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Research and implementation of virtual circuit test tool for smart substations

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Abstract

This paper describes the technologies of virtual circuit and analyzes the SCL configuration files of smart substation. Based on the traditional virtual circuit test method, the visual technique of .NET is employed to develop the smart substation virtual circuit test tool accorded with the standard of IEC61850 9-2, the static test scheme and dynamic test scheme are presented respectively. The problem of SCL configuration of smart substation network could be detected quickly by the visual simulation of secondary virtual circuit for smart substation. Our work provides an effective virtual circuit test tool for smart substations.

Keywords: Smart substation, IEC61850, virtual circuit;

1. Introduction

State grid corporation has made it clear that in the "twelfth five-year" plan "to build in high voltage network backbone network frame, the coordinated development of various grid strong smart grid" development goals, intelligent substation is an important basis for smart grid alternative points, the technical standard, working principle and application method need further research. The communication standard used by the digital substation is the IEC61850 standard system. In the new standard, the intelligent substation will use optical fiber for communication, so the traditional electrical signals must be converted into optical signals for transmission. In traditional way before transmission monitoring atresia, protection, blocking sampling, switching, start signal must be converted into a light signal can be transmitted, it also puts forward new requirements to the whole control system, how to find out a new

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test method, under the new demand is intelligent substation development put forward new requirements to us. This new change brings digital substation from the design, commissioning, acceptance and maintenance, each production link needs to change accordingly, how to adapt to the new secondary circuit debugging mode [1], is the current digital substation construction process is an urgent need to solve the problem.

Therefore, the transmission in the secondary circuit of digital substation is no longer the traditional single signal, but the parallel transmission of a variety of signals in the optical fiber transmission network, we will not be able to use the traditional physical method to carry out point-to-point testing, how to ensure the correctness of the circuit, has become the focus of current research. In the smart substation design, debugging, acceptance can no longer use the traditional method such as the traditional universal meter test the second virtual circuits [2], there is no way to relay device. The control test, this study will be used. The.net visualization development method [3], the visualization technology of intelligent substation virtual circuit was simulated, then the terminal access network system was analyzed, a dynamic signal loading, sent via information simulation to verify the security of network signal transmission, inspection virtual circuit configuration is correct.

2. Technical route

2.1. Introduction of SCL

Substation configuration language (SCL) is a special substation configuration language recommended by THE IEC61850. It is a grammar rule to describe the structure and function of substation automation system. Combined with the IEC61850 unified model, it can clearly describe device configuration information and realize the sharing of information among different devices.SCL mainly describes system structure, primary device function, intelligent device function and service, network communication, data template and so on.

Figure 1 and Figure 2 respectively reflect the four parts of SCL language in terms of understanding and documents: 1) The part of substation primary equipment;2) Substation communication section;3) The measurement and control equipment part of secondary intelligent protection of secondary manufacturers;4) Data model template.
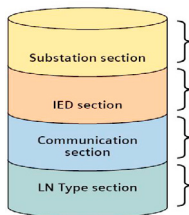

Fig. 1. Contains four parts of the SCL   Fig. 2. Contains four parts of the SCL

2.2. Analysis of GOOSE data model

The configuration files of smart substation describe GOOSE data model in the form of hierarchical structure. How to effectively demonstrate its core information is the key to detect GOOSE virtual loop in smart substation.

SCD file contains five main elements: the Header information (head), Substation, Substation description), ieds (intelligent electronic device description), Communication (Communication system description) and Data Type Templates (data type template).

Header contains the version number of the SCL file and the mapping information for its namespace; Substation mainly describes the function of the Substation structure, identify the electrical connection in the relationship between a device and its; IED describes the configuration of each IED in the substation and its functions, including access points, logical devices, logical nodes, data objects and other information; Communication describes the connections of Communication networks through logical buses and IED access points; Data Type Templates defines the logical node type of the file and the data objects and data properties that the logical node contains[4].

