Research and Application of Unified Configuration Technology for Substation Automation Equipment

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Abstract. At present, there are many substation automation equipment manufacturers and equipment models, and different manufacturers have a great difference in the configurations of the same type of equipment. The operation and maintenance personnel are faced with such problems as the complexity of work, error-prone configuration, strong dependence on manufacturers, etc. It is difficult to standardize the operation process and professional management, and there are certain security risks. From the point of view of the unified operation and maintenance configuration of substation automation equipment, the unified configuration technology and methods of different types of equipment are studied in this paper, and the unification of the operation and maintenance configuration parameters, tools and operation process is realized.

1. Introduction

At present, the structure of the substation automation system is mainly decentralized and distributed, and there are many types of equipment. There are more than ten mainstream manufacturers in China that can provide complete sets of products to meet the needs of different types of substations. There are great differences in the design of products from different manufacturers [1-2]. To achieve the same function, different manufacturers need to configure different parameters. There are many private configuration parameters of the manufacturers, and the meaning of the characterization of each parameter is not clear for the users. The private configuration tools of the manufacturers must be used in the work of inspection and maintenance, their versatility is poor. The number of substation automation equipment managed by the operation and maintenance personnel is huge, and these common differences bring great inconvenience to the later operation and maintenance management [3]. For example, the operation and maintenance personnel need to take a lot of time and energy to familiarize themselves with a manufacturer's maintenance tools, while there are many automation manufacturers, and the operation and maintenance personnel cannot fully grasp all manufacturer's tools. The burden of carrying out their own work is heavy and the misconfiguration is easy to happen, which result in their strong dependence on the manufacturers. A large number of routine maintenance work needs the cooperation of the manufacturers.

In view of the above situation, starting from the actual requirements of the later operation and maintenance work, the research on the unified parameter configuration technology of substation automation equipment is carried out in this paper. According to the main types of automation
equipment in the current substation, different technical ideas to realize the unified configuration are put forward in this paper, and the technical popularization work has been carried out.

2. Operation and maintenance configuration parameters of substation automation equipment
There are many configuration parameters of substation automation equipment. Take the gateway as an example, its configuration parameters are less than 100 items and more than hundreds of items in domestic mainstream manufacturers. The design methods of different manufacturers are different, and there are fewer common parameters. If the unification of configuration parameters is considered from the perspective of refining the common parameters, there will be a situation that the common parameters cannot fully describe the operation mode of the equipment and cannot meet the application requirements.

The automation technology is developing rapidly and the equipment upgrading speed is faster, but the stability of the operation and maintenance demand is stronger. Therefore, the configuration parameters of substation automation equipment can be redesigned from the operation and maintenance demand, and the integrity of the description of equipment operation mode can be considered to achieve the goal of the unification.

Based on the above ideas, the outline design of the operation and maintenance configuration parameters of various equipment is as the following:

(1) The operation and maintenance configuration parameters of the gateway include system parameters, access parameters, channel parameters, protocol parameters, transmission table parameters and so on.

(2) The operation and maintenance configuration parameters of the monitoring background include secondary equipment parameters (four-remotion definition table), interval parameters, main variable parameters, network node parameters, user management parameters and so on.

(3) The operational and maintenance configuration parameters of the monitoring device include telemetry parameters, telecommunication parameters, telecontrol parameters, synchronization parameters and so on.

(4) The operation and maintenance configuration parameters of the switch include port parameters, VLAN parameters, port mirror, storm reduction, QoS parameters, multicast parameters, LLDP parameters, system monitoring parameters, upgrade backup parameters, hardware monitoring parameters and so on.

3. Unified configuration realization methods of different types of automation equipment
At present, the protocol IEC61850 has been fully applied in substations. The secondary equipment model and communication method have been standardized [4-5], and many related detection work and interoperability experiments have been carried out [6-7], which provide a good basis for the unification of equipment configuration. For the monitoring devices and switches, their equipment standardization is relatively high with the unified models (CID and MIB). For the monitoring background and gateway, there is no unified equipment description model, and its standardization basis is not as good as the two types of equipment mentioned above. Therefore, for different equipment, different technical methods are adopted to achieve the unification of the operation and maintenance configuration.

