Research of Communication Interface between PMS2.0 and IEC61850 based on Model Mapping

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Abstract. In recent years, the State Grid has been vigorously developing PMS2.0 system and intelligent substation system based on IEC61850 standard. Because the two systems follow different standards, the models are not uniform and the information is difficult to share. In this paper, the mapping relation between the two models is found by analyzing and comparing the structure of the IEC61850 model with that of the PMS2.0 model. Using the MMS communication protocol in IEC61850 Standard, the MMS communication module is designed on the CompactRIO platform of NI Company to realize the data interoperability between PMS2.0 and intelligent substation System. The simulation test effect is good, which shows that the design is effective.

1. Introduction

In 2012, Full Service Unified Data Center-Power Production Management System(hereinafter referred to as PMS2.0)\cite{1} is a production management information system oriented to smart grid, which realizes the full coverage of power production execution layer, management layer and decision-making layer, and supports the integration of operation and maintenance, maintenance specialization, efficient and intensive management and so on.

Through the establishment of PMS2.0 system, a complete, accurate, cross-professional integrated design of the digital unified power grid has been realized, in order to open up the core business at the grass-roots level, realize efficient collaboration across specialties multi-service integration, and realize the transformation of equipment management to power grid management and asset management.

But there are also some problems in the construction and application of PMS2.0 system: (1) large amount of data rectification. PMS 2.0 daily maintenance and engineering projects has the problems about large amount of input information, too many links, high data quality requirements and time constraints. (2) The operations and maintenance staffs are unstable. Some staffs are highly mobile, and the newcomers are not proficient in the operation of the system, which results in the untimely rectification of the problem data. System data entry is not standardized. In order to improve the completion and commissioning rate of the network reform project, some users build false account in the
system before the project is completed, which leads to the decline of various indicators and affects the system maintenance later[2, 3].

In view of the above problems, according to the consistency between PMS 2.0 system data and IEC 61850-based intelligent substation data, this paper studies the communication interface between PMS 2.0 and IEC 61850 based on model mapping. It is found that although the data of the two models has some consistent rules, there are great differences between the two models, which lead to the problems of data interoperability, large repetitive workload and so on. In view of these situations, this paper develops a communication interface between PMS system and IEC 61850 to realize data interchange with intelligent substation system. This can not only reduce the workload of basic data maintenance for relay protection personnel, but also ensure the consistency of data and power grid.

2. Introduction of PMS 2.0 and IEC 61850 model

2.1. Detailed Layer Model of PMS 2.0 Data Warehouse

The detailed layer model of PMS 2.0 data warehouse includes equipment assets account, physical assets management, equipment assets operation and maintenance, equipment assets maintenance, equipment assets lose efficacy, environment of equipment assets, equipment assets monitoring and so on. The system data view is shown in Figure 1. The specification of detailed logical model design for data warehouse of full-service unified data center of State Grid Corporation mainly describes the entities, entity relations, entity attributes and entity source system in detail data model of enterprise-level data warehouse, and standardizes the hierarchical relations, association relations and mapping relations of detailed data objects of enterprise-level data warehouse. It is used for the development and implementation of detailed storage model of data warehouse of PMS data analysis domain data warehouse in various subsidiaries of State Grid Corporation, in order to supports data cleaning and conversion in full service.

![Figure 1. PMS 2.0 System Data View](image-url)
2.2. IEC61850 Hierarchical Information Model

IEC 61850 standard is the only international standard in the field of substation automation. Since it was translated into DL/T860 standard in 2004, it has become the guiding standard for the development of substation in China. This standard aims to improve the develop-ability, generality and extendibility of the system, and realize the interoperability between different devices from different manufacturers [4-5].

