on service performance. It is necessary for the actual power grid security and power system performance evaluation.

At present, some researchers have studied the SDH optical network self-healing protection and network simulation models. For example, Li Yang and others from Ningxia Electric Power Co., Ltd. have studied the effect of SDH fiber self-healing protection on the power communication system [3] and proposed appropriate Network protection program. Qinghai Electric Power Wang Hua et al. studied the number of transmission nodes, time delay and protection method of SDH fiber ring network [1]. Zhao Houbin of Southeast University analyzed the channel requirements and transmission format of the SDH fiber self-healing ring and verified that only the SDH fiber self-healing ring network adopts the multiplex section switching ring protection mode to meet the requirement of differential protection [4]. Bai Jingru of Beijing University of Posts and Telecommunications has studied the

improved method of SDH self-healing rings. By analyzing the protection switching principle, switching time and capacity in different situations, various application suggestions for the structure of different network topologies of SDH self-healing rings are proposed [5]. Most of the above studies have studied the mechanism, optimization, and application of SDH self-healing rings. However, studies on the self-healing ability assessment of SDH optical networks have not yet been conducted, and the designed SDH self-healing ring capabilities cannot be evaluated.

In addition, existing data network simulation platforms, such as OPNET and NS2, lack support for SDH optical network simulation [6]. Calvet J.T and Girault C. jointly designed and developed the SDH synchronization network planning simulation platform, simulating the impact of different synchronization configurations [7]. Schwartz S. H. and Zager D. designed a discrete event-based telecommunications network simulation platform to simulate the failure process of various types of networks including SDH networks [8]. Ruepp S et al. proposed a database-based SDH transmission network self-healing model simulation model, which focuses on the occurrence of simulated failures and business recovery processes [9]. Li Jianhua and others of the Institute of Communication Engineering of PLA University of Science and Technology of China developed the SDH optical end device simulator based on the client-server model to simulate the functions of configuration management, fault management, performance management, and accounting management of the SDH network management system. However, this system is mainly aimed at the training of network management operations. It is used for SDH students to master the network configuration and operation functions, and it lacks a deep-level simulation of the SDH protocol system, technology system and equipment [10]. The above studies mostly simulate the network topology through the bottom-up modeling at the process level, node level, and network level, and cannot simulate the SDH network from the service perspective. In addition, in the existing network simulation model research, the network resource model and alarm model are mainly studied, and no self-recovery simulation study of SDH optical network has been conducted, and the behavior model of network resources and the protection switching behavior of services cannot be simulated. And it is self-healing process for accurate simulation.

Therefore, based on the Exata simulation platform, this paper implements SDH self-healing process simulation from two aspects of resource simulation and behavioral imitation, modeling the resources of SDH network from three levels of equipment, network and business, and combining the behavior of SDH equipment in the event of a fault. Action and state change, and finally realize the whole process simulation of the self-healing function of power SDH transmission.

SDH SELF-HEALING SIMULATION MODEL

SDH Resource Simulation Model.

In this paper, the SDH optical transmission network resources are divided into three levels: device layer, network layer and service, and they are modeled separately. Device layer modeling objects are physical networks such as physical devices and physical circuits; network layer modeling objects are protocols including network element logic processes and link logic processes; service layer modeling pairs are service networks and are mainly service transmissions. Links and circuits that carry service links.

The device layer model mainly establishes four basic network element models of the SDH transmission network, including a terminal multiplexer (TM) simulation model, an add-drop multiplexer (ADM) simulation model, a regenerative repeater (REG) simulation model, and synchronous digits. Cross-connect device (SDXC) simulation model, as shown in Figure 1.

The idea of establishing the SDH equipment simulation model in this paper is: according to the signal processing process and the role of each device in signal processing, the functional simulation of each logic module is performed according to the signal stream processing sequence, and it is completed under the unified management module organization control. SDH signal frame interpolation, multiplexing and demultiplexing this base function.