In the SCD file, the elements related to GOOSE and SV configuration are not independent from each other, but related by the attributes of the elements. Figure 3 shows the hierarchical relationships of various elements in GOOSE configuration and the corresponding relationships among them. As can be seen from Figure 3, the elements related to GOOSE configuration are scattered at different positions in the SCD file, and the dispersed elements are linked by element attributes. For example, the Name attribute of an IED element is associated with the iedName attribute of a ConnectedAP element. The correlation between elements associated with an SV configuration is similar to that of a GOOSE configuration.
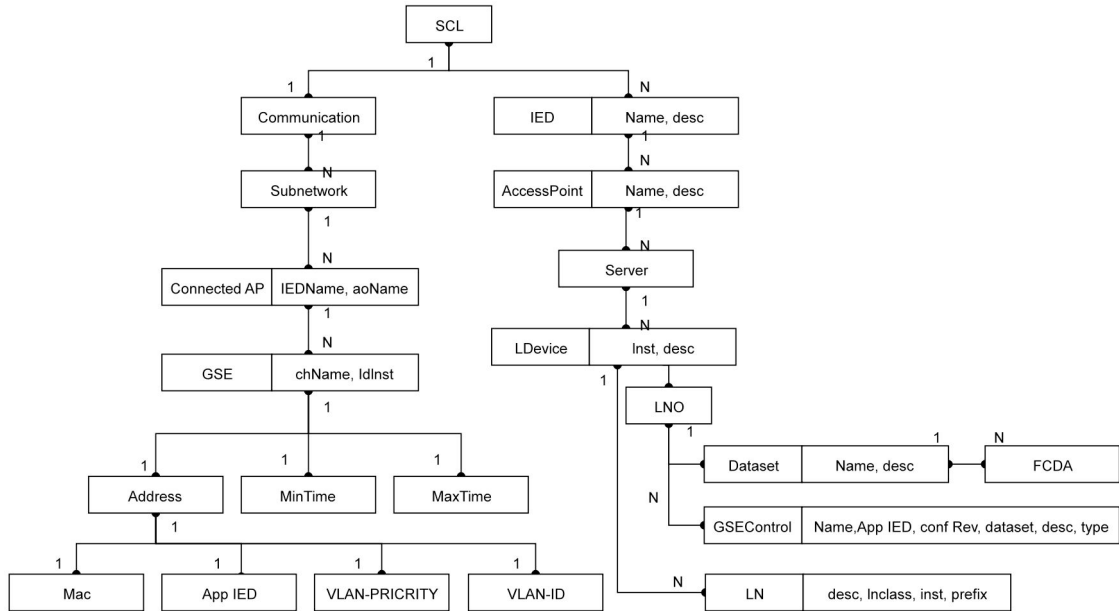
Fig. 3. Composition of GOOSE data model

2.3. SV data model analysis

Similar to GOOSE data model analysis, configuration files of smart substation describe SV data model in the form of hierarchical structure. How to effectively demonstrate the core information is the key to GOOSE virtual loop detection in smart substation.

This topic studies the correspondence between different classes of SV data model and forms the data association graph, as shown in Figure 4.
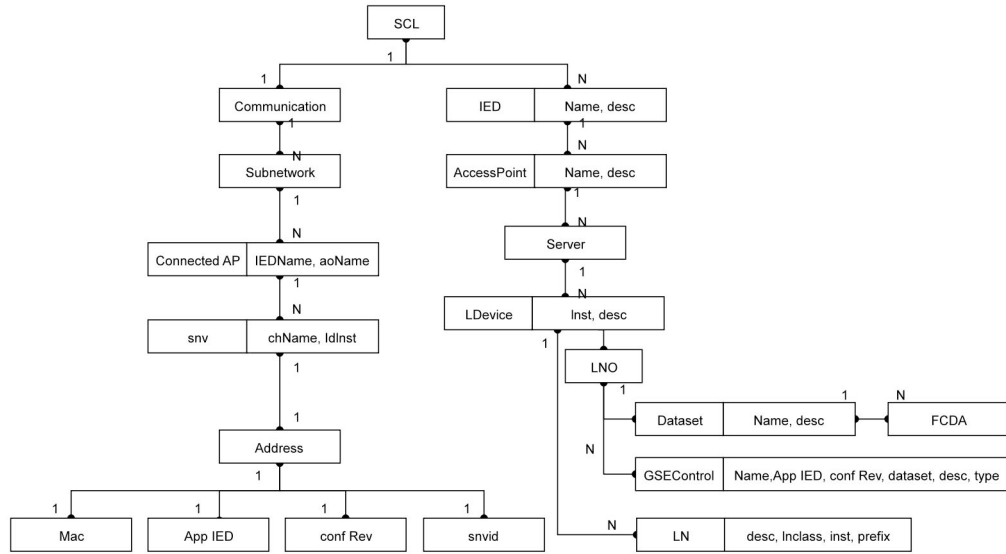
Fig. 4. Composition of SV data model

