Research on Self-Configuration Technology of Intelligent Recorder Based on Graph and Model Integration

Xu Chen¹, Chi Zhang¹, He Huang¹, Peng Xu¹, Jingchao Yang², Zhongnan Xu²*

¹China Southern Power Grid Dispatch and Control Center, Guangzhou, Guangdong, 510000, China
²Wuhan Kemov Electric Co., Ltd, Wuhan, Hubei, 430223, China
*E-mail: jiangzhuoyan@kemov.com

Abstract. Intelligent recorder configuration related to smart operation and maintenance of secondary equipment has a large workload and a long configuration cycle, and it is difficult to guarantee and verify the correctness. Based on analysis of intelligent recorder function model including smart operation and maintenance, fault recording, network message analysis. This paper defines the requirements of self-configuration of intelligent recorder. On this basis, it puts forward the information model foundation that self-configuration depends on, including primary equipment model, correlation model between primary and secondary equipment, relays’ ICD information model, intelligent recorder acquisition unit, management unit model, and finally gives the self-configuration technique scheme in order to effectively improve the configuration efficiency of the intelligent recorder based on graph and model integration configuration, by which the RCI model file of the intelligent recorder and the SVG graphic file of the protection panel are formed.

1. Introduction
The intelligent recorder is integrated with fault transient recording, network packet recording, secondary system visualization, intelligent operation and maintenance, and protection and fault information substation. It is the most comprehensive and centralized system for monitoring, analyzing and diagnosing substation relay protection equipment, providing technical support for operation and maintenance of intelligent substations [1].

At present, the advanced applications of intelligent recorder, such as wave recording, protection and fault information, network analysis and intelligent operation and maintenance, mainly rely on manual configuration, which requires a large amount of configuration work and cannot guarantee the correctness; SCD has many modifications in various links, such as the construction process of intelligent substation, design naming and dispatching naming changes, reconstruction and expansion, defect treatment, each modification relies on the system integrators for reconfiguration, which cannot meet the needs of advanced applications such as source end maintenance.

Aiming at these problems above, the paper introduces a self-configuration method of the intelligent recorder based on the graph module integration, and then establish the indicator primitives based on the operating state of the IED, and associate the indicator primitives with the corresponding manufacturer's SVG base map to create the SVG diagram of the front panel.

According to the port information of the IED, the associated primitives of the plug-in and the optical port, the SVG diagram of the back panel of the device according to the numbering sequence of...
tand the optical port, the SVG diagram of the back panel of the device according to the numbering sequence of the plug-in can be established. According to the configuration information of the intelligent recorder, the RCI (Recorder Configuration Instance) file and SVG file are established by intelligent recorder configuration tool, importing the SCD file, dispatch-name, management unit ICD file. Further, via graph and model Integration function model of intelligent recorder, automatic function configuration can be finished.

2. Technical Proposal

According to IEC61850 standard, the ICD model of intelligent recorder is established in the technical specification of intelligent recorder. However, the configuration mode conforming to the SCL language specification cannot establish the association between the MMS information of the protection device and the MMS information of the intelligent recorder, and it is difficult to achieve the automatic configuration of the intelligent recorder and other advanced applications. Therefore, it is recommended to model the configuration information of the intelligent recorder in the way of external files. The basic scheme is as follows:

The intelligent recorder ICD and SMCD are still modeled according to the “Technical Specifications for Intelligent Recorder”, which are used for sub-master station communication and uploads service results to the master station. According to different manufacturers, an SVG base map composed of a liquid crystal panel, an operation direction, and an indicator area is established. According to the dsDeviceState operation state data set entry of the IED in the SCD file, indicator primitives are established, and according to the manufacturer of the IED, the indicators are associated to the indicator area of the SVG base map of the corresponding manufacturer to establish the SVG diagram of the front panel of the device; according to the port information of the IED in the SCD file, establish the association between the plug-in and the optical port, establish the plug-in and the optical port associated graphics, according to the order of the plug-in build an SVG diagram of the back panel of the device; describe configuration model of intelligent recorder based on the service requirements of the recorder and the "Code Description Specification for Relay Protection and Related Secondary Equipment Information of Intelligent Substations". During project implementation, importing management unit ICD file, dispatch-name file and SCD file, generate the RCI model file, SVG file of the intelligent recorder management unit, and CID file, CCD file of the intelligent recorder acquisition unit through the intelligent recorder configuration tool, as shown in figure 1.

