Research on Interface Mode and General Information Transmission Technology in smart Substation

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Abstract. Through the analysis of the system architecture of smart substation, the interface mode and information transmission protocol between secondary equipment and primary equipment are defined. The general information transmission protocol for data acquisition and control instruction transmission is studied, which improves the reliability and security of the secondary system of smart substation.

1. Introduction
The secondary system of smart substation adopts the structure of "three layers and two networks", which is composed of station control layer, interval layer, process layer, station control layer network and process layer network. There are many problems in the secondary system, such as complex structure, many intermediate links, reduced reliability and speed of protection, wide influence range of single equipment failure, which are not conducive to the safe and stable operation of smart substation.

At present, relevant research work has been carried out at home and abroad on the secondary and secondary interfaces and networking schemes of smart substations. In terms of a secondary interface, the International Electrotechnical Commission (IEC) has developed standards for electronic voltage and current transformers. The communication uses FT3 transmission. Since the application data for the output is not specifically defined, the current data output definitions of major manufacturers are different, cannot be interconnected. In terms of networking solutions, HSR networking solutions have begun or are planned to be used in smart stations in multiple countries. The HSR ring network communication technology has been adopted between the local inter-spaced protection sub-machines, and the network trial operation has been carried out.

By analyzing the architecture of the smart station system, this paper clarifies the interface mode and information transmission protocol between the secondary device and the primary device, and studies the general information transmission protocol for data acquisition and control command transmission, thereby improving the reliability of the secondary system operation of the smart station. , safety [1-3].

2. Smart Substation System Architecture
2.1. Smart Substation System Structure
According to IEC61850 standard, the smart substation system is divided into three parts: substation layer, spacer layer and process layer, and connected by layered, distributed and open network system.
(1) Process layer
   The process layer is directly connected to the sensor signals, status signal interfaces and actuators of the primary device. The device can be installed on-site with the primary device, and the working status and equipment of the primary device are realized by the merging unit (MU) and the smart terminal. The digitization of the attribute, the process layer device is connected to the bay level device through the process layer bus, and the system synchronizing clock signal is generated by the GPS timing signal.

(2) Bay layer
   The interval layer device mainly implements the protection and monitoring functions, and implements the related human-computer interaction function of controlling the blocking and the interval level information. The interval layer device can realize the mutual dialogue mechanism between the devices through the interval layer bus, and the interval layer device can concentrate the group screen or PUT it underground.

(3) Station control layer
   Substation level equipment includes substation local operation back-end system, external data interaction interface (control center data forwarding, protection information management system data interface, equipment management system) and general function services. The universal function service module realizes the substation level interval control service through the information transmitted by the interval layer device, such as substation anti-missing lock function, voltage reactive power control, and can also receive commands from the control center to realize regional system anti-disoperation and regional security. Stable control and regional voltage reactive power optimization control.

2.2. Smart Substation Communication Network
At the logical level, the smart substation connects the process layer, the bay level and the substation layer equipment through the process layer network and the substation layer network.

   (1) Substation layer network
The function and structure are basically similar to the monitoring network of the traditional substation. It relies on MMS/GOOSE for communication, which realizes the aggregation of the whole station information and the function of preventing mis-locking.

(2) Process layer network

The process layer network is divided into SMV sample value network and GOOSE network. The main function of the former is to realize the uploading of current and voltage AC. The main function of the latter is to realize the uploading of the switching quantity and the downlink of the switching control amount.

The data flow on the process layer communication network can be divided into: sample value SAV message periodically sent by the merging unit to the IED; the substation event GOOSE message for the universal object periodically sent by the smart terminal to the IED, that is, the switch The input message; the GOOSE message sent by the IED to the smart terminal, that is, the switch output message, including switch split, device retreat, tap adjustment, gear shift, etc.; simple network time protocol (simple network time protocol, SNTP) or IEEE 1588 time synchronization message.

3. Interface between secondary device and primary device

3.1. Current status

The traditional electromagnetic transformer uses the principle of electromagnetic induction to convert the high voltage and large current in the power grid into small voltage and current. Electromagnetic transformers have many disadvantages: 1) With the increase of voltage level and system capacity, the insulation of the secondary side of the electromagnetic transformer is more and more difficult to realize, and the volume required for implementation is getting larger and larger, so the cost is higher. The higher the dynamic range; 2) the dynamic range of the electromagnetic transformer is small; 3) there may be magnetic saturation and ferromagnetic resonance problems, especially for the accuracy and reliability of higher harmonics and impact power measurement.