3. Overall architecture and software development of the testing system

3.1. Overall architecture diagram of the system

According to the characteristics of the secondary virtual loop of smart substation and the engineering implementation process of IEC61850 standard, the virtual loop test tool of smart substation should have the following basic functions:

1) Check the design correctness of virtual loop logical connection. Compare the virtual terminal connection in THE SCD file with the design requirements of the substation to check the correctness of the SCD file. The detection process is called static detection;

2) Check the correctness of virtual loop logical connection configuration. Look up MAC address and IP address in SCD files to find out whether there is configuration duplication and prevent the occurrence of multi-pair conflict in virtual loop.

3) Panoramic visualization of IED devices through a visual environment.
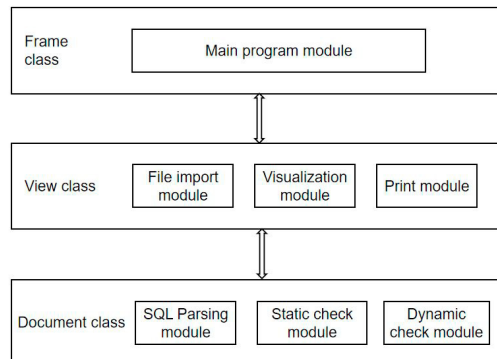
The system structure diagram is shown in Figure 5:

Fig. 5. System architecture framework design drawing

3.2. SCL loading and parsing process

The SCL loading process mainly includes the following technical points: 1) Tree node creation and naming; 2) XML document transformation tree; 3) Tree graph transformation XML.

In the process of tree node creation and naming, tree node naming rules is the most important technical link, "TreeNodeName = logical node name + name attribute value + LNClass attribute value + LNType + ID attribute value + INST attribute value". If some logical node does not have some of its properties, the corresponding value is empty. At the same time as the creation, you also need to insert the node into the memory tree to ensure proper operation of the tree node.

The TAG of the node stores the XMLNode address. When the TAG of a node is selected, XML nodes in the corresponding memory tree can also be obtained, so that operations can be carried out on this node, which is conducive to engineers to obtain virtual loop information at a glance.

The XML document transformation tree module is mainly used in the parsing process of file import[5]. The principle of parsing is as follows: first, the file is read into memory to form an XML memory tree. According to the structure of the memory tree, SCL naming rules are used to parse and display the detailed information of the node.

The loading process of SCL is shown in Figure 6, which mainly realizes the import of files, the analysis of node information and other functions. The operations on import and parsing are encapsulated in a file management class, CSCLManage, which is instantiated and then called directly by the main program. When the file is imported, the program will automatically call the verification function to verify the file, after the verification is correct, then use THE DOM interface function to query the entire file, extract the Header, Communication, IED and other parts of the node information and attribute information, node information will be filled in the tree control file management window.

Figure 7 represents the parsing flow of SCL. By clicking on a node in the tree control, reading the Attribute value Getname (), and getting the IED details, you can accomplish a graphical representation of the virtual loop by drawing input and output.

It should be noted that the document management class CSCLManage is called directly by the main program, while the rest of the classes at the document layer are called indirectly by the main program module through the view layer.
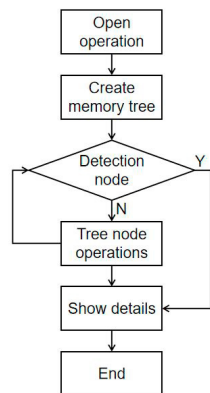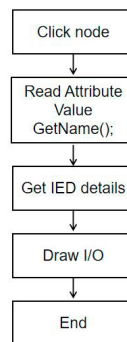
Fig. 6. SCL loading Flowchart   Fig. 7. SCL parsing flowchart

3.3. Two detection schemes of the detection system

1) Static detection scheme

Static detection of virtual loop is mainly used to verify the consistency of SCD files and engineering design drawings. Intelligent substation in virtual circuit logic relationship at this stage of design is provided by the design

institute of design drawings, system integration manufacturer according to drawings to complete the SCD file configuration, so will have different circuit design for different units, is the essence of the static test of SCD file and design drawings do check, ensure the integrators provide virtual loop relationship is consistent with the design institute[6].