3. Service Analysis

The intelligent recorder is mainly composed of five functional modules including panoramic monitoring, fault recording, network message analysis, relays information management and intelligent operation and maintenance and other public service components, as shown in figure 2.

Information configuration is an important basic work in the field engineering implementation of the intelligent recorder. Import the SCD file of the whole station, and map the output information of the device to the intelligent recorder according to the system function of the intelligent recorder, so as to meet the application requirements of the intelligent recorder and realize the system function. The
information configuration of the intelligent recorder includes basic parameters, analog quantity monitoring, logic link alarm, pressing plate, front and back panels of the device, homology, exit reverse calibration, enumeration and other configurations. When the intelligent recorder is connected to a smart substation with a high voltage level, a large scale, and a large number of IEDs, manual configuration will increase the information configuration time of the intelligent recorder. The information configuration of the intelligent recorder can be modeled to realize the automatic information configuration.

Based on the above service analysis and configuration information of intelligent recorder, the self-configuration requirements are summarized in table 1.

![Table 1. Self-configuration requirements of function models](image)

| Function Model            | Configuration Item                                                                 | Configuration Requirements                                                                 | Configuration Information Type          | Configuration Information Carrier |
|---------------------------|------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|------------------------------------------|----------------------------------|
| Panoramic monitoring      | Primary topology connection; Primary and Secondary Equipment Association.           | primary equipment model, graphic primitives of primary equipment; primary and secondary equipment association, and primary equipment parameters. | graphic information, model information | SCD file (including SSD)         |
| Fault recording           | Analog channel; Binary channel; Sequence component group configuration; Fault location configuration; Trigger configuration. | analog channel name, parameters; binary channel name and type; signal group configuration; fault location parameters; trigger parameters. | model information                      | CID, CCD file of data acquisition unit |
| Network message analysis  | Network interface configuration; Abnormal message configuration.                     | Fiber connection configuration; Abnormal message items configuration.                         | model information                      | CID file of data acquisition unit |
| Relays information management | On-line monitoring; Four files calling; Relay information inquiry.              | On-line monitoring information configuration.                                               | model information                      | SCD file, RCI file of data management unit |
| Intelligent operation and maintenance | Secondary circuit visualization; Secondary fiber circuit monitoring; Relay behavior analysis; Intelligent inspection, periodic inspection; Homologous data comparison. | Front and back panel of relays configuration; Fiber link configuration; Trip verification configuration of relay; Device status configuration; Inspection point configuration, etc. | graphic information, model information | RCI file of data management unit, SVG file and SCD file |

Figure 2. Main function models of intelligent recorder
4. Configuration Information modeling

4.1. Modeling method
Intelligent recorder configuration model mainly describes the standard information of intelligent recorder configuration, which is an abstract expression of function in essence. Therefore, to establish recorder configuration model file, we should start with analyzing the system service function of intelligent recorder, decompose the system service function, extract the required information, and establish configuration information model, which mainly including basic parameter model, information point model, service configuration model, homologous model, event sequence model, and enumeration model [2-5]. According to the idea of object-oriented, layered objects are used to build IED service function model based on voltage level, equipment type, element and element attribute, as shown in Figure 3. A basic information point model and service configuration model are used to build IED service function model. Several homologous models and event sequence models are used to build interval service function model. A basic parameter model, several IED services function models, one interval service function model and several enumeration type models are constructed into recorder configuration model, and the root element is RCDF, as shown in figure 3.

