Research on SCD Management and Control Technology in Smart Substation

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Abstract. Based on the current status of configuration file management and control, in smart substation, this paper introduce the function composition of configuration file management and control system in smart substation. It includes management process, control strategy and so on.

1. Introduction

With the rapid development of smart substation technology, smart substation construction vigorously promoted. Compared with the conventional substations, the secondary circuit of smart substation replace the cable connection by a fiber optic connection, the secondary cable loop becomes a "virtual loop", and the design, debugging, operation and maintenance methods of the smart substation have undergone great changes. As a smart substation core configuration file(Substation Configuration Description, SCD), the virtual circuit in the SCD file includes the sample circuit and the trip-close circuit of the circuit breaker. Whether the SCD file is correct or not directly affects whether the relay protection function can be correctly implemented. Therefore, the correctness of the SCD file configuration is very important for the safe operation of the substation. Smart substation SCD file to replace the secondary circuit design drawings as the direct basis of a debugging, operation and maintenance and reconstruction [1-8].

At present, substations in most areas lack SCD document flow control in their production processes. The process control such as flow of configuration documents, the handling of defects, the defect assessment among departments including construction units, electric power research institutes, operation and maintenance departments, regulatory agencies uses personal storage and integrator management, etc., which can not guarantee the smart substation configuration file specification, correct and unique. In view of this problem, by implementing the flow management of check-in, check-out, audit and archiving process of the SCD files, running the CRC check, SCD Standardization checks, comparison of SCD variance, checking of SCD files, modification of CID files and other means to ensure the safety, integrity and consistency of SCD files so as to protect and enhance the safe operation of smart substation.

The paper analyzes the current status of SCD document management and control, introduces the current SCI management system of SC substation, summarizes the SCD document management and control process, management strategy and so on, and helps to improve on-site infrastructure, operation and maintenance management of smart substation.
2. SCD Management and Control Status

2.1. Problems

At present, there are a large number of problems in the construction and operation of smart substations:

(1) IEC61850 standard is widely used in the secondary substation of smart substation. The levels of various domestic manufacturers are uneven. There are differences when digesting and understanding the IEC61850 standard and the relevant specifications of the State Grid Corporation of China, resulting in the configuration file not being able to fully meet the requirements of the State Grid Corporation of China, that causes concealment of problems, it is difficult to find through on-site commissioning, to bring lurking peril to the operation and maintenance of smart substation.

(2) The connection between the virtual terminals replaces the traditional secondary circuit. The secondary circuit is not as intuitive as the conventional substation. The operation and maintenance personnel need to debug and overhaul according to the smart substation configuration file. Because of the poor readability of the smart substation configuration file and the lack of technical means of inspecting and modifying SCD documents, the maintenance department has difficulties in operation and maintenance (for example, replacing individual protective devices, plug-ins or changing virtual circuits, etc.) over-reliance on factory implementation.

(3) After the smart substation is put into operation, with the progress of power grid construction, the overhaul, technical renovation and overhaul projects involved in the modification of drawings and configuration files have resulted in problems such as over-drawing of drawings, confusion in site modification and inconsistency with design to the scene Work has brought great difficulties and distress. Smart substation configuration files may undergo multiple changes during the operation and maintenance phase to ensure that the actual model files of the field devices are derived from the final version of the SCD file and can not ensure that the system configuration files and drawings transferred after the acceptance of the new and expanded expansion project can be authentic Reflect the scene, all kinds of information between each other to permit proof.

(4) With a large number of smart substation put into operation, both regulatory departments and inspection departments are lack of effective control of configuration files technical means, a reasonable division of responsibilities and system management, resulting in smart substation configuration file management measures, information barrier, work coordination difficulties and many other management difficulties.

2.2. SCD Management and Control Measures

According to the requirements of State Grid Corporation of China, SCD model documents for smart substation need to be put on record and standardization assessment. The quarterly SCD model files and calibration reports of smart substations of 110kV and above put into operation in this quarter are submitted to the model standards Library for the record. If we rely solely on labor to carry out this work, it takes time and labor and the quality can not be guaranteed.

At this stage, the domestic technology tools for the configuration file detection, mainly around whether the test in line with norms, and did not go deep into the intrinsic relationship between the secondary system testing. There may be a situation that configuration files pass the check of tools but still there is a problem of missing information, which impact the site commissioning work.

The establishment of targeted intelligent substation profile management and control system is of great significance to accurately understand the real situation of intelligent substation and precisely control the running status. At present, some parts of China have carried out the construction of related systems and put into use, the actual effect is significant.
3. System Functions and Control Processes

3.1. SCD Management and Control System Functions
SCD management system overall structure shown in Figure 1, the system consists of two parts: SCD acquisition system and SCD control module. SCD acquisition system is responsible for the transmission and collection of SCD files; SCD management module is for data access, storage and processing, implements a graphical human-machine interface to achieve the centralized management of SCM file within the scope of intelligent scheduling substation, and provide external Visual view, information browsing and file downloads and other functions.

References are cited in the text just by square brackets [1]. Two or more references at a time may be put in one set of brackets [3, 4]. The references are to be numbered in the order in which they are cited in the text and are to be listed at the end of the contribution under heading references, see our example below.

