Key Technologies of Intelligent Debugging Platform for the Whole Process of Automation System

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Abstract. Based on the smart dispatching support system and the smart substation system, and based on the functional requirements of the dispatching center to the substation, a source maintenance plan of integrated sharing of model, graphical and communication points between the smart substation and the dispatching center is proposed, and the traditional source maintenance process is optimized according to the actual requirements. According to the plan, an intelligent debugging platform for the whole process of the automation system is developed, and a new mode of smart substation access dispatching center is explored. In this paper, the key technologies of the debugging platform are introduced from the aspects of primary equipment model transformation, primary equipment and measurement association, automatic generation of RCD file, and online master sub - station communication point checklist technology.

1. Introduction
Smart substation and smart dispatching support system are two key links of smart grid [1]. Smart substation system follows the IEC61850 standard, the use of substation configuration description (substation configuration description, SCD) model, the model includes the primary and secondary equipment [2]; And the function parameters of communication network [3-4] and the information of intelligent electronic equipment (IED) meeting IEC61850 standard [5] in the whole station; The intelligent dispatching system follows the CIM/E grid physical model standard. This inconsistency leads to the isolation of the grid model, repetitive modelling, limit the further improvement of automation and intelligence. Along with the continuous deepening of the reform of our country electric power and across regions, with the rapid development of interconnected power grid dispatching automation system more and more signals are connected to the master substation. The signal debugging of routine master station generally follows the modelling, drawing and warehousing of the master station, then the steps of communication and data debugging with the substation are time-consuming and laborious. This pattern presents the following common problems:

Primary equipment and signal information monitored by the master station are actually modelled in the substation. The master station belongs to repetitive modelling, and does not follow the principle of "source maintenance, resource sharing".

Due to the delay in the construction period of the network channel between the master station and the substation or the delay in the commissioning work, it leads to the short commissioning time in the later stage and substation.
For the new signal, it must be initiated by the station, the substation shall provide the new signal information, and the master station shall be put into database and to start debugging.

Research institutions at home and abroad have carried out long-term studies on the above issues, and proposed their own solutions from different perspectives, such as unified standards, model semantics, engineering applications, seamless communication, etc., including direct unified model [6], common semantic model [7], model mapping [8-9], seamless communication system [10-11], share technology on demand [12], etc. However, in the above research results, the source maintenance plan is all generated by the station side CIM/E model and G format graphics and sent to the master station. This mode has four main problems: 1) There are many sub-stations, so there are differences in the understanding of the master station model standards. 2) The G file style provided by the station is different from that of master station, so it cannot be used directly. 3) The dot information for IEC104 communication cannot be provided, which requires manual input by both parties, which is time-consuming and error-prone.

This paper proposes a new source maintenance plan and develops an intelligent debugging platform for the whole process of the automatic system based on this plan. Considering the large amount of existing system investment, and making full use of the research results of SCD conversion CIM/E, the plan is designed on the existing SSD/SCD/RCD standards. In addition to the primary equipment model, the core contents of the source maintenance of the communication point information and the automatic graphics generation are all considered. The plan can shield more substation manufacturers, and has different understanding of the master control center model. At the same time, the master station obtains the SCD model, which can flexibly add signal information. By generating RCD file, the master station and the substation import the file respectively, the communication debugging can be carried out, which effectively improves the operation speed of the new station.

2. Overall plan of intelligent debugging platform for the whole process of automation system

2.1. Overview of overall plan

The architecture diagram of the intelligent debugging platform for the whole process of the automation system is shown in figure 1.

![Figure 1. Schematic diagram of intelligent debugging platform for the whole process of automation system](image)

The master station mainly includes three parts, automated debugging platform is responsible for parsing the SCD model, generate the CIM/E model and generate remote configuration file RCD, CIM/E model including primary equipment information and a corresponding point information. The
RCD file includes the telemetry, remote signaling and remote control point number information required by the master station, importing single substation model and RCD file into the three zone debugging system of dispatching center, the master station automatic drawing technology is used to generate the wiring diagram of the substation, at the same time, it is responsible for debugging with the station, after commissioning, reverse synchronization of the substation model to the master station one area system. The remote station accepts the RCD file issued by the debugging platform and imports it into the remote station for communication with the master station.

2.2. Source maintenance process
This paper introduces the design plan of source maintenance, and the maintenance process includes two directions: 1) The master station generates model, graphics, and RCD file through SCD file and imports these three files. 2) The remote driver at the station imports the RCD file generated at the master station.