4.2. IED service model design
The basic parameter model includes the parameters such as frequent alarms, disk alarms, IED acquisition time, intelligent patrol, and intelligent fixed inspection. The basic parameter model is established based on the threshold parameters of the intelligent recorder system function in the “Technical Specifications for Intelligent Recorder”.

4.3. IED service model design
The IED service model is established based on the voltage level of the relay protection device and the type of the primary equipment. It includes a basic information point model and a service configuration model.

The basic information point model refers to the function information point of IED, which provides the basic information for other services of the recorder. The basic information point model is established based on the device output information in the “Information Specification of Protection Relays and related Secondary Devices of Smart Substation”, mainly including setting value, pressing plate, GOOSE output / input, action event, fault signal, communication condition, internal monitoring, protection telemetering, device operation state, protection telemetering, protection function state, power on transmission, etc [2, 6-10].

The service configuration model indicates the association between different information points or the information points required for related services in the process of the recorder. The service
configuration model is established according to the functional requirements of the device in the “Technical Specifications for Intelligent Recorder, mainly including analog online monitoring, logic link alarm, pressing plate, front panel of the device, back panel of the device, etc.

4.3.1. Analog quantity monitoring model. Analog quantity monitoring modeling refers to the establishment of the relationship between the monitoring object and the internal monitoring information output by the relay protection device.

The monitoring object is established according to the relay protection monitoring information specified in the “Information Specification of Protection Relays and related Secondary Devices of Smart Substation”, mainly including device temperature, device power supply voltage, process layer port sending / receiving light intensity and optical fiber longitudinal channel light intensity.

The attributes of threshold value of monitoring object include type, unit, alarm parameter, alarm control word, etc. Alarm control word has three states: acquisition, calculation and exit. The meanings of the three states are as follows;

- Acquisition: Analyze the alarm signal of the monitored object.
- Calculation: Analyze the value of the monitoring object, and when the threshold control word is calculated, design the alarm threshold of the monitoring information.
- Exit: The monitoring object does not participate in the analysis.

4.3.2. Logical link alarm model. Logic link alarm modeling refers to the establishment of the association between the control block subscribed to the relay protection device port and the output link broken link alarm.

The subscribed control block in the logical link alarm model is established according to the subscribed control block of the relay protection device, which mainly includes process layer 1 network control block and process layer 2 network control block. The link types include SV, GOOSE and SV/GOOSE. Link broken is described as process layer 1 network link interruption N or process layer 2 network link interruption N. For different manufacturers, the process layer dual network expression will be inconsistent, so it is necessary to establish keywords describing the dual network of the process layer of the device, mainly including process layer 1 network, process layer 2 network, network A GOOSE, network B GOOSE, network port A, and network port B, etc.

4.3.3. Pressure plate model. The pressure plate model includes the hard pressure plate model, the functional pressure plate model, the SV input pressure plate model and the GOOSE input / output pressure plate model.

Hard pressure plate modeling and functional pressure plate modeling refer to establishing the relationship between the pressure plate and the pressure plate information output by the relay protection device. SV input pressure plate modeling and GOOSE input / output pressure plate modeling refer to establishing the relationship between the pressure plate and the pressure plate information and data set information output by the relay protection device.

4.3.4. Device front panel model. The front panel modeling of the device refers to the establishment of the relationship between the operation indicator and the operation status information output by the relay protection device.

The operation indicator is established according to the operation of relay protection specified in the “Information Specification of Protection Relays and related Secondary Devices of Smart Substation”.

The indicator lights include three types of indication, alarm and action, and the types of indicator lights of different types of devices are different.