![Figure 1](image)

Figure 1. Overall structure of SCD management and control system.

The intelligent substation operation and maintenance unit uploads the received system configuration file to the intelligent substation configuration file management and control system. The SCD acquisition module of the intelligent substation configuration file management and control system first checks the integrity of the uploaded system configuration file, and then submits the complete system configuration file to Control module. The management and control module is responsible for parsing the system configuration file and performing syntax and semantic verification, project CID, CCD file and SCD file consistency detection, project ICD file and SCD file homology detection on the submitted system configuration file. If the verification result is incorrect, the user presentation module prompts that the system configuration file is an invalid file and returns a specific verification error message. If the verification result is correct, it shall be filed by the person in charge at all levels for approval.

Control module can also process SCD visualization, SCD differential alignment, SCD file validation, different versions of CID, CCD file comparison.

From the functional division, SCD control can be divided into online calibration and offline calibration.

The purpose of online verification is to verify whether the actual model of the virtual terminal (IED) is consistent with the intelligent substation configuration file. The online verification includes the intelligent station process layer verification and station control layer verification.

The process layer check is implemented through the process layer interface of the IED device, receives and parses the SV and GOOSE packets sent by the IED device, checks the parameter of the
packet, the number of channels, and whether the data type is consistent with the description of the SCD file. The process layer check also sends SVs and GOOSSE packets with specific packet parameters and data to the IED to check whether the IED can correctly receive the packet and complete the correct action response.

Station-level inspection accesses the IED through the station-level network in the station. It mainly examines three aspects: model consistency, data description consistency and service consistency.

Offline verification is mainly to check whether the model described in the smart substation configuration file conforms to the model definition of the relevant standard and is consistent with the actual engineering needs and errors resulting in unable to construct should not exist.

### 3.2. Management and Control process

From the time division, the existing smart substation configuration file management and control system control process basically divided into three phases: construction commissioning phase, project acceptance phase and operation and maintenance phase.

Commissioning stage: The commissioning unit shall commission the intelligent substation configuration file provided by the integrator, verify whether the intelligent substation configuration file is correct during the commissioning. That the commissioning unit is responsible for the change of intelligent substation configuration file ensures the configuration file of the final commissioning is the perfect version. Commissioning unit will eventually hand over the configuration file which is consistent with the scene of the smart substation to the operation and maintenance units.

Project Acceptance Stage: The operation and maintenance unit is responsible for verifying that the version of the configuration file provided by the commissioning unit is consistent with the actual configuration of the field device. The system configuration files during the acceptance process are checked and verified by the construction management unit, commissioning unit, equipment supplier and operation and maintenance unit, and they should sign the Guarantee of Consistency, then will be uploaded by the operation and maintenance unit to the intelligent substation configuration file management system for archiving.

During the operation and maintenance phase: 1) The operation and maintenance unit is responsible for the configuration file management of the operation and maintenance phase, and make sure that the configuration files of the devices are consistency with the archived configuration files during operation and maintenance. 2) If changes of configuration file caused by defect handling, countermeasures requirements, technical transformation construction, equipment maintenance is needed, operation and maintenance unit initiates a application to change and verify the intelligent substation configuration file and the configuration file and change records and other information should be archived. Thus, the existing control process can be achieved intelligent substation configuration file management of the entire process.

### 4. SCD Management and Control Strategy

Advanced technologies, such as visualization technology, CRC verification technology, are used to make SCD document control strategy of smart substation configuration file management and control. Currently commonly used control strategy includes schema test, information consistency testing, information uniqueness verification, legitimacy verification.

#### 4.1. SCD Control technology principles

SCD control system is capable of SCD visualization, SCD differential alignment, SCD file validation, different versions of CID, CCD file comparison.

#### 4.1.1. Visualization Technology. Due to poor readability of SCD files, visualization technology can parse SCD file configuration information and display intelligent substation configuration information through friendly interface including secondary loop wiring configuration, voltage level and interval information display, device virtual loop signal diagram display, device logic link map display and so
on, so that construction workers, operation and maintenance personnel, commissioning personnel and dispatchers can clearly obtain the substation configuration information, which brings great convenience to construction, operation and maintenance, commissioning and management.

The completeness, consistency and correctness of SCD files are achieved by means of comparison. Since SCD files use a digital language and can not be read directly, an auxiliary tool is needed to visualize the intelligent substation profile.

Through the SCD visualization tools, ICD, SCD, CID and other documents in the network, object, object interoperability relations are displayed in the forms of subnet diagram, information flow diagram, virtual circuit diagram, virtual terminal diagram. Supplemented by the property list and File fragments, SCD visualization tools transform the invisible network, the virtual circuit into a visible network, loop that visually display SCL file configuration information, and convert the unrecognized code language to the secondary circuit equipment which the debug, operation and maintenance personnel can understand. After the smart substation configuration file visualization, by comparing the network configuration, object name, object properties, object interoperability relations and other information, you can compare the smart substation configuration file detailed differences, debugging and operation and maintenance personnel can also be aided by the tool of the difference list or Graphics and other ways to show the difference between content, thus integrity, consistency and accuracy of the smart substation configuration file can be manually determined.