IEC 61850 standard regulates substation configuration description language SCL, which is used to configure substation IED. SCL mainly describes the substation system structure, primary equipment function, intelligent equipment function and service, network communication and data template, as shown in Figure 2:

- It mainly includes three levels:
  1. Substation: this section describes switching interval devices (process devices), which are based on single-line graph connection (topology), describes which primary equipment functions are used and how primary equipment is connected, and describes the allocation of equipment and functions.
  2. IED: this part describes all objects related to substation automation system products, such as intelligent electronic devices (IED), logical node realization, etc.
  3. Communication: This section contains object types related to communication, such as sub-net, communication node and descriptions of communication paths between logical nodes as clients and servers based on connections between intelligent electronic devices.
IEC61850 standard uses object-oriented modelling technology, which makes the information model inheritable and reusable. According to IEC61850 standard, the information model of intelligent electronic equipment is a hierarchical structured class model. Each layer of the information model is defined as an abstract class, encapsulating the corresponding attributes and services. Attributes describe the external visual characteristics of all instances of this class; services provide a way to access attributes. From the level of modeling, each IED contains one or more servers, each server itself contains one or more logical devices, logical devices contain logical nodes, and logical nodes contain data objects. Data objects are named instances of common data classes composed of data attributes [6].

3. Communication Method of PMS 2.0 and IEC 61850 Model

The PMS2.0 system is a management system based on the life cycle management of assets and takes state maintenance as the core. PMS2.0 system realizes data sharing through integration of business systems, avoids duplicate data entry, and opens business processes to achieve business closed-loop. In order to share real-time data of distribution automation system, PMS2.0 system should make full use of existing IEC61850 logical nodes and data objects. The relation between PMS 2.0 and IEC 61850 is shown in Figure 3.

3.1. Mapping Relation between PMS 2.0 Model and IEC 61850 Model

The fundamental difference between PMS 2.0 and IEC 61850 is that PMS 2.0 mainly describes the primary equipment model in substation, but seldom describes the actual function model in substation. IEC61850 mainly describes secondary intelligent electronic equipment, and also describes the primary equipment model in substation. However, the description of primary equipment is much simpler than that of PMS2.0. The differences between the two models concentrate on type and relation [7-8]. Relational differences are manifested in PMS 2.0, and the relation between classes is bidirectional and reticulated. The relation between classes and classes in IEC 61850 is one-way and tree-like. Type differences mainly include conductive equipment type differences, measurement object differences, time mark, and unit and quality object differences.

(1) Mapping of device level and topological relations

Both PMS2.0 and IEC61850 models have equipment containers at three levels: substation, voltage level and interval. Terminals, connection objects and their relations are used to describe electrical topological connection, and only conductive devices have connection with terminals [9]. The description of substation structure by the two models is basically the same, so mapping relation between them can be established directly. As shown in Table 1, IEC61850 and PMS2.0 differ greatly, and the mapping relation is complex. There are one-to-many cases [10].
Table 1. Mapping of Device level and Topological Relations

| Serial number | IEC61850 class                        | PMS2.0 class                                      | mapping type       |
|---------------|--------------------------------------|--------------------------------------------------|--------------------|
| 1             | tSubstation                          | pms: BelongStation, pms: Substation               | one-to-many        |
| 2             | tVoltageLevel                        | pms: Voltage Level, pms: Voltage Rating, pms: PowerStaVol,L | one-to-many        |
| 3             | tBay                                 | pms: IntervalUint, pms: BelongLine, pms: BelongTower | one-to-many        |
| 4             | tConductinEquipment                  | pms: Breaker, pms: Ground Disconnector, pms: Line, pms: ACLineSegment, pms: DCLineSegment etc | one-to-many        |
| 5             | tPowerTransformer                    | pms: Power Transformer, pms: Transformer, pms: columnTransformer | one-to-many        |
| 6             | tTransformerWinding                  | pms: Transformer Winding                         | one-to-one         |
| 7             | tTerminal                            | pms: Terminal                                    | one-to-one         |
| 8             | tConnectivityNode                    | pms: ConnectivityNode                            | one-to-one         |

PMS 2.0 and IEC 61850 differ greatly in describing the data. IEC 61850 focuses on the data in logical nodes from a substation while PMS 2.0 configures data acquisition and redundant data sources from the perspective of the whole network [11].