Create SVG base maps of front panel of devices from different manufacturers, which consists of LCD, operation direction building and indicator area. The dsDeviceState running state data set of IED describes the state information of the panel indicator of the device. The dsDeviceState operation state data set of line protection model PCS-931A2-DG-N-Z is shown in figure 4.
LD0/LLN0.dsDeviceState
BOOLEAN:Running,LD0/1NDGGIO5.Ind1
BOOLEAN:Abnormal,LD0/1NDGGIO5.Ind2
BOOLEAN:Checking,LD0/1NDGGIO5.Ind3
BOOLEAN:Longitudinal protection blocking,LD0/1NDGGIO5.Ind4
BOOLEAN:Phase A trip,LD0/1NDGGIO5.Ind5
BOOLEAN:Phase B trip,LD0/1NDGGIO5.Ind6
BOOLEAN:Phase C trip,LD0/1NDGGIO5.Ind7
BOOLEAN:Reclosing,LD0/1NDGGIO5.Ind8
BOOLEAN:Finished charging,LD0/1NDGGIO6.Ind1

Figure 4. Device operating status data set

Establish the indicator primitive according to the dsDeviceState operation state data set entries, and add them to the indicator area of the corresponding SVG base map. The order of the indicator lights is consistent with the order of the dsDeviceState operation state data entries. The indication of the indicator lights of the equipment of different manufacturers may be different. There are two main ways to represent: 1) round indicator; 2) square indicator. According to the actual situation of the equipment, establish the actual indicator primitives and the color attributes of the indicators "on" and "off", as shown in figure 5.

Figure 5. Front panel SVG diagram

4.3.5. Device back panel modelling. The back panel modeling of the device refers to the establishment of the correlation between the plug-in, the optical port and the fault information output by the relay protection device.

Different types of devices have different optical port types and plug-in categories on the back panel. The relay protection device plug-in and the optical port use intuitive vector to represent different objects [10-14]. Communication/ConnectAP/PhysConn describes the attribute information of the port, and the Port attribute of the optical port is:

\[
\text{<P type = "Port"> 1-A </ P>}
\]

"1" indicates the plug-in, "A" indicates the optical port plug-in. Traverse the IED, establish the plug-in and optical port associated graphics, and establish the back plane SVG diagram in the order of the plug-in number. The representation of the optical port primitives of equipment of different manufacturers may be different. There are two main ways to represent: 1) circular optical port; 2) square optical port.

According to the actual situation of the equipment, establish the optical port primitives and the RX / TX attributes of the optical port, as shown in figure 6.

Figure 6. Back panel SVG diagram
4.4. Interval service modeling

Interval service model includes homology model and event sequence model.

The homology model indicates the related channels that the recorder compares in the process of performing the homology service.

The homologous modeling mainly establishes the correlation between the voltage, current, switching information collected by the recorder and the voltage, current, switching information of the protection device based on the recording files of the intelligent recorder and the protection device.

The event sequence model provides the correct information template for the protection action analysis service, and is the basis for the recorder to perform the verification related protection action sequence service. The event sequence model can be described with the basic information points in the IED model, and indicate the order of the information point. When the line fault line protection single-phase trips, its information feedback situation is shown in figure 7. The line protection sends out trip A command to the intelligent terminal, the intelligent terminal receives the trip A command and trips the switch, at the same time, issues a “received the skip A command. The intelligent terminal collects the switch displacement signal and sends out the A position signal of the circuit breaker to the line protection.

When the fault disappears, the line protection sends a reclosing A command to the intelligent terminal. The intelligent terminal receives the reclosing command and closes the switch. When the switch is in the closed position, the intelligent terminal sends out the extraction signal of phase A tripping outlet, and at the same time sends out the position signal of phase A with opening and closing of the circuit breaker to the line protection.

When the line protection sends out the trip A command, it will send the single phase start failure signal to the bus protection at the same time. The bus protection receives the single phase start failure signal and changes its single-phase failure input remote signal.

```
Busbar protection
   Single phase failure
      Management unit
       Single phase start failure
          Trip MMS signal
             Intelligent Terminal
                           Switch
                  Acquisition unit
                      Single phase trip reverse comparison
                         Single phase export mining

Figure 7. Logic diagram of tripping and closing
```

The event sequence modeling mainly establishes the relationship between the GOOSE output signal of the protection and the position of the circuit breaker, the GOOSE command feedback, and the recovery signal of the intelligent terminal, and the start and failure signals received by the bus differential protection based on the subscription relationship of the process layer signals output by the device and the logic circuit driving sequence. The attributes of the signal include the sequence of events, the expected value, and the device type of the receiving end. The expected value has two states of "0" and "1". For example, the circuit breaker position is expected to be "0" when tripping, and the circuit breaker position is expected to be "1" when closing.