Before the plant is put into operation, the SCD model file containing SSD information is first provided to the master station. After the master station debugging platform receives the SCD model, the SCD file is analyzed. SCD analysis mainly includes the following steps:
1) Extract the primary equipment model information in the SCD model.
2) Extracting the information of measuring points in SCD model, it is divided into two parts: telemetry and remote signaling.
3) The master station selects the corresponding measurement of the primary equipment according to the measurement information collected by each device obtained by the analytical model.
4) For the selected telemetry and remote signaling information, the forwarding point number is automatically generated by the program, and the RCD file is generated.
5) The CIM/E model of the substation is generated according to the primary equipment model and selected measuring points after analysis.

The master station sends the generated RCD file to the remote driver at the substation. After the remote driver imports the RCD file, it can communicate and debug with the master station.

3. The key technology

3.1. Primary equipment model transformation
Reference [13] studied the description form, structure, function and characteristics of substation specification model file in IEC 61850 ed.2 and public information model file in IEC 61970, compared and analyzed the similarities and differences and characteristics of the two model files, and discussed the mapping relationship between the two models. The conversion technology between SSD model and CIM model is studied and implemented. In the SCD model, the primary equipment model definition is rather general, only the type attribute is defined, while in the CIM/E model, each specific equipment defines a class. Therefore, primary equipment needs to form a mapping relationship by identifying the type attribute and the concrete class defined in CIM/E. The mapping relationship between primary equipment type and the class defined in CIM/E is shown in table 1. There is no corresponding equipment in the CIM/E model for some primary equipment types, so there is no need to establish a mapping relationship, such as casing, cable, etc.

| Primary equipment type | CIM/E class object                  |
|------------------------|-------------------------------------|
| CBR                    | Breaker                             |
| DIS                    | Disconnector or GroundDisconnector   |
| LIN                    | ACLineSegment or DCLineSegment       |
| ...                    | ...                                 |

Table 1. SCD primary equipment type maps to CIM/E class objects.
In the SCD model, equipment such as substation, voltage grade and interval form a one-to-one strict mapping relationship with CIM/E model, and the corresponding device container class in the CIM/E model can be conveniently generated through the direct transformation from class to class. The type attribute of primary equipment and the conversion in CIM/E adopt the method of attribute to class conversion, that is, by analyzing the type attribute of primary equipment model in SCD, the primary equipment type name in SCD is converted to the class name corresponding to CIM/E according to the mapping relationship.

In CIM/E model, the topological relationship of the equipment is stored as a certain attribute of the record. In SCD, the topology of the primary equipment model is described by a separate terminal class under each primary equipment label. In the terminal class, the attribute connectivity node describes the topological relationship of the primary equipment. Therefore, the topological connection of the equipment can be obtained by analyzing the terminal sub label under the primary equipment information.

3.2. Equipment associated with measurement

In the SCD model, logical nodes are defined to represent measurement, and the description structure is as follows: IED (intelligent electronic equipment) -> logical equipment -> logical node -> data -> data attributes, and the measurement information is described in a hierarchical and detailed manner. In CIM/E model, two classes, analog and discrete, represent telemetry and remote signaling respectively. The master station concern of measurement mainly includes a functional power, reactive power, current, voltage, the location of the switch or breaker and protection signals, etc. Reference [14] proposed a reasonable method to extend the protection model in CIM.

In the SCD model, the primary equipment contains the description of measurement, which is mainly described by the sub tag logical node of the primary equipment. The attribute logical node type in the logical node tag represents all measurement information owned by the logical node, and most of the measurement the dispatching center are unnecessary. Therefore, it is not appropriate to directly provide all the measurements contained in the logical node type attribute to the master station.

After analyzing the SCD model on the master station, the maintainer can independently select the measurement corresponding to the primary equipment and correlate the primary equipment model with the selected measurement. The associated steps are as follows:

1) The measurement information of logical nodes corresponding to the primary equipment is instantiated. According to the type of logical node, it is divided into two parts: telemetry and remote signaling. The type of logical node is MMXU, and MMXN represents telemetry information such as active power, reactive power, current and frequency, etc., and the analog class in the CIM/E model is corresponding. The logical node types of remote signaling information that represent the position of switch or disconnector and protect signals mainly include XCBR, XSWI, CSWI, GGIO, etc., which correspond to discrete classes in the CIM/E model. All instantiated measurements consist of three pieces of information: measurement name, measurement type, and IEC61850 path name reference.

2) According to the primary equipment model information obtained by analyzing SCD, select the corresponding measurement information for each equipment, such as bus. The telemetry information obtained by logical nodes under the bus can be analyzed from step 1, and telemetry information such as line voltage and frequency can be selected.