(1) Terminal Multiplexer TM

The function of the terminal multiplexer is to multiplex the low-speed signal from the tributary port to the high-speed signal STM-1 of the line port, or to demultiplex the low-speed tributary signal from the high-speed signal. Among them, the line port inputs/outputs a STM-1 signal, and the branch port can input/output multiple low-speed tributary signals.

FIGURE 1. Basic network element location map in the SDH network

To achieve the above functions, the functional flow of information flow through each logical module is as follows:

FIGURE 2. The function flow of the signal via the terminal multiplexer

- 1) Establish a switching device: establish a Layer 2 switching device for data exchange based on the MAC address;
- 2) Low-speed tributary signal acquisition: When the data packet obtained from the low-speed tributary has a large SDH minimum virtual container VC-12 size, the data packet needs to be fragmented and loaded into multiple virtual containers of the signal respectively. Messages will be sent in frames and combined at the receiver.
- 3) Complete the multiplexing/demultiplexing simulation: Obtain an array of multiplexing rules, perform byte interleaving on the data packets according to the SDH frame structure, multiplexing/ demultiplexing principle, and complete multiplexing/demultiplexing.

(2) Add/Drop Multiplexer ADM

The add/drop multiplexer ADM consists of multiple ports and is mainly used for the switchover of the SDH transmission network. ADM can realize the multiplexing of low-speed signals and can also realize high-speed signal to low-speed split.

The insertion and insertion multiplexer modeling process are as follows:

FIGURE 3. The function flow of signal via add/drop multiplexer

1) The line signal is delivered: The IP header of the line signal detected by the ADM device determines the destination address, or the first 32-byte flag, to determine whether the node needs to issue the low-speed tributary signal. If it needs to issue, the line will be Signal demultiplexing, the corresponding branch signal will be issued;

2) The line signal is fully loaded: the ADM device demultiplexes the received line signal, and judges whether there are 63 base frame frames according to the first byte of the demultiplexed base frame, or which channels are still able to be filled;

3) Branch signal multiplexing: If the existing line signal in the ADM equipment is not full, the branch signal is stored in the corresponding way and multiplexed to form a multi-frame and forwarded out. If the line signals in the ADM equipment are all fully loaded, each branch signal is directly multiplexed to form a multi-frame and forwarded out;

4) Line signal forwarding: For fully loaded and unneeded line signals, the ADM equipment directly forwards according to the MAC forwarding table; other line signals are demultiplexed/multiplexed to form a new branch signal forwarding.

(3) Digital Cross Connection Equipment DXC

The DXC function of the digital cross-connect equipment is to realize the cross-connection of the tributary signals, and it can realize controllable connection and re-linking to various port rates. Specifically, it can multiplex any of the low-speed STM-N signals and also demultiplex any high-speed STM-N signals.

FIGURE 4. The functional flow of signals via digital cross-connect equipment

1) Line signal demultiplexing: the DXC device demultiplexes the acquired line signal to m parallel cross connect signals;

2) Multiplexed Channel Arrangement: The DXC device rearranges the cross-connect channels to generate an internal cross-connect list according to dynamic calculations or pre-stored cross-connect diagrams.

3) Signal multiplexing: Using the multiplexing function, the rearranged signal is multiplexed into a high-speed/low-speed signal output.

(4) Regenerative repeater REG

The regenerative repeater REG mainly converts the optical signal into an electrical signal, and then undergoes sampling, amplification shaping, and regeneration planning as electrical signals, and then modulates the optical pulse signal transmission to ensure the integrity of the transmitted signal waveform, and at the same time, the transmission distance is also extended. Since REG's main functions are concentrated in the physical layer, this paper adopts transparent transmission of data packets to simulate the function of the device.