PMS2.0 describes measurement model with measurement name, measurement value, measurement range, and measurement unit and measurement accuracy. The measurements in PMS 2.0 can be either actual measurements or calculated values, even neither measured value nor calculated value. Any equipment can include measurements, such as temperature measurements in substations, switching state measurements, oil temperature measurements in transformers, tank pressure measurements and so on, intervals can include measurements of power flow calculation results, and circuit breakers can include switch position measurements. A measurement can have multiple measured values from different data sources.

In IEC 61850, logical nodes are used to describe the data available in IED. Data are organized into data types of different complexity. They form a tree-like structure through inclusion relations. The end of the tree structure (leaf nodes) is the most basic data type, which stores the data values actually collected by IED. In order to describe different types of data objects, various CDC types and DA Types are defined in IEC 61850-7-3. The CDC class describing the sequence component is SEQ, and the CDC class describing the relative measurement information of three-phase system is WYE. Logic nodes in IEC61850 can establish relations with any power system resources, and conductive devices, substations, voltage levels, and intervals and so on are sub-classes of power system resources. In this way, the data collected by IED (measurement) can be correlated with conductive devices, equipment containers and so on through logical nodes. However, the terminal units in IEC 61850 are not associated with logical nodes; that is to say, the data collected by IED cannot be associated with the terminal units of conductive devices.

From the above analysis, the establishment of mapping relation between PMS 2.0 and IEC 61850 measurement model mainly includes the following aspects: (1) Mapping between data objects of IEC 61850 and measurement types of PMS 2.0,(2) mapping of data attributes (such as quality, time, etc.) between the two models; (3) mapping of data types between the two models.
Table 2. Measurement Object Mapping (Part)

| PMS2.0 Measurement | PMS 2.0 date type | IEC61850 Measurement | IEC61850 date type | IEC61850 reference name of date | Instruction |
|---------------------|-------------------|----------------------|-------------------|--------------------------------|-------------|
| phaseACurrent       | int               | phsA                 | float             | IEDName+LDName/prefix+MMXU+lnInst$MX$ phsA | Data types need to be converted |
| Inusestate          | enum              | pos                  | bool              | IEDName+LDName/prefix+CSWI+lnIns t$CO$Pos | Data types need to be converted |
| Temperature         | int               | tmp                  | float             | IEDName+LDName/prefix+SIML+lnIns t$MXSTmp | Data types need to be converted |
| power               | int               | TotW                 | float             | IEDName+LDName/prefix+MMXU+lnInst$MXSTotW | Data types need to be converted |
| aPhasiffereceValue  | int               | none                 | no                |                                  |             |

4. Communication Interface Design Between PMS 2.0 Model and IEC 61850 Model

4.1. Design of Communication Mode

Two logical nodes are defined in the IEC 61850 model, one is the reporting logical node that transmits messages to the PMS 2.0 system, and the other is the log logical node that stores logs. According to the mapping relation between the two models, the data that the IEC 61850 system needs to transmit is determined and aggregated into the data set of logical nodes. According to the types of data, multiple data sets can be defined under these two logical nodes, and then report control block and log control block are added to these data sets.

IEC 61850 system transmits reports to PMS2.0 system according to the set buffer time through the report control block, so that the data of PMS2.0 system can be input quickly and accurately. PMS2.0 system can also actively query the logs stored in IEC61850 system in order to verify the data of PMS2.0 system, query the reasons and time of data changes.