3.3. Automatically generate RCD file

Reference [15] proposed a complete set of remote control point-to-point system based on the idea of modularization, and adopted the algorithm of check sum and checksum to check the end-to-point table of dispatching master station and substation to ensure the correctness and reliability of the results. Remote Configuration Description file (Remote Configuration Description, RCD) is a substation between the main station and information published, RCD file is already part of the data communication network shutdown equipment model specification, each gateway factory domestic manufacturers has supported this file import and export, mainly defines the RCD file IEC104
information body address (dot) and the IEC61850 reference directly map format. Among them, reference is the MMS message path of IEC61850 interval layer communication. Therefore, as long as the main station instantiates logical nodes corresponding to the measurement, generates reference corresponding to the path name of IEC61850, the RCD file can be generated.

In the correlation between equipment and measurement in 2.2 above, the main station has selected the required telemetry and telemetry information, and the selected reference of measurement has been formed according to the path name of IEC61850.

The main station keeps one copy of the RCD file generated each time. If the measurement information needs to be added later, the original measurement point information can be kept unchanged by analyzing the previous file. For the newly added telemetry and telemetry, the maximum point number obtained in the previous file will be increased successively.

3.4. Remote information automatic debugging module
Debug area after complete model, RCD file to import, need to be checked against the substation communication validity period, by the main station debug area according to import the dot information, such as remote communication period, debug area through the simulator will be required to drive signal simulation, form a JSON format message sent via TCP to stand on the simulation system, from the stand model to the transmission of signals sent to the RTU, after receiving from the transmission of the dot corresponds to the information sent by 104 specifications to the main station debug area, According to the received information, the debugging area checks whether the point number information sent by the station is consistent with the point information issued.

3.5. Automatic mapping technology
Automatic mapping technology is widely used in dispatching master station at present. Reference [16]proposed automatic mapping based on a hierarchical assembly system from bottom to top, and reference [17] proposed automatic mapping technology of distribution single line diagram based on GIS coordinate layout, the main station automatic mapping technology is made by machine learning technology depth analysis station topology relationship, user drawing habits, establish library user graphical features, typical substation information form, use regulation rule strategy based on automatic identification equipment, the connection between the interval and the bus, supplemented by tiny artificial audit work, eventually automatically graphics drawing automatically, complete graph model, to ensure the substation drawing the consistency and accuracy of the module. Through this technology, the wiring diagram of the substation can be generated in accordance with the usage habit of the main station, thus avoiding the inconsistency of style caused by the traditional wiring diagram provided by the substation.

3.6. The model is put into the online system
After debugging in the three zone with the substation side, the model shall be synchronized to the system in the first zone, and the model shall be put into use in the system in the zone one.

The debugging zone exports the CIM/E model of the debugging substation, which includes the primary equipment model and the extended communication model. The model is sent to the system of zone one through reverse isolation, and the system of zone one imports the CIM/E model of the substation to complete the warehousing of the model.

4. The application situation
The whole process intelligent debugging platform of the automatic system was successfully put into operation in a 220kV intelligent substation in a province. The overall application is shown in figure 2.
Substation first offer intelligent SCD file to debugging platform, the platform is responsible for parsing the SCD model, a model of equipment information and SCD point of information, complete the information selection of measuring point and the debugging platform associated with a equipment, and completed by the platform CIM/E model file and RCD files generated, RCD file via wireless network distributed to end far motivation, motivation to complete communication configuration information storage, at the same time the D5000 debug three-zone complete CIM/E model import, can with the station began to remote debugging, debugging is completed. The CIM/E model of the station is derived to complete the input zone one online system.

Through the application of this platform, the power company of this province saves the maintenance of the station model, point number and graphics on the side of the dispatching master station, which greatly reduces the time and workload of the new adding station in the system of the master station. The maintenance at the source end initiated by the master station improves the interoperability and information exchange between the dispatching master station and the substation.

5. Conclusion
The intelligent debugging platform for the whole process of the automation system introduced in this paper, through the source maintenance process initiated by the dispatching center, shields the problems of many stations and manufacturers at the station and different understanding of the master station model, Because the SCD contains all the acquisition information of the station, the dispatching center can flexibly increase the required acquisition information without the cooperation of the station, which greatly improves the flexibility. At the same time, the automatic mapping technology is used to effectively avoid the problem that the dispatching center cannot be used due to the graphic difference between the dispatching center and the station. This source maintenance mode initiated by the dispatching center is applicable to a wide range and has a high maturity. It can be used for reference and extended to various dispatching systems in the future.

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