B. Network layer model

The network layer model mainly includes links, protocols, network traffic models, and network topology models. The SDH transmission network is an optical fiber link. It is only necessary to model the link delay. In this paper, EoS (Ethernet over SDH) technology [11] is used to map Ethernet signals to data frames transmitted by SDH devices. Divided into the following steps:

(1) Delete the preamble and frame start delimiter of the MAC frame;

(2) The data frame is encapsulated based on the LAPS (Link Access Procedure SDH) protocol;

(3) The encapsulated data frame is mapped to the SDH VC (virtual container) virtual concatenation to achieve transmission;

(4) The receiving side extracts and parses the protocol frames in the VC virtual concatenation;

(5) Add the preamble and start of frame delimiter.

The recovery of LAPS protocol frames is closely related to its mapping. At the receiving end, the recovery of LAPS protocol frames requires the following three steps:

(1) Receive data from VC-12-3v;

(2) cache the load in the VC and adjust the delay;

(3) Restore LAPS protocol frames.

Due to the size of the Ethernet and IP packet signals and the fixed size of the SDH virtual container VC, resource utilization is low. In order to improve the resource utilization, SVC VC cascading technology is used to implement the cascade of N VC n virtual containers as a container with a capacity size of $N \times VCn$. In practical applications, the dynamic adjustment of the packet signal capacity in the transmission process can be dynamically adjusted to improve the channel utilization of the SDH.

The network topology structure modeling adopts an object-oriented modeling mechanism and establishes the equipment model and connection model of the power communication network according to the types of power communication networks (such as point-to-point, bus, and wireless). Starting from the type of power communication network, network topology modeling mainly includes point-to-point, bus and wireless structures. Based on the object-oriented modeling mechanism, the internal equipment model and link model of the power communication

network are reasonably structured. Starting from different network functions, the model version of the complete network equipment is implemented to support various simulation needs.

For different occasions, the following three traffic modeling techniques are used to establish a network traffic simulation model.

(1) Explicit traffic modeling: Establish a simulation process model for generating, queuing, transmitting, and receiving data packets, and clarify the process traffic;

(2) Background interactive traffic modeling: According to the traffic routing conditions and traffic matrix to describe the end-to-end traffic;

(3) Background utilization traffic modeling: When no simulation packet is transmitted, the model clarifies the background traffic in the network, which is mainly used for capacity planning and application analysis.

C. Business layer model

Business modeling, that is, data flow modeling. This article uses a standard application business model to model and simulate the required services. There are two types involved in the simulation: the OFF/ON business model and the end-to-end business model.

The OFF/ON business model is a mathematical analysis model. This business is represented by the discontinuity of data transmission, and the alternating of ON and OFF states. Among them, there is data transmission in the ON state and no data transmission in the OFF state. In general, the ON state and the OFF state are subject to independent distribution. To describe the random elements of the OFF/ON data source, it is necessary to grasp the distribution of the ON and OFF interval lengths. This service model can not only set the time period for each node device to start sending packets, but also the packet size and the arrival interval of each packet.

The end-to-end service is Client/Server (client/server) service. Commonly used application protocols have been set and these applications are modularized. Users can select corresponding parameters according to service requirements and configure such standard applications. It is generally divided into four steps: setting application parameters; setting business inquiries; configuring applications supported by the server; and setting client service inquiries.

Self-Healing Behavior Simulation Model

Self-healing behavioral simulation is mainly divided into fault occurrence behavior, fault detection behavior, and self-healing recovery behavior.

A. Failure behavior

The common faults in the SDH network fall into three categories: transmission device failure, trunk cable failure, and peripheral failure.

a) Transmission equipment failure

Transmission device failure in the emulation device, all ports or fault ports of the device are set to be unavailable, and the fault information is synchronized to the adjacent node ports of the fault port, that is, the node failure makes the adjacent node ports to all Timeslots are not available.

b) Link failure

Link failure in the emulated device, the connected device port is set to the unavailable state, that is, the link failure makes the ports at both ends of the link unavailable to all time slots.

c) Peripheral equipment failure

Peripheral devices [12] such as synchrophasor measurement devices and stability control devices are greatly affected by the external environment. Maintenance personnel are required to pre-qualify the power supply on a regular basis to ensure stable, safe, and stable operation of the equipment. Such failures require human intervention. Unable to recover business through self-healing.