By displaying the network, object and object interoperability in SCD and other files in the form of subnet, information flow, virtual circuit diagram and virtual terminal subgraph, supplemented by the attribute list mode, the network, and virtual circuit data are expressed as the corresponding network structure, secondary circuit graphics, and intuitive display SCD file configuration information.

Specific features include:

(1) Subnet information display
The basic information of each communication subnet, the smart devices in the subnet and the connection information of the smart devices and subnets, such as IP address, MAC address, etc are displayed in a graphical way.

(2) Intelligent device interoperability relationship display
Display the smart devices and the control blocks included in graphically and display the data sending and receiving relationship between the smart devices through the control block.

(3) Virtual circuit display
Display the virtual loop between smart devices graphically.

(4) Virtual terminal display
Graphically visualize the input and output terminals of the smart devices and display the external information associated with the terminals.

(5) Object property display
A comprehensive list of SCD file versions and change records, subnet properties, smart device properties, control block properties, data set property information.

4.1.2 CRC (Cyclic Redundancy Check) Technology: (1) At present, the smart substation configuration file verification technology mainly applies the CRC technology because the CRC verification code is a unique identification code formed by extracting process layer information or basic information of an smart substation configuration file, and has accuracy and uniqueness. Any configuration information changes can be reflected in the CRC check code, so using the CRC check code to control the smart substation configuration file, can improve the accuracy and efficiency. Other calibration techniques such as two-dimensional code verification are also based on CRC verification.

(2) There are two kinds of CRC checksum, one is to extract the information of the virtual terminal of the process layer, generate CRC check code, the second is to extract information from the intelligent substation system configuration file, generate CRC check code. The generated check code and the system configuration file upload time together as a version number, you can timely and accurate grasp of the system configuration file change time and change information.
(3) Taking a virtual terminal of a process layer as an example to generate a CRC code, first, process layer configuration information related to the IED device needs to be extracted in units of an IED device, including control block configuration information of the publish / subscribe, basic GOOSE and SV protocols Parameters and data structures, private address information mapped between control blocks and internal variables, configuration information between control blocks and device physical ports. The configuration information is expressed in binary, and then use a 32-bit CRC generation algorithm to generate a unique CRC.

The CRC check module is responsible for calculating the CRC check code and returning the calculation result to the control kernel module. Meanwhile, the control kernel module generates the virtual terminal sub-graphic, and returns the generated virtual terminal sub-graphic file to the control module. Finally, the profile management system generates the version information of the system profile, and stores and archives the submitted system configuration file, the CRC check code, and the virtual terminal graphics file. Smart substation configuration file management system by adding CRC verification process, make effective control of the system configuration file version, correctness, integrity.

4.2. Schema test
Schema test SCD is described in XML format to detect whether the smart substation configuration file structure is correct and the information is complete.

4.3. Information consistency testing
Consistency detection refers to the establishment of a set of test case sequences. In a specific test environment, a black box test is performed on the tested object, and the difference between the output result and the predicted result is compared to determine whether the detected device object is consistent with the protocol description. Common conformance testing consists of the device under test and conformance testing software.

Information consistency testing refers to simulating the specific operating state of the tested IED during the test. By analyzing the MV, GOOSE, MMS and other messages, the output and expected output of the tested IED are analyzed and judged, and the correspond the test results.

The process of information consistency detection is as follows: First, check whether the IEDName of the CID file is the same as a certain IEDName in the SCD file. If there is no match, the configuration of the CID file is inconsistent with that of the SCD file. If match exists, continue to detect the key configuration information of the CID file. Whether the virtual loop configuration is exactly the same as that of an IED device configuration in the SCD file (extract the key information, generate a CRC code and compare the two CRC codes). If the CRC codes are identical, then the CID and the SCD consistency check are passed.

4.4. Information uniqueness verification
This verification means to verify that certain information about the smart substation configuration file is unique. For example, the name of the virtual terminal, the GOOSE connection, etc. If the information is duplicated or interactive, it may cause confusion of the protection function, so the information of the intelligent substation configuration file must go through uniqueness check.

4.5. Validity verification
Legitimacy verification is divided into two steps: first, parse the intelligent substation configuration file to extract relevant information, such as automatically generating interval information according to the name and description of the IED; extract IED related information according to the channel instantiation description, and then the extracted information are classified according to transformer, bus, union, segmentation, lines and other information, which is prepared for the virtual terminal validity check.

The content of validity verification includes:
(1) Validation of documents according to IEC 61850 and other standards;
(2) CID file and SCD file consistency detection, SCD file and ICD file consistency detection;
(3) Standardization check.
Check the results sub-error, warning, reminder three types. When no error is found, check in is allowed.

5. Conclusion
With the continuous improvement of smart substation technology, the requirements for on-site infrastructure, operation and maintenance are constantly improving. Along with SCD document management and control work, further research on new technologies and principles of intelligent substation configuration file management is necessary. For example, there are optimized management and control strategies to make really effective control of configuration files to ensure the safe and stable operation of smart substation.

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