Research on Advanced Application Configuration Design Technology of Smart Substation

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Abstract. The application transparency of secondary equipment in Smart Substation is low, the logical linkage is poor, and the intercommunication ability of equipment from different manufacturers is limited, which seriously restricts the promotion and application of advanced application functions. In view of the above problems, this paper carries out the research on advanced application configuration design technology of Smart substation, realizes automatic generation of advanced application logic through configuration configuration technology, realizes real-time display of logic status through configuration monitoring technology, and develops a measurement and control device supporting configuration design. The research results of this project are applied to a 110kV Smart substation in Hubei Province. The application results show that the technology described in this paper can effectively improve the application quality and efficiency of advanced application functions.

1. Introduction

Smart substation is an advanced, reliable, integrated and environmental protection intelligent equipment. It takes the digitalization of the whole station information, networking of communication platform and standardization of information sharing as the basic requirements. It can automatically complete the basic functions of information collection, measurement, control, protection, measurement and detection. At the same time, it can support real-time automatic control, intelligent regulation, online analysis and decision-making and collaborative interaction. And other advanced functions of the substation [1].

Advanced application function is the expression form of Smart substation supporting operation monitoring and production management integration ability, which is based on the basic function of secondary equipment, aiming at higher application goals and constructed by systematic integration means.

At present, the engineering application transparency of Smart substation secondary equipment is low, the logical linkage of bay equipment and the status monitoring of primary equipment are not intuitive, which is not convenient for systematic management and control of equipment isolation, access and expansion. The secondary equipment has poor support ability for advanced application, and the interoperability ability of equipment from different manufacturers is poor, which restricts the application
and promotion of advanced application functions of Smart substation Effectively ensure the safe and reliable operation of Smart substation [2,3,4].

Aiming at the problem that "black box" characteristics of secondary equipment in Smart substation restrict the practicality of advanced application functions, this paper takes improving the transparent application degree of secondary equipment as the technical basis, takes the configuration design of advanced application functions as the technical means, and takes the integrated demonstration application of sequence control and standby automatic switching advanced functions as the technical goal, and carries out the corresponding research work and engineering application. The results of the project effectively promote the operation and maintenance work of Smart substation to reduce cost, increase efficiency and universal exchange of secondary equipment.

2. Technical architecture

The advanced function configuration design technology of Smart substation studied in this paper, through the development of general configuration architecture and rules, the development of general configuration software and hardware platform, realizing IED logic circuit configuration and on-line monitoring. It has the functions of equipment configuration standardization, function configuration graphical, data identification grassroots, automatic operation flattening, operation status visualization and so on.

Specifically, the advanced function configuration design technology of Smart substation includes configuration configuration technology, configuration monitoring technology and measurement and control device supporting configuration design function. The overall technical structure is shown in Figure 1. Configuration configuration technology is responsible for configuring specific function logic, which is used to generate logical relationship and algorithm sequence. Configuration monitoring technology is responsible for the real-time display of the logic state of the measurement and control device, completing the functions of data monitoring, logical sequence display, logic debugging, inversion, etc. The measurement and control device is the execution equipment of specific application. It is installed in the Bay layer of Smart substation. It receives the logic configuration such as logic relationship and algorithm sequence generated by advanced application function configuration design software, and completes the specific algorithm module.

![Figure 1. Overall architecture of configuration design technology](image-url)
3. Configuration technology configuration

Configuration technology completes the logic configuration of advanced applications by graphical way. According to the completed logical configuration, the corresponding logical relationship, algorithm sequence and other configuration information are generated and sent to the bay level equipment. Configuration technology takes configuration visualization design ladder diagram as the core, including drive package management, engineering management, equipment management, logical configuration design, device data mapping, configuration generation, configuration download to measurement control equipment, device configuration, calibration configuration and other technical links.

3.1. Configuration visualization design technology based on ladder diagram

The ladder diagram is composed of one or several independent steps, each of which is composed of one or several lines. Each row is composed of many elements. The ladder structure is shown in Figure 2.