The communication mode is mainly divided into two layers: the first layer is substation layer, which is mainly used for IEC61850 MMS message acquisition, parsing, framing and communication with PMS2.0 MMS server. The second layer is PMS layer, which mainly parses the received MMS message according to the data set defined by IEC61850 model and the protocol of MMS, and updates the relevant table data in PMS2.0 system with the data in the message.
The communication mode includes IEC61850 MMS client and PMS2.0 MMS server. Substation MMS client is mainly divided into three modules: message receiving module, message parsing module and message reorganization frame module. The client receives the report and log message of the substation MMS server for parsing. The client receives the report and log message of the substation MMS server for parsing, integrates and converts the acquired data by the formulas according to the data in the data set defined above, then compares it with the data of the latest data set. If it exceeds stipulates range, the data will be updated and the control block can be reported. After the set buffer time, the data will be framed into MMS messages and sent to the PMS 2.0 MMS server. MS 2.0 MMS server parses MMS message and updates data of PMS 2.0 system according to IEC 61850 model self-defined data set and MMS protocol. The IEC61850 MMS client communicates with the substation MMS server through the optical network port, the IEC61850 MMS client and PMS2.0 MMS server are connected through their respective Ethernet network ports.

The communication flow chart of the two systems is shown in Figure 4. The IEC61850 MMS client includes message receiving module, message parsing module and message reorganization frame module. The message receiving module receives the report and log messages from the substation MMS server and transmits them to the message parsing module. Message parsing module parses the report and log messages of substation MMS server according to IEC61850 model and MMS protocol, and then transfers them to message reassembly frame module. Message reorganization frame module integrates and calculates the parsed data according to the report data set of IEC61850 model and MMS protocol, and then reassembles the MMS message into MMS message and transmits it to PMS2.0 MMS server.

![Communication flow chart between PMS 2.0 system and intelligent substation system](image)

**Figure 4.** Communication flow chart between PMS 2.0 system and intelligent substation system
Figure 5. Conformance Testing Device Structure Diagram

PMS2.0 MMS server includes message receiving module, message parsing module and data storage module. The message receiving module receives the report and log messages sent to PMS2.0 MMS server by MMS customers of substation and transmits them to message parsing module. The message parsing module parses the MMS messages sent by IEC61850 MMS clients according to the message data set of IEC61850 model and the MMS protocol. The data obtained after parsing is transmitted to the data storage module to update the table data of PMS 2.0 system.

4.2. Design of Communication Interface Device Based on NI CRIO

NI Company’s CompactRIO (hereinafter referred to as CRIO) platform provides an open embedded architecture, including built-in embedded controllers, programmable FPGA and small, robust and hot-plugging industrial I/O modules. It is a repeatable configurable control and acquisition system with a solid hardware architecture. It can meet the application requirements of high performance and reliability. The development of CRIO platform is an innovation of engineering application. Graphical programming technology can be used to develop embedded system, which changes the traditional mode of using hardware programming language to develop system and facilitates the development of embedded module.

Therefore, based on NI CRIO platform, this paper proposes a communication interface device between PMS 2.0 system and IEC 61850. As shown in Figure 5, the device includes optical network port, Ethernet PHY module, FPGA module, power conversion module, recording and storage module, CRIO control module and display module. The optical network port is connected with Ethernet PHY module, Ethernet PHY module is connected with data port of the FPGA module through the FPGA bus, another data port of the FPGA module is connected with CRIO control module, and CRIO control module is connected with CRIO control module. The two data output interfaces of CRIO control module are connected with the recording and storage module and the display module respectively, and the power conversion module is connected with the power input of the FPGA module.

The test device uses modular design scheme to minimize the coupling between modules, so as to facilitate upgrade and modification in future. According to the characteristics of the hardware structure of the system, it is mainly divided into three layers: the baseboard FPGA layer, which is mainly used for the control of configuration file collection. The controller layer (CRIO control module), which is mainly used for data analysis, tests analysis and communicates with the host computer. And the PC layer
(storage and display) which is mainly used for the display of system configuration and analysis test results.