In order to complete static detection, SCD files need to be converted into a file format that is easy to understand intuitively. Table files are adopted in this scheme. The detection software developed in this study imports the SCD file configured by the system integrator, and fills the table with the relevant attributes and descriptions in the device model that need to be verified as the input end of the virtual terminal. Export the path specified IED name, data set name, data object name in the data set and related communication configuration information, as the output side of the virtual terminal input table, the final software for each device in the SCD file to establish a virtual terminal associated information table, virtual loop static detection and comparison work.

2) Dynamic detection scheme

The dynamic detection of virtual circuit is mainly to verify the correctness of the operation of intelligent substation IED equipment, through monitoring the communication message between IED equipment and the equipment simulation communication test, complete the detection function. During dynamic detection, GOOSE virtual loop and sampling virtual loop should be respectively detected according to the difference of message contents, and the network adaptive function should also be supported.

A) GOOSE virtual loop detection

GOOSE virtual loop is based on SCD file for detection, and detection is carried out for the connection relationship of GOOSE messages in each device. For the outgoing loop of the device, the test software will subscribe to the outgoing data set as the subscriber, and monitor whether the multicast address, heartbeat time, APPID, data number and data type of the data set of GOOSE packets are consistent with the configuration in the SCD file. Monitor the order of data release through the transmission test of the device, and see if the data displacement status is consistent with expectations.

For analog circuit devices, test software as the issuer, the information released to the needs of the configuration of SCD as source, simulation chicago-brewed GOOSE message sent, by monitoring the subscription of subscription equipment, judge whether the equipment operation is normal, for example, monitoring equipment own restore the alarm signal communication, state when the deflection displacement subscribe to the equipment of the remote communication signals, etc. FIG. 8 is the flow chart of GOOSE virtual loop detection.
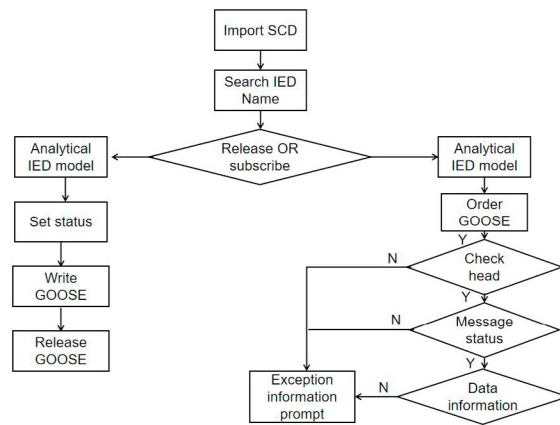
Fig. 8. Flow chart of GOOSE virtual loop detection

The detection software will automatically complete the detection according to the above information to be identified during the loop detection. When there is any abnormal information, it will provide warning prompts and prompt the error contents in as much detail as possible to help the debugging personnel to find the cause of the error.

B) Virtual loop detection of sampling value

The virtual loop of sampling value is also based on SCD file. For the output of the sampling value of the merged unit, through subscription of sampling message, the multicast address, APPID, ASDU number, sampling rate and other information are analyzed to see whether they are consistent with SCD files, and at the same time, whether the counter and status symbol in the message are normal or not. The sampling values show the sampling amplitude and phase Angle in the form of waveform or vector graph to determine whether the sampling output is consistent with the expected value.