Electronic transformers can overcome the above problems. The interface used by different manufacturers and the input data required may be different, which leads to the interface problem between the electronic transformer and the secondary device. Therefore, the concept of a merging unit is proposed. The merging unit was first defined in IEC 60044-8 for the connection of electronic transformers with digital outputs. Its main function is as a standard digital interface for electronic transformers, using a uniform communication protocol to seamlessly interface between devices. Communication. The merging unit receives the sampled data output by the electronic transformer, processes it, and transmits it to the bay layer in a communication manner.

Currently, MU has been extended to maximize its performance and functionality. The enhanced merging unit is actually a measurement data acquisition system that not only captures the output data of the electronic transformer, but also the measured values of the traditional transformer. At the same time, the MU allows the secondary device to be connected via a point-to-point link, a process bus, or both.

According to the IEC 60044-7/8 standard and the IEC 61850-9-1/2 standard, the merging unit has the following basic functions: 1) It can receive the data information transmitted from the high-voltage side electronic transformer in real time, and can timely put the data into IEC61850. The specified frame format is transmitted to the Ethernet; 2) the synchronization function. It can receive the external clock signal and control 12 channels for simultaneous sampling. If the synchronization function fails, it should also be able to issue synchronous fault flag. 3) It can supply power to the active electronic transformer, generally using laser the energy mode transmits electric energy in the form of light to the high-voltage side electronic transformer through the optical fiber.

3.2. There is a problem

The smart substation merge unit has a large impact range. At present, the voltage sampling of smart stations of 220kV and below generally uses the bus voltage cascade mode, that is, the busbar merging
unit uniformly samples and sends them to each interval merging unit. If the busbar merging unit fails, the related protection, measurement and control work is abnormal, and the impact range is large.

In the actual use of the smart substation, the merging unit has poor reliability and frequent failures, which has caused many incidents. In 2015, State Grid Corporation has explicitly requested the cancellation of the merging unit of the 330kV and above voltage class substation and the corresponding SV network.

3.3. Solution

The embedded industrial chip is used to develop a standardized, low-power, high-reliability decentralized local module (analog local module, switch local module, operation module), which is compact and high-protection with the same device design. Anti-interference, configuration-free, low-power consumption, non-power-off replacement, realizing voltage, current, oil temperature, oil level and circuit breaker status, tap position, non-electricity signal and other analog and digital inputs. The local modules are arranged close to each other at intervals, with two sets of redundant configurations to improve system functional reliability.

The analog local module 4000 point/second rate transmission technology, the implementation scheme of sampling data transmission according to the IEC61850-9-2 protocol. The switch-on-place module uses the IEC61850-8 protocol to transmit device switching information. The standard IEC61850 is used for data transmission between the interface module and the interval measurement and control sub-machine.

4. Process layer general information transmission technology solution

4.1. High Availability Seamless Ring Network Redundant HSR

The high-availability seamless redundant ring network (HSR) can be regarded as an improvement of the PRP network to a certain extent. The structure is as shown in the figure. The A network and the B network in the PRP are processed into different transmission directions, and the A and B networks are connected. Finally connected together, this creates a simple, seamless ring network structure.

![Figure 2. Example of a PRP network (multicast)](image)
Like the PRP network, the HSR network can implement dual-network redundancy. Each node has two independent network access ports. The sending node is used as the sending source. When transmitting the packet from the upper layer protocol (C-frame), the HSR label is first added to the data frame, and then sent to the two different directions in the network through the two ports of the source node. A-frame and B-frame. The other nodes receive the packet as the destination address. One of the ports must receive the packet first. The node will discard the received duplicate packet.

Obviously, in the HSR network, a large number of switches are eliminated, which is reduced by half compared to the PRP network, which greatly improves the economics of the network. In the latest version of IEC 61850-9-2, the HSR network has excellent fault network recovery time, simple network structure and good economy, meeting the requirements of smart substation automation systems of various scales.

4.2. High Availability Seamless Ring Network Redundant Network HSR

The high availability seamless ring network redundant network (HSR) can be regarded as an improvement of the parallel redundant network (PRP) network to some extent, and the A network and the B network in the PRP are processed into different transmission directions, and A The B network is finally connected together, thus establishing a simple, seamless ring network structure. It is also mentioned in the latest version of IEC 61850-9-2 that the HSR network has excellent fault network recovery time, simple network structure and good economy, and meets the requirements of smart substation automation systems of various scales.

4.2.1. HSR Network Topology. The topology of the HSR network is shown in the figure, which is unicast communication and multicast communication. Each node has two ports connected to each other to form a ring network. For each frame of data transmission, the transmitting node first copies the data frame into two copies, that is, the A-Frame and the B-Frame in the figure are respectively sent to both ends.

