Research on Shared-port and Shared-network HSR Network in Smart Substation

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ABSTRACT

In this paper, the realization method of Shared-port and Shared-network in smart substation based on HSR network is studied. In the first, the time division multiplexing of HSR network is studied, then service mapping to different wavelength based on wavelength division multiplexing is studied. Through these studies, we can establish the HSR network with high real-time, high reliability and physical isolation function. This HSR network can provide technical support for the construction of a high speed shared-port and shared-network communication network in smart substation.

INTRODUCTION

IEC61850 "Communication networks and systems in substations" standard is the international standard of substation automation system based on general network communication platform. The smart substation automation system based on IEC61850 realizes the information sharing and interoperability between intelligent electrical equipments by hierarchical distributed. On the logic function, the smart substation consists of station level, bay level and process level. Station level network is used to connect the station level equipments and bay level equipments, and the process level network is used to connect the process level equipments and bay level equipments[1][2]. In the current engineering practice, the station level network and process level network are physically separated[3]. In order to ensure the reliability of the network, each level network is usually uses a redundant dual-star topology. The process level network is divided into independent GOOSE (object oriented substation event generic) network and SV (measured value sampled) network.

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“Shared-port and Shared-network” refers to the communication network in smart substation is no longer divided into independent station level and process level network and GOOSE, SV and MMS message of one IED connected to the communication network by one Ethernet port. The development of new generation of smart substation communication system is to build a high-speed “Shared-port and Shared-network” communication network.

The recovery time requirements of process level and station level network are not the same. IEC61850-2010 standard puts forward specific network recovery time requirements, the recovery time of command information in station level is 100ms, the recovery time of interlock, trip and reverse blocking in station level is 4ms, the maximum propagation delay of time-critical information sample values in the process level is not more than 4ms, and the recovery time of sample values is zero. So the recovery time of “Shared-port and Shared-network” should be zero and the sample values propagation delay should be not more than 4ms.

For these redundancy protocols specified in the IEC 62439 series, PRP (parallel redundancy protocol) and HSR (high availability seamless ring) with no frame loss and zero recovery time for the considered failures [4], have been introduced as part of the IEC 61850. PRP and HSR with high reliability, high flexibility and no changes to the network topology, will be the future trends in smart substation automation network communication system.

In the PRP, two directions of a node operate as two separate networks. It is a simple, seamless loop structure, which is called HSR. HSR ring structure uses a different direction with a ring as an independent network to realize redundancy and costs reduced. The DANH (Doubly Attached Node with HSR protocol) has two ring ports, interconnected by full-duplex links. A source DANH sends a frame passed from its upper layers, inserts an HSR tag to identify frame duplicates and sends a frame over each port. A destination DANH receives, in the fault-free state, two identical frames from each port within a certain interval, removes the HSR tag of the first frame before passing it to its upper layers and discards any duplicate [3]. Figure 1 shows the DANH and bus topology.
HSR tag is located at the beginning of the data frame, followed by the destination address, so direct exchange technology can be applied in forwarding data frame. The node can forward data frames from one port directly to another port after the frame destination address, source address and serial number of data frames have been received and not need to accept full data frames confirm the need for forwarding data frame. The delay time caused by the forwarding process is greatly reduced, which can meet the requirements of real time.

Figure 2 shows the redundant network topology scheme in smart substation based on HSR. This topology without costly switches, is a more simple and unified redundant connection solutions for seamless recovery n smart substation \[3\].

**TIME DIVISION MULTIPLEXING**

According to the theoretical calculation, the process level SV message flow only occupies about 4% of the 100M port, the flow rate of GOOSE message in the process
level is much smaller than SV. At present, in the smart substation, the SV message traffic of one interval is not more than 5MB/s, and the GOOSE message traffic is not more than 0.1MB/s\[^{[5][6][7]}\]. If the entire substation has 30 intervals, taking into account the GOOSE message traffic is far less than SV, the process level network load will not exceed 150M, and will not exceed 15% in Gigabit network. This flow is relatively easy for the switch, but for the protection, measurement and control and other intelligent devices is not a small flow.

When the SV, GOOSE and MMS in the substation are transmitted in “Shared-port and Shared-network” HSR network, the priority of SV should be set to the highest, then GOOSE, MMS minimum. But if a long low priority packet is being sent and a SV packet needs to be sent, it is impossible to cancel the packet being sent to send the SV packet. Therefore, a more reliable way is time division multiplexing. Because the SV rate is 4 kHz in engineering application, the time slice is divided into 250 μs units for each time slice, which is further divided into two parts:

- part 1: 0~50 μs, for SV only;
- part 2: 50~250 μs, for GOOSE, MMS and others.

![Figure 3. Model of Time Division Multiplexing.](image)

In order to ensure the real-time performance of GOOSE, priority scheduling should be used to store GOOSE in a high priority transmission queue. Only the queue is empty, the MMS is considered. Figure 3 shows basic model for common port transmission.

Considering the signals of IED with a time scale, and the GOOSE retransmission mechanism is generally 2 ms, so the two GOOSE packets are inserted between the two SV packet will not cause the problem of the accumulation.

**WAVELENGTH DIVISION MULTIPLEXING**

WDM (Wavelength division multiplexing) is one of the main techniques to improve the capacity of a single optical fiber, which is similar to the frequency division multiplexing technology in the radio system. The transmitter multiples a number of different wavelength optical carrier signals (carry various information) together by the multiplexer and coupled to the same fiber, the receiver uses the de-multiplexer to restore the original signals. As long as the distance between the adjacent wavelength channels is far enough, the different wavelength channels will not interfere with each other, so the multiplexing transmission of optical signals can be realized in a single optical fiber. In addition, bidirectional transmission also can be arranged in two directions at different wavelengths. Figure 4 shows the WDM in DANH.
As shown in Figure 4, the wavelength is equivalent to the forwarding queue in DANH, different services are mapped to different wavelengths and each service will not interfere with each other, the same type of service using FIFO scheduling strategy in switching unit. The packets form IED will be classified according to the service type and put into different forwarding queues and sent by different wavelengths. Different wavelengths are coupled into one fiber by the multiplexer, the de-multiplexer restores the original signals and put them into different receiver port. If the received packet is for IED, time division multiplexing will be applied in the service identification module. In “Shared-port and Shared-network” HSR network, MMS, SV and GOOSE can be physical isolation and not affect each other.

**CONCLUSIONS**

This paper studies the time sharing transmission method based on time division multiplexing, and service mapping to different wavelength method based on wavelength division multiplexing. HSR network with multiplexing technology has high real-time, high reliability, physical isolation function and can provide technical support for the construction of a high speed shared-port and shared-network communication network in smart substation.

**ACKNOWLEDGEMENTS**

This work was financially supported by the Science and Technology Project Funds "Research on High Reliability Network Redundancy Technology and Relaying Protection Network Communication Path Automatic Generation Technology in Smart Substation", State Grid Corporation of China, 2015.

**REFERENCES**