For devices that subscribe to sampling values, the test software simulates sampling message output, monitors the communication recovery alarm signal of the device itself, and determines whether the device receives normally. When the simulated sampling message is released, it can simulate various abnormal states, such as sampling drop point, synchronization loss and sampling rate abnormality, to test whether the behavior of the equipment under the abnormal state can meet the operation requirements. FIG. 9 is the flow chart of virtual loop detection with sampled values.
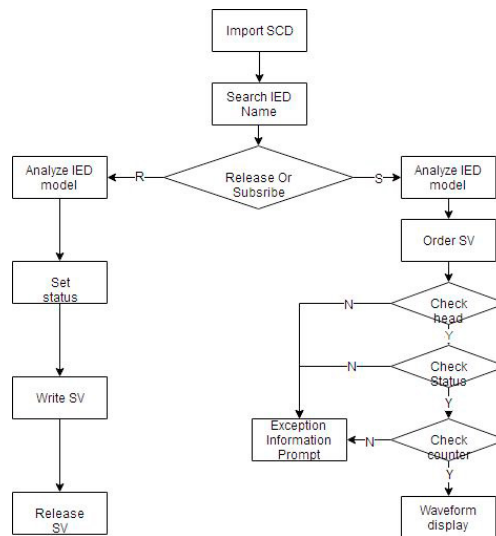

Fig. 9. Flow chart of virtual loop detection with sampled values

3) SCD configuration file comparison module algorithm

For smart substation, the model, structure and configuration of the whole station are all stored in THE SCL file, and it is particularly important to effectively manage the SCL file during the operation and maintenance of substation. If the contents of SCL files are missing or wrong due to improper management, it will have a serious impact on the operation of the substation. Therefore, strict version management should be carried out for SCL files. The applied SCL configuration comparison tool should be able to accurately locate the differences between versions and prompt users to trace the historical version in case of on-site SCL file problems and quickly restore the substation operation.

Based on the comprehensive analysis of smart substation configuration files, the SCL configuration file comparison tool should include the following functions: a) It can introduce the concepts of version tree, View and so on in software engineering, and manage the effective version comparison of SCL files; B) can compare different SCD file version, namely select two versions comparison between any two nodes in the tree, and perform the application level of semantic comparison, directly show the different versions in the model, data collection, reporting and communication configuration, making it easy for users to clear on the difference between different versions.

The various requirements for the above, this study proposes a mass data fast automatic matching algorithm of SCL configuration file comparison tool, through the configuration file inputs regional block storage, with as the only test and verify identification code, in the process of comparison in different areas of the validation verification

identification number are the same, thus achieve the rapid positioning. Then, through the function signature extraction module, the SCD files provided by the design institute and the manufacturer are extracted digitally, and input into the function signature comparison module for classification comparison. Finally, the paired function and non-paired function are used to classify and output the comparison results of SCD files. FIG. 10 shows a schematic block diagram of rapid comparison in the study.
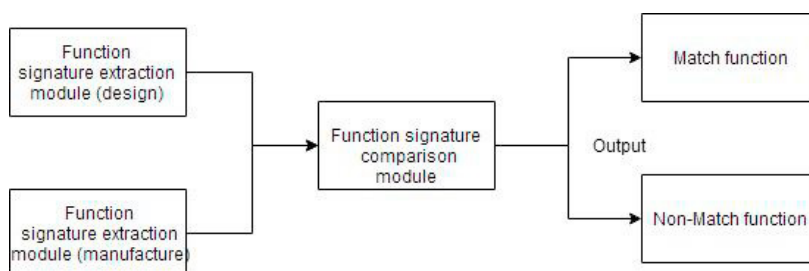

Fig. 10. Quick comparison of schematic block diagrams

3.4. Test software development

Based on the above test work of virtual circuit of smart substation, the second virtual circuit detection tool of smart substation was independently designed and developed in this study according to SCL standard grammar (IEC61850-6) and object model (IEC61850-7-3, IEC61850-7-4).

4. Conclusions

Intelligent detection software for virtual circuit of smart substation makes up for the lack of application tool software during substation debugging. Based on SCD file as the detection basis, virtual terminal connection in SCD file is verified to ensure the correctness of virtual secondary circuit of smart substation. The software fully considers the characteristics of the smart substation network and the communication details specified in THE IEC61850 standard, strictly checks the information that needs to be identified in the virtual circuit, so as to ensure that the virtual circuit can meet the design requirements after the completion of the test of the substation, and has been widely and successfully applied in hubei power grid.

Acknowledgement

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