B. Failure detection behavior

The fault detection of the SDH network is divided into two modes: fault detection of the normal transmission equipment and the selective equipment.

a) Failure detection of ordinary transmission equipment

The ordinary transmission device detects the status of each time slot of each sending port every 0.125 MS, including whether the message received by the time slot carries alarm information and whether the receiving port of the time slot is available.

If there is alarm information in the current time slot or the receiving port of the time slot is unavailable, a message carrying the alarm information is sent; if the fault has no effect on the current time slot of the current node, a normal message is sent.

b) Fault detection of selective devices

The receiving device receives the same message from the primary slot and the backup slot. Normally, the message from the primary path does not carry alarm information, and the receiving device receives the message from the primary path.

When the message of the primary path carries the alarm information of a certain time slot, the selective receiving node detects that the primary path of the time slot is faulty and takes corresponding protective measures. If the selective receiving device only receives the message of the backup path, the corresponding protection measure is adopted in the case of confirming the failure of the active path.

C. Self-healing recovery behavior

In the communication and transmission process of power grids, there are many self-healing protection methods for data and information communication transmission in SDH networks. According to the functional structure of actual power communication networks, the self-healing protection method chosen in this paper is automatic line switching protection [13].

Automatic protection switching According to the actual use requirements, there are the following two ways of working:

a) does not automatically return

The receiving node works on the main line. If the main line is faulty, the receiving node automatically selects the alternate line message and works on the standby line (except for manual intervention or failure of the standby line); after that, until the backup line fails, select the receiving node is automatically switched to the main line (except for manual intervention or failure of the main line).

b) Automatic return

The receiving node works on the main line. If the main line fails, the receiving node automatically selects the standby line message and works on the standby line; after that, if the main line returns to normal and can operate normally for a period of time, the receiving node automatically Return to the main line.

SIMULATION EXAMPLES AND RESULTS

Self-Healing Process Verification Examples

Simulation Scenario

Based on the topology of the SDH communication network in Mianyang, Sichuan Province, this paper implements self-healing simulation of the power SDH transmission network. The network includes an access layer ring network and a corresponding convergence layer ring network. The service is a security control service. The service is a real-time data service. The service bandwidth requirement is not high. The bandwidth of each channel is generally 2 Mbps. The two-fiber bidirectional channel protection is used. The acquisition equipment includes a PMU (Power System Synchrophasor Phasor Measurement) device and a power stability control device. The frequency of the two packages is 0.01s and 0.833 ms, respectively.

Under normal circumstances, the SDH network adopts a dual-transmission protection mechanism. After the terminal equipment information is multiplexed by the SDH equipment, it is transmitted at the same time in the active path and the backup path. Finally, the receiving node on the ring selects and receives better communication quality. The message on the primary path. The network simulation scenario is shown below.

FIGURE 5. Topological Simulation of SDH Communication Network in Mianyang Area

Failure Behavior Simulation

SDH network fault simulation includes two types: communication device failure and link failure, in which the communication device failure is a red flag and the link failure is a yellow flag, as shown in the following figure.

FIGURE 6. SDH network fault simulation

The total simulation time is 1 hour. The fault includes:

- 1 starting from 1min, once every 40s, there is a link failure, duration 20s, affecting the primary path of a time slot of the same ring, and the backup path of two time slots;
- 2 From 2 min, once every 1 min, there is a communication device failure for a duration of 20 s, affecting the main path of two time slots in the same ring and the backup path of one time slot.

Self-Healing Recovery Simulation

There are two ways to recover from self-healing: automatic return and automatic return. You can set the recovery mode of self-healing nodes on the graphical interface, as shown in the following figure.

FIGURE 7. Self-healing recovery mode settings

In the automatic return mode, the self-healing process is:

11min-1min20s, 2 nodes as the selection node of the time slot, switch to the standby path, and always work in the standby path;

22min-2min20s, the main path of nodes 20 and 19 is affected by the fault, switches to the standby path, and has been working on the standby path; the standby path of the 2 node is faulty, switches back to the active path, and is always working on the active path.