![Figure 3. High Availability Seamless Redundant Network Topology (Multicast)](image-url)
In the HSR ring network, all data is added to the HSR network and HSR tags are added and propagated between the HSR and HSR networks. Data transmission, forwarding, and reception are generally performed between dual-connection switching nodes. For a general node, as shown in the single-connection switching node SAN, it cannot directly participate in the data exchange of the HSR network. If it is to participate, The HSR network must be connected via a Red Box.

![Image](image_url)

**Figure 4.** High Availability Seamless Redundant Network Topology (Multicast)

4.2.2. Working Principle of HSR. The principle of HSR is similar to that of PRP. It is mainly composed of Double Attached Node with HSR (DANH). Each node contains two Ethernet access ports, labeled as A and B ports. The same media access control address (MAC) and Internet Protocol (IP), working mode is dual full-link mode. The sending node simultaneously sends 2 identical copy frames (A-Frame and B-Frame) to each port in the ring network. The two data frames are transmitted in opposite directions, and each node in the ring network will receive it. The data frame is forwarded to a destination node with a unique address identifier or to a node other than the source node. In the ring network in a healthy state, each target node will receive two data frames of the same identity, that is, copy frames. The data frame received first is processed by the upper layer, and the data frame arrived after being discarded. In order to identify duplicate frames, data frames in the HSR ring network generally need to add HSR tags like VLAN tags. In addition to the Double Attached Node with HSR (DANH), there is another node in the HSR network, that is, a Single Attached Node (SAN). The SAN does not support direct access to the HSR network, as shown in Figure G. The SAN must be connected to the Red Box (Redundancy Box) to access the HSR network. Compared to DANH, Red Box can be understood as a network proxy for SAN access to HSR.

4.2.3. Communication rules for switching receiving nodes in an HSR network

(1) Sending rules

The transmission of each frame represents a higher layer protocol, and the transmitting node decides which form (HSR communication or non-HSR communication) to transmit downward. This decision is
application dependent, for example, depending on the protocol type or priority order. Generally, by default, they are all in the form of HSR frames.

1) For HSR communication (if the node is directly connected to the ring network): send data frames with HSR tags added to both ends, the two data frames are identical, called copy frames;
2) For non-HSR communication (the node is not directly connected to the ring network): Send unmodified data frames to the switching unit.

(2) Receiving rules
The receiving node determines whether to receive the data frame based on the principle of the HSR label.
1) For a non-HSR data frame (if the node is not directly connected to the ring network): no modification is made to the data frame, and is received and transmitted to the upper layer;
2) For an HSR data frame (if the node is directly connected to the ring network): If the frame is detected for the first time (if it is an A-Frame in the copied frame), remove the HSR tag and receive the modified data frame is transmitted to the upper layer;
3) If the data frame is detected a second time (if it is a B-Frame in a duplicate frame), it is discarded directly.

(3) Forwarding rules
Nodes in the ring network not only send and receive data, but also act as a forwarder.
1) If the node detects that the frame is a non-HSR data frame, it will discard.
2) If the node recognizes that the frame is an HSR data frame and does not perform a discard operation, the frame will not be modified and will be forwarded directly to the next section. The frame will be discarded in the following cases: 1 it is detected that the frame has been forwarded once in the same direction; 2 the node is a transmitting node.

(4) Direct forwarding
The dual connectivity node DANH can use pass-through to reduce latency when forwarding messages. After receiving the three parts of the destination address, source address and serial number of the data frame, if the node confirms that the data frame has never been received or forwarded before, it does not need to completely receive the data frame, and directly on the other port. It is forwarded to the next node. Therefore, the network transmission time is greatly saved, and the node burden is also alleviated.

(5) Bad frame processing
In general, the discard operation for bad frames is after the reception is completed. Because the node receives the qualified data frame after judging the repeated frame or the cyclic frame, and then after checking that the frame is a complete good frame, writes its entry communication information into the communication table; if the frame is detected as a bad frame, then discard it and do not write the corresponding ingress communication information to the access list.

Of particular note is the processing of bad frames by the node when performing a pass-through forwarding operation. If a bad frame occurs before the pass-through forwarding operation, it is discarded directly. If after the pass-through forwarding operation, a garbled sequence is appended to the end of the frame, and the source address of the frame will be registered on the node.

5. Conclusion
By studying the interface mode and information transmission technology of secondary equipment and primary equipment, this paper determines the general information transmission protocol for data acquisition and control command transmission, which is beneficial to improve the stability of the intelligent system secondary system operation and has significant economic benefits. And social benefits.

Acknowledgments
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