3.1. Unified configuration realization methods of the monitoring devices and switches
The standardization basis of the monitoring devices and switches is good, and they all have standard model definitions. On this basis, the parameter configuration model can be extended according to the rules provided by the relevant protocols [8]. Based on this configuration model, an independent third-party configuration tool can be developed to realize the online acquisition and delivery of device configuration parameters by the standard communication protocol. It is suitable for similar devices of different manufacturers and has strong adaptability.
3.1.1. Expansion of the unified configuration model for the monitoring devices [9]

In modeling, the configuration parameters of the telemetry, telecommunication, telecontrol and synchronization are defined according to the actual function requirements of the device. There are many configuration parameters in the actual device, that is, the same number of DOs should be defined in the model.

The configuration parameters of the telemetry, telecommunication and telecontrol are unified by adopting the generic process I/O (GGIO) to establish the corresponding LN, which is placed under LD0 that is one of the LDs. These three types of the configuration parameters GGIO contain two parts of information, in which one is public LN information, including the mode, health status, LN nameplate and other information, the other is configuration parameters information, such as the configuration parameter information in the telemetry GGIO shown in Table 1.

Table 1. Configuration parameter information in the telemetry GGIO.

| Attribute name | Attribute type | M/O | Chinese semanteme                          |
|----------------|---------------|-----|--------------------------------------------|
| Aindb          | SPG           | EO  | Telemetry dead zone (Voltage, current and power dead zone) |
| Frdb           | SPG           | EO  | Frequency dead zone                        |
| TapChgMod      | ING           | EO  | Gear synthesis mode                        |

Note: M/O indicates the attribute is mandatory or optional, where M is mandatory, O is optional and EO is optional for the extension.

The device parameter data set dsParameter is established, which is defined in the IED capability description file (ICD) according to the actual functional requirements of the device by the manufacturer and in accordance with the sequence of synchronization parameters, telecommunication parameters, telemetry parameters and telecontrol parameters. The desc attribute of each data set describes the name of the parameter. At the same time, according to the actual situation of the monitoring device, multiple parameter data sets of dsParameter can be established for each type of configuration parameters.

The device parameters are not controlled by the setting group control block (SGCB), which support getting the configuration parameter values through the services of GetDataSetDirectory and GetDataSetValues and modifying the parameters through the service of SetDataValues. Because the configuration parameters will not change actively in the actual operation process, there is no need to enable the reporting service, nor need to establish the corresponding reporting control block.

3.1.2. Expansion of the unified configuration model for the switches

At present, all switch vendors support the network management function of SNMP, and the switch equipment can be accessed through the protocol of SNMP to manage their MIB libraries, but the MIB libraries among the vendors are not uniform. Therefore, to achieve the unified operation and maintenance configuration, the unified standard MIB library is the foundation.

Starting from the configuration demand of the substation switches, the configuration parameter list of the switches is arranged, there are 10 categories in total as mentioned above. According to the list, and based on the existing MIB, the redundant parameter nodes are tailored, the parameter node model which needs to be extended is supplemented, and the unified parameter template is compiled. Based on these, the unified MIB library of the switches is established. In the process of formulating the MIB library, the relevant switch vendors should be convened to carry out the discussions, and the final MIB library should be consulted by various vendors many times. The significance of each parameter module for the switch operation and maintenance is shown in the table below.
Table 2. Significance of each parameter module of MIB