4.5. Enumeration type model

The enumerated type model defines the types of objects involved in the information configuration of the intelligent recorder. The enumeration type model includes secondary equipment type, primary equipment object, process layer network type, analog quantity monitoring object type, analog quantity...
monitoring control word value, unit type, method of obtaining IED time, anti-calibration signal type, etc.

5. Self-configuration implementation of intelligent recorder

Intelligent Recorder configuration model describes the basic parameters, the correlation between the IED service and the output information of the relay protection device, and the correlation between interval service and the output information of the relay protection device, which provides basic information for establishing RCI model file [14-19].

The RCI model file is related to the type and quantity of IEDs in the substation. In order to adapt to the automatic generation of RCI model file of panoramic model intelligent recorder, a generation tool based on graph and model integration is developed. Import the SCD file, dispatch-name file and data management ICD file, and then instantiate the interval information automatically. The process of generating the RCI model file of the intelligent recorder is shown in figure 8.

![Figure 8. RCI model file generation flow chart](image)

1) Parsing SCD and other files. Parse the SCD file to extract the type, the voltage level, the data set information and the port information of IEDs; parse the management unit ICD file to extract the basic parameter information, information point of the IED, service configuration information, homology configuration information, and event sequence configuration information.

2) Instantiate the IED service information. Match the basic information point and service configuration information of the IED according to the type and voltage level of the IED. Taking 220kV line protection as an example, the specific example steps of analog monitoring are as follows: Obtain the port number of the IED, add the light intensity monitoring object of the optical port, and fill in the description of the corresponding light intensity monitoring object in the model file. Traverse the IED, establish the association between the plug-in and the optical port, add keyword for the optical intensity and the optical of port 1 according to the optical port associated with the plug-in, and then loop this keyword, and traverse the dsAin and dsWarning datasets to identity whether the DOI description contains the keyword, and if so, establish a one-to-one correspondence mapping relationship between the light intensity monitoring item and the status information. Otherwise, establish the association mapping of the next optical port intensity monitoring object until the association mapping of all optical port monitoring items is completed.
3) Instantiate interval service function information. According to the description of the elements and element attributes of the IED business model, match with the homology model and event sequence model to instantiate the interval business configuration model.

4) Generate RCI file of intelligent recorder. Use the intelligent recorder configuration tool to export a standard XML format file, which describes the basic parameters, all IED instance configuration association relationships and interval service instance configuration association relationships.

6. Conclusion

This paper proposes an intelligent recorder self-configuration modeling method based on integrated graph and model. It instantiates IED service information according to the type of IED and the corresponding voltage level, and then instantiates interval service function information to establish an RCI model. According to the operating status of the IED to create SVG base maps for different types of equipment from different manufacturers, according to the type of IED manufacturer to create indicator primitives, then associate the indicator primitives to the corresponding manufacturer’s front panel SVG base map to establish front panel SVG diagram of the device. According to the port information of the IED, the connection between the plug-in and the optical port can be established, according to the plug-in numbering sequence, the back panel of the SVG diagram can be created. The self-configuration and corresponding model method proposed in this paper provides a data source for the service functions of the intelligent recorder system, and the configuration information is modeled, so that the configuration of the intelligent recorder does not depend on the manufacturer, which is convenient for the future operation and maintenance application.

Acknowledgments

This work was financially supported by science and technology project of China Southern Power Grid Corporation (No. 000000KK52180019).

References

[1] State Grid Corporation of China, (2018) Q/GDW1429-2012 Technical specification for intelligent recorder, Beijing China.

[2] China Southern Power Grid, (2017) Q/CSG1203045-2017 Information Specification of Protection Relays and related Secondary Devices of Smart Substation, Beijing China.