5. Conformance Test of PMS 2.0 and IEC 61850 Communication Interface

5.1. Conformance Test Content of Communication Interface

The third-party IEC61850 model configuration tool is used to describe the communication interface model and function of PMS2.0 system, then generate ICD configuration file. The static and dynamic conformance tests of the model are carried out.

(1) Static conformance test

According to the conformance description of ICD configuration file and model implementation, the static conformance test of configuration file is carried out. The main test contents are as follows:

The first step is to check whether the grammar of the file conforms to the basic grammar specification of XML.

The second step is to check the validity, integrity and consistency of the configuration files according to the eight Schema files in Part 6 of IEC 61850 standard, including elements attribute and their data types.

In the test, the data analysis process refers to Figure 6. By operating the parsed nodes, the node element information of the storage module is compared in various ways. If it does not meet the requirements, an error alarm is issued, and then the error type and target index in the configuration file will be output.

![Flow Chart of Static Conformance Testing](image)

Figure 6. Flow Chart of Static Conformance Testing
(2) Dynamic conformance test

The communication process between the PMS2.0 system and the intelligent substation system is that
the intelligent substation system transfers the on-line monitoring data to the PMS2.0 system. CRIO
device provides associate service to establish communication links between the two sides. Report and
other services are used to upload online monitoring data. Since the ACSI services mentioned above are
mapped to MMS services of IEC61850 standard, communication is achieved though the MMS protocol
and TCP/IP protocol.

According to PICS and PISIT, the dynamic consistency test of the communication interface model
is carried out, and the ACSI and MMS communication services are determined as the test items to test
the basic interconnection and communication behaviour [12]. Through the record and analysis of MMS
PDU, the conformance check is carried out, and the test conclusion is given to verify whether the
implementation of service interface and protocol stack conforms to the standard.

5.2. Testing Process and Results

Taking the experimental system of an intelligent substation as an example, the CRIO communication
device is connected through the optical network port, and the CRIO communication device is connected
with the PC through the Ethernet network port.

The IEC61850 model of the intelligent substation system is opened through the IEC61850
configuration software of Nari Company. An MMS report data set of line protection IED of the model
is shown in Figure 7.
Taking protection record table of a line in PMS model as an example, as shown in Figure 8, the mapping relation between IEC61850 model report data set and PMS model protection record of a line table is as follows:

![Figure 8. Mapping Diagram between a Line Protection Record Table of PMS2.0 Model and IEC61850 Model Reporting Data Set](image)

The experimental steps are as follows:

1. In the first step, CRIO platform receives MMS message from substation system, obtains three-phase analog data of one line, and calculates three-phase differential current value of one line according to differential calculation method.

2. The second step is to compare the calculated data with the latest data. If the difference exceeds the prescribed range, these new data groups are framed into MMS messages according to the location of data in the report data set customized by IEC61850 model.

3. The third step is to start timing from the first new data group frame and send the report service through TCP/IP protocol and MMS protocol to the MMS server of PMS2.0 system after reaching the set buffer time.

4. In the fourth step, the PMS2.0 MMS server receives MMS messages and parses them. According to the report data set of self-defined logical nodes in IEC61850 model, the three-phase differential current value data and time in a line protection record table of PMS2.0 system are updated.

The MMS report message transmitted from intelligent substation system to PMS 2.0 system is captured by software named Wireshark. The mapping relation between the data parsed by Wireshark and the PMS model is shown in Figure 4-4 below.

6. Conclusion

This paper presents a communication interface between PMS 2.0 and IEC 61850 based on model mapping and implements it on the CRIO platform of NI Corporation. Uses IEC61850 standard to customize the corresponding report and logical log nodes, then creates the report and log data set...
according to the mapping relation between PMS2.0 model and IEC61850 model. Intelligent substation system uses the report service of MMS protocol to transmit data to PMS2.0 system. Taking the intelligent substation experimental system as an example, the data exchange between the two systems is realized, and the efficiency of data input of PMS2.0 system is effectively improved.

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