Figure 2. Ladder diagram

Ladder diagram is a kind of graphic programming language which can express circuit logic intuitively and easily. The ladder diagram is used to draw and display the application configuration of logic functions. The signal data link of a function module and the status of equipment nodes in the link are mapped by ladder diagram steps. The ladder diagram from top to bottom indicates the sequence of function modules executed successively by logical functions, which helps to clearly show the logic execution process of high-level application functions such as sequence control [5].

The ladder diagram configuration design and application, which realizes the logic advanced application function, mainly needs to realize two major functions

1) Ladder diagram drawing and editing module: realize the data structure definition of ladder diagram, and provide graphic element library such as primitive node and connection according to the application requirements of intelligent station interlayer equipment, so as to complete the drawing and editing functions of application logic requirements.

2) Configuration storage loading module: according to the design of the configuration database, establish the storage and loading interface to ensure the persistence of the current project configuration and load and edit again. At the same time, the configuration ladder diagram is converted into configuration data file that can be recognized by the device, and then sent to the entity device to generate the corresponding function block and execute the logic function.
3.2. Configuration module and function

(1) Driver package management module. The main functions are: import drive package, export drive package, upgrade drive package. The "driver package" describes the resource area of each model of bay level universal device.

(2) Project management module. The configuration of each station is managed in the form of project, including new project, delete project, open / close project, import / export project and so on.

(3) Device management module. Equipment management includes adding equipment, deleting equipment and equipment level management. The hierarchical management of equipment is in the form of substation structure: the hierarchical mode of substation, voltage level, bay and equipment is used to store and display the equipment. It has a hierarchical structure, which is easy to find, and conforms to the actual situation of substations and the requirements of IEC61850 for equipment classification, so the substation mode is recommended for formal projects. However, in order to consider flexibility, it is allowed to add devices under any level node.

(4) Configuration design module. Configuration design module is the core module of the tool, which mainly realizes the visual editing function of logic.

(5) Data mapping module. The data mapping module is the core module of the tool, which mainly realizes the mapping between the data involved in logical operation and the resources of device driver package.

(6) Configure the output module. The main functions of configuration output module include: generate configuration configuration, download configuration, upload configuration, etc.

(7) Relational database interface module. Implement the encapsulation of relational database access interface.

3.3. Example of ladder diagram design

This paper introduces the logic configuration design of the station area control high-level function example of standby automatic switch. The standby automatic switching logic is composed of charging logic, starting logic and action logic. These logic refinements are encapsulated in corresponding function blocks, such as standby charging function block, standby switching starting function block, standby switching action function block, load shedding function block and post acceleration function block. In the editing system, they are organized by programming language to form the logic program diagram of automatic switch in, which is very intuitive and clear. Fig. 3 is the logic program diagram of the two bus sectional connection mode designed by configurable software.

The charging function block of standby automatic switching includes three input interfaces of charging conditions, instantaneous discharge conditions and charging time, and one charging result output interface. The charging and discharging conditions that need to be changed frequently are built by logic gates, which can meet the requirements of most of the charging logic of standby automatic switching. The charging mark is stored in the "charging mark" coil, which is used for judging the start-up logic of standby automatic switching. The start-up function block includes two input interfaces of start-up condition and start-up time, and two output interfaces of report serial number and start-up signal, which completes the judgment task of the total start-up and the corresponding report output work. The action function block of standby automatic switch is the execution unit of standby automatic switch, which is used to switch off and record action report. It includes three input interfaces, i.e. allowable condition, completion condition and action delay, and three output interfaces, i.e. output serial number, report serial number and completion signal.
Figure 3. Ladder diagram of standby auto switch logic

4. Configuration monitoring technology
Configuration monitoring technology is responsible for the real-time display of the logic state of the measurement and control device, completing the functions of data monitoring, logical sequence display, logic debugging, inversion, etc.

4.1. Joint verification technology
(1) Project configuration library. The project configuration library is a database file, which is saved and generated by the configuration design tool after the configuration is completed.

(2) Configure the load module. The configuration loading module is used to load and parse the project configuration library.

(3) IEC61850 communication module. Complete the communication with the device and receive the data sent by the device.