[3] Ye Yuanbo, Ji Ling, Huang Taigui, Sun Yueqin and Yang Xiaofan, (2018) Extended common information model for the condition based maintenance of secondary equipment in smart substation. Power System Protection and Control, 46: 49-58.

[4] Hu Shaoqian, Li Li, Qi Zhong, Lin Qing, Dai Xiaoliang, Xiong Hui, (2016) Research on and application of IEC61850 modelling and CIM extension for protection relay information management system. Automation of Electric Power Systems, 40: 119-124.

[5] Gao Lei, Yang Yi, Su Lin, Lou Yue, Cao Weigu, Li Peng, (2016) A modeling approach and design implementation of secondary system physical circuit for smart substation. Power System Protection and Control, 44: 130-139.

[6] Chen Gejun, Zhou Hongyang, Li Wenyun, Gu Quan, Yang Mengnan, Zhao Yunfeng, (2012) ACIM general protection model and its application. Automation of Electric Power Systems, 36:.49-53.

[7] Zhang Qiaoxia, Jia Huawei, Ye Haiming, Xiao Liang, Li Jianglin, Zhang Ting, (2015) Design and application of virtual secondary circuit monitoring in smart substation. Power System Protection and Control, 43:123-128.

[8] Ji Ling, Li Zhongming, Jiang Yanjun, Qiu Yutao, Qiu Qunhui, Jiang Weijian, (2015) Research on description of secondary virtual loop object information model in smart substation. Huadian Technology, 37: 4-8.
[9] Chen Jian, Zhang Jiehua, Li Peng, Cao Weiguo, Zhang Guohui, Shen Liangpin, Xiong Jing, (2018) Research on optimization of smart labels based on panoramic model files. Power System Protection and Control, 46:110-116.
[10] Cao Haiou, Gao Xiang, Yang Yi, Yin Jijing, (2016) Analysis of online monitoring and intelligent diagnosis based on the full model SCD secondary system. Power System Protection and Control, 44: 136-141.
[11] Qin Hongxia, Wu Fangying, Peng Shikuan, Ge Liang, You Tao, (2015) New technology research on secondary equipment operation maintenance for smart grid. Power System Protection and Control, 43: 35-40.
[12] Zhu Guiying, Zhang Hong, Huang Haifeng, Hu Jihao, Zhang Haidong, Xu Xianfeng, (2014) A mapping method of communication applied to smart substation and control center. Power System Protection and Control, 42:112-116.
[13] Zhu Botong, Cheng Zhihai, Tang Zhiqiang, Jiang Wei, (2013) Interoperate research of the intelligent substation and dispatching center based on CIM model. Power System Protection and Control, 41: 93-97.
[14] Chen Dehui, Yang Zhihong, Gao Xiang, (2016) Research and implementation on function sequence visualization of relay protection based on IEC61850. Power System Protection and Control, 44:182-186.
[15] Dong Ke, Guan Bin, Wang Wei, (2010) Research on mapping between IEC61850 and MMS. Power System Protection and Control, 38: 92-95.
[16] Miao Bin, Tong Xiaoyang, Zheng Yongkang, Zhen Wei, Liu Mingzhong, (2013) Prototype design of graphic system configuration tool for intelligent substation based on IEC61850. Automation of Electric Power Systems, 37: 82-87.
[17] Xie Jun, Li Feng, Li Yong, Lu Wei, Li Zhongmin, (2014) A test template and its generation method for protection devices in an intelligent substation. Electric Power, 47: 122-127.
[18] Yang Hui, Wen Dongxu, Gao Lei, Liao Zeyou, Wang Yonggang, (2017) Automatic generation of secondary circuit virtual connection in smart substation. Power System Protection and Control, 45: 116-121.
[19] Zhu Lijun, Shao Jianfeng, Li Eqing, Rong Jiliang, (2012) Intelligent Substation Equipment Modeling and SCD Configuration. East China Electric Power, (6): 967-969.