| No. | MIB module                              | The significance of operation and maintenance of the switches in the substation monitoring system                                                                 |
|-----|----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | MIB design of CPU and memory           | Assist the operation and maintenance personnel to master the running status of the power switch in real time.                                                                                       |
| 2   | MIB design of LLDP module              | Assist the operation and maintenance personnel to obtain the network topology and its connection status in real time.                                                                                |
| 3   | MIB design of QOS                      | Used to distinguish the importance of different power sources.                                                                                                                                      |
| 4   | MIB design of VLAN                     | Used to logically isolate different service flows of the power.                                                                                                                                     |
| 5   | MIB design of the port management      | Assist the operation and maintenance personnel to manage the port mode.                                                                                                                            |
| 6   | MIB design of the port mirror          | Provide the data interface for the power network analyzer.                                                                                                                                            |
| 7   | MIB design of the storm reduction      | Prevent the network storm of the power switch.                                                                                                                                                        |
| 8   | MIB design of the optical module digital diagnosis | Assist the operation and maintenance personnel to obtain the status of the optical module in real time.                                                                                                   |
| 9   | MIB design of the monitoring and alarming | Support and realize the alarm management function.                                                                                                                                                  |
| 10  | MIB design of the static multicast     | Used to logically isolate different service flows of the power.                                                                                                                                     |

3.2. Unified configuration realization methods of the monitoring background and gateway

There is no standard model definition for the monitoring background and gateway equipment. Each manufacturer uses the private maintenance tool to configure the parameters. The parameter acquisition and delivery processes are mostly private. For these two types of equipment, it is necessary to adopt a unified maintenance tool interface to achieve the unification of parameter configuration.

3.2.1. Unified configuration tool interface design

The tool interface mainly includes a menu bar, a navigation area, a main workspace, an attribute area and an information output window.

a. The menu bar is the functional navigation area of the configuration tool, and all operation functions are laid out in the area by icons.

b. The navigation area is divided into multi-level menus, which are divided by the functional modules, and the configuration parameters of each node are set under the functional module.

c. The main workspace displays various configuration parameters. All parameters are displayed in the tabular form. The first line is the configuration parameter header and the configuration parameter contents start from the second line, in which the configuration parameters can be edited.

d. The property area displays all the parameter contents of the single configuration item.

e. The information output window is used to display the whole process content of the configuration operation, which is divided into three tabs, including the personnel operation record, parameter modification record, inspection and verification information. Its information display should include the personnel, time, object, change information, result information, etc.

3.2.2. Unified configuration tool function design

The unified configuration tool should be able to meet the requirements of the on-site operation safety risk management and professional management. The following requirements should be considered in their functional design.
a. It should have independent personnel right management function. The personnel with different rights to log in should have different corresponding functions such as open for viewing, configuration and so on.

b. It should be able to obtain the current operating configuration parameters of the equipment online and have the function of parameter comparison between two devices. Try to avoid using the backup file to modify.

c. It should have the backup function and backup file management function.

d. It should have the function of checking the parameter modification correctness.

e. It should have the functions of parameter downloading, confirmation before downloading and automatic parameter validation.

f. It should have the function of on-line parameter calibration, by which it can compare whether the current operating parameters of the equipment are consistent with those of the configuration tool.

g. It should have the function of the parameter modification form and printing the whole parameter form to meet the requirements of the task management.

4. Unified configuration technology application and promotion

The unified configuration technology and methods of substation automation equipment proposed in this paper have been implemented in many domestic mainstream manufacturers, and the unified configuration tools of the monitoring devices and switches have been developed, and the configuration of similar equipment of different manufacturers can be completed with a set of tools. The gateway and monitoring background configuration tools based on the standard interface are essentially multiple sets of software tools. However, the tools provided by different manufacturers are consistent in display and operation mode, which effectively solves many problems existing in private maintenance tools, so there is no difference in application for the operation and maintenance personnel.

The relevant equipment and tools have been applied in Guangdong power grid, Foshan, Dongguan, Jiangmen, Huizhou, Maoming, Zhaoqing, Shaoguan, Yunfu and other power supply bureaus, and many digital and conventional substations with the voltages of 220kV and 110kV to verify their reliability and effectiveness, and have entered the promotion stage. The practice shows that the unified configuration methods can effectively improve the operational efficiency of the operation and maintenance personnel and enhance the safety of on-site operations.

5. Conclusion

Aiming at the problems of heavy burden and high risk of operation and maintenance work caused by many and different equipments in substation automation system, this paper puts forward the unified configuration technology of parameters for different types of substation automation equipment, which realizes the unification of operation and maintenance configuration parameters, tools and operation process. Through the pilot test, it can effectively improve the operation efficiency of operation and maintenance personnel and enhance the safety of field operation.

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