(4) Data processing module. It is used to process the data transmitted by 61850 Communication module and store the data as needed.

(5) Visual display module. The visual display module displays the logic according to the logic function and device data.

(6) Logic debugging module. Logic debugging module provides logic debugging function.

(7) Logic inversion module. The logic inversion module carries out logical inversion for the historical logic action records.

(8) Relational database interface module. Implement the encapsulation of relational database access interface.

4.2. Application example 1: visual monitoring of sequence control operation
Configuration platform design function according to the device needs to provide sequence control operation of external devices, configure to generate sequence control order sheet and logic sequence
algorithm, bind sequence control signal; through configuration design module, configure configuration graphics corresponding to various states of device (knife switch, ground knife, etc.) of sequence control steps, and generate visual picture of complete configuration logic display of sequence control ticket in ladder diagram configuration design mode. And generate the device recognizable logic configuration file, and finally issue the device to realize the device sequence control function configuration.

The logic loop configuration platform monitors the device to initiate sequence control task execution command, and displays the configuration logic display screen of sequence control ticket. After receiving the command, the device will execute the sequence control operation according to the configured sequence control ticket and its logic algorithm, and feed back the operation results and status of each step to the platform software. The platform software can make the user observe the execution of the sequence control process visually and intuitively by changing the graphic elements corresponding to the configuration graphic elements of the step sequence control signal, and judge whether the sequence control execution is correct according to the logic sequence algorithm of the sequence control configuration, and give timely alarm feedback to the abnormal execution.

4.3. Application example 2: Logic inversion

The tool consists of four modules: ladder diagram configuration analysis module, record reading module and record analysis module. The ladder diagram configuration analysis module mainly completes the analysis of the ladder diagram configuration. According to the ladder diagram configured by the configuration tool, the data block required by the interface display module is analyzed. The record reading module mainly reads the sequential control record file, reads the sequential control record file from the device through IEC 61850 file service, and provides it to the record parsing module and stores it to the historical data. The record analysis module is responsible for the analysis of the record file, and the record file is analyzed according to the recording data. The interface display module of ladder diagram is mainly responsible for logic inversion and dynamic demonstration of recording files according to ladder diagram and recording data.

5. Application of Technology

5.1. Measurement and control device

The equipment is based on industrial grade and high-performance PowerPC chip development, board card structure, allowing hot plug and plug. When any module fails to repair, the normal operation of other modules will not be affected. The boards communicate with each other through high-speed LVDS bus and 100Mbps Ethernet management bus. High speed LVDS bus, including data bus, IO bus and timing bus, transmits all kinds of data with high real-time requirements. The Ethernet management bus adopts TCP/IP protocol. The main board, management board, communication board and LCD board interact with each other in management information, device self-test and alarm information. The device itself has led signal indication, and all parts of the device have electrical isolation measures on the input and output circuits.

The device has the functions of state acquisition, AC sampling and measurement (with time scale data transmission), single wiring status and digital display in software; it has 61850 Communication Function, which can send telemetry and remote signaling data to monitoring configuration, and receive remote command from monitoring configuration.

The device can compile and form functional modules according to the configuration information issued, and execute according to the functions. There are three types of configuration files for interaction between device and configuration tool

(1) drive package file: describe the maximum realization of device function.

(2) operation drive file: the logic configuration information sent to the device after customization and configuration.

(3) ICD file: IEC 61850 capability description document of device, which is used for communication.
5.2. **Engineering application**  
The configuration design technology and the corresponding measurement and control device described in this paper are applied to a 110kV Smart substation in Hubei Province, which greatly facilitates the on-site configuration and debugging of the intelligent station, significantly promotes the practicability of the advanced functions of the intelligent station, and obviously improves the application rate of the advanced functions.

6. **Conclusion**  
In this paper, a kind of advanced application configuration design technology for Smart substation is studied, which realizes automatic configuration and dynamic monitoring of advanced application logic such as standby automatic switching, and develops the measurement and control device applying this technology. The project result is remarkable in the 110kV substation in Hubei, and proves the practicability and advanced nature of the research work in this paper.

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