After 32min40s-3min, the standby paths of nodes 20 and 19 are affected by the fault, switch back to the active path, and work on the active path. The active path of node 2 is faulted, switches to the standby path, and is always working on the standby path.

In the automatic return mode, the self-healing process is:

11min-1min20s, 2 nodes as the selection node of the time slot, switch to the standby path, and always work in the standby path;

21min21s, the 2 node receives a valid message from the active path for this time slot, switches back to the active path, and works on the active path.

32min-2min20s, the main path of 20, 19, and 2 nodes is affected by the fault, switches to the standby path, and always works in the standby path.

42min21s, 20, 19, and 2 nodes receive a valid message from the active path in the time slot, switch back to the active path, and work in the active path.

The subsequent self-healing process repeats the above four processes.

(a) Link failure self-healing

(b) Communication equipment failure self-healing

FIGURE 8. SDH network self-healing simulation

Comparing the statistical results of all services received and sent out, we can see that the self-healing model based on this paper simulates the SDH network failure and its recovery process, and there is no packet loss phenomenon, and the effect is good.

Self-Healing Ring Application Evaluation Example

Figure 9 shows a protected communications network in a certain area. The network includes 2 provincial transmissions, 2 tones, 16 substations, and 2 power plants. The flow of its business is mainly for each 500kV substation and the ground adjustment sub-power plants and 220kV substations, the business will be brought to the

province to adjust, while provincial regulation, tones, substations issued corresponding protection orders. In order to increase the reliability of the network, each station node of the plant uses a dual 2M fiber link to uplink to the backbone node through the router. After the links are bundled, the backbone node is connected to the ground adjustment point of its own area.

FIGURE 9. Topology of a protected communications network in an area

The protection communication special network is divided into four areas, including three-star access networks and a ring backbone network. Stations 19 and 40 are provincial deployment sites and are the convergence core of the entire system protection communication network. Station 15 and station 20 and station 22 are convergence cores of access network 1, access network 2 and access network 3, respectively, and station 12, station 15, station 17, station 20 and station 22 are connected through a fiber ring network. The backbone network that forms the system protection communication network, each access network is connected to each site in a star manner.

In an actual network, since the failure rates of the network elements are not the same, the failure rate of the available network elements can be obtained by counting the failure-free working times of the network elements for a period of time.

TABLE 1. Availability of system protection communication network in a certain area

Network name	Number of interfaces	Device interface availability	Fiber count	Optical fiber availability	Overall availability
Overall network	126	0.999779	61	0.999958	0.999749
Backbone network	20	0.999816	10	0.999989	0.999814
Access Network1	44	0.999659	20	0.999989	0.999641
Access Network2	38	0.999816	18	0.999936	0.999795
Access Network3	28	0.999785	13	0.999906	0.999754

From Table 1, it can be seen that the fiber optics availability and overall availability of the backbone network are significantly higher than the access network's fiber availability and overall availability, which is due to the channel protection function of the SDH self-healing ring. The effect of fiber failure on the reliability of the entire network. It can be seen that, compared with a star network, the reliability of the ring network structure is better, and it is more suitable for the backbone layer and the core layer. At the same time, improving the availability of device ports is the key to improving the overall network reliability.

SUMMARY

In view of the fact that there is currently no study on the self-healing capability assessment of the system protection network, this paper first models the simulation resources of equipment, networks, and services of the SDH optical communication transmission network; then, when the network fails, the behavior of the SDH equipment the state change process is simulated to realize the whole process simulation of the self-healing function of the power SDH transmission network. The self-healing ability and effect of the SDH network are visually demonstrated. Finally, the validity of the SDH optical communication transmission network is evaluated by statistical network effectiveness. The availability test verifies that the channel protection function of the SDH self-healing ring can improve the safety and reliability of the power grid.

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