Protection Relay and Fault Information Analyzing System for Smart Grid

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Abstract – For smart grid, the fault information from protection relays and fault recorders is useful for dispatchers to identify the grid fault and resume the power supply fleetly when a fault occurs. Traditionally, EMS/SCADA doesn’t have the ability to collect the fault information. An application of protection relay and fault information analyzing system is proposed. In order to implement smarter analyzing functions, three approaches are adopted. First, the system unifies IEC61850 and IEC103 for modeling. Second, an analyzing method of relay characteristic is proposed to evaluate the action behavior of protection relays. Finally, the paper presents an approach to replay the actual action sequence with relay’s logic diagram. The system has been carried out and the paper concludes that the system is effective and useful for dispatchers and relay operators in smart grid.

Keywords: Protection relay, Fault information, Action behavior, Smart grid

1. Introduction

In recent years, to build smart grid[1][2] becomes a new focus, and smart grid is regarded as a promising emerging technology for the power industry to drive energy revolution. How to fully collect and make effective use of the information of the intelligent secondary devices get abroad attention in smart grid time. For dispatching center, the fault information from protection relays and fault recorders is important for dispatchers to identify the grid fault and resume the power supply fleetly when a fault occurs. Traditionally, EMS/SCADA can not collect the fault information. An application of protection relay and fault information analyzing system[3] is proposed in the paper.

The system acquires fault information from protection relays and fault recorders automatically. It consists of master system, slave system and high-speed communication channel. Slave systems in substations or plants connect with protection relays and fault recorders through Ethernet, RS485 or other media, collect fault information from IEDs, and transfer the information to the master system in the dispatching center. Master system is a platform of fault information intelligent processing. In case of grid fault, the master system concentrates relevant fault information from slave systems and forms the fault report for the dispatchers automatically via fault analyzing function.

Smart grid needs smarter analyzing functions for grid dispatching centers. In order to implement analyzing functions in the master system, three approaches are adopted. First, the system unifies IEC61850 and IEC103 for modeling. IEC61850 is one of the most important standard for smart substations[4]. Protection relays should be modeled by following IEC61850 standard. But in traditional substations, many relays can’t support IEC61850. How to model new relays and traditional relays in one way is a great challenge for the system. The paper presents a method to make modeling more compatible. Second, an analyzing method of relay characteristic is proposed to evaluate the action behavior of protection relays. The method is based on a kind of script language to support definition of many types of relays. The action track will be drawn in the characteristic graph according to the calculation of collecting information from the system. The relay characteristic analysis is like “black box” method to evaluate relay’s action behavior. In order to get more information about action behavior, the paper presents an approach to replay the actual action sequence of relay with its logic diagram. Using special communicating technology, the system acquires acting information in more detail and replays the logic processing procedure in the logic diagram by visualization.

2. System Overview

Comparing with EMS, the system is designed especially for secondary devices. The system is used for acquiring the running state and acting information of the secondary devices (mainly refer to protection relays and fault
recorders). Based on the information, the system provides processing and analyzing function to analyze grid fault, to evaluate action behavior of relays and to help dispatchers to make a decision when an accident occur in power grid.

The system includes master system, slave system and high-speed communication channel. The structure is illustrated as Fig. 1.

![Fig. 1. System structure.](image)

The slave system is data source for the system. It acquires information from relays and fault recorders and transform the information to the master system.

The master system is illustrated as above of Fig. 1. It consists of data server, communication server, web server and some workstation and so on. From the view of software structure, the master system is designed as a hierarchical structure. The logic architecture is shown as Fig. 2.

![Fig. 2. Architecture of master system.](image)

Using object-oriented distributed components technology, the master system is founded on CSGC-3000 generic platform. The CSGC-3000 generic platform provides the generic component-based capabilities, including the generic OS interface, network communication middleware, distributed real time database service and business database interface. The middle layer includes the foundational applications such as basic graphic interface, SCADA and FEP. The various power application is located at the top layer. Different layers realize the corresponding function by using the services provided at the lower layers and provide the interface to the higher layers. The hierarchical structure masks the differences of the hardware platform, OS, database and network communication, so the applications can be flexible, reliable and portable at the higher layers.

The master system offers the graphical monitoring function to monitor the running state of secondary devices, slave systems and so on. For dispatchers, the system provide the analysis functions such as real-time fault report creation, device fault diagnosis, waveform analysis and so on. Also, the system provides some tools for relay operators to evaluate the action behavior of relays.

### 3. Relay Modeling

The implement of analyzing grid fault smartly in the system should be based on establishing primary device model and secondary device model correctly. But there wasn’t any modeling specification for secondary devices (especially for protection relays) to be committed for a long time. In fact, most of relays in traditional substations communicate with other systems or devices by IEC 60870-5-103 protocol or other protocols[5]. The exchanging message between two sides is on the basis of data point mapping. The semantic meaning depends on the appointment of two sides. This means protection relays don’t have normative modeling standard, and that restricted the implement of the analyzing function.

Nowadays, IEC61850 is being adopted in many projects, and relays have uniform modeling specification. But for large number of traditional relays, if 61850 is used to re-model in the system, the accuracy of modeling can not be assured and the workload of modeling is too huge to be realized. The system presents an approach of multi model compatibility which can model new relays and traditional relays in one way. The method ensures that traditional relays don’t need to model following 61850 standard, and processing information from relays is effective.

The modeling method refers to IEC 61850 standard. Some hiberarchy object model, such as IED, Server, LDevice and LNode are imported. Each object corresponds to one table in relational database. Fields of each table includes but not limited to all of attributes in IEC 61850,
and each attribute maps to one or several fields. The ‘Data’ object in LNode and the ‘DataAttribute’ object in Data will be mapped to some relational tables according to function constraint, such as digital table, analog table, settings table, control table, event of relay table and so on, and fields of each table also includes but not limited to all of attributes in IEC 61850. The structure is shown as Fig. 3.

For those traditional relays that haven’t specific model but point definition, the system provides a modeling tool to create IED, Server, LDevice, LNode object automatically, and some necessary attributes will be set according to the rules defined by the tool. The creating rules includes some pre-defined rules, and also can be extended by users. Measurement points of traditional relays will be mapped to the corresponding relational table in term of semantic type, and each measurement point is mapped to one record in relevant table.

The relational tables, such as Digital, Analog, Settings, Control and Event, exist a field mapping to unique index of Data objet and DataAttribute object in IEC 61850, and some fields are designed to correspond to slave number, relay address, group ID and point ID. These fields are used to identify a unique data point of traditional relays. The communicating process will compare information index from IEC 61850 relays with unique index field in the table and obtain the record number of the information from relays. If the process receives information from traditional relays, the process will use slave number, relay address, group ID and point ID to position the record number in same tables.

4. Relay Characteristic Analysis

In case of grid faults, the system will receive plenty of information from relays and fault recorders, and form the fault report for the dispatchers to report action information of relays. The system is not only served for the dispatchers in the dispatching center, but also for protection relay operators. The relay operators need fault information in more detail to analyze and evaluate action behavior of relays when some complex accidents occur.

The system provides an analyzing tool for relay operators which is named relay characteristic analysis. The tool will draw relay characteristic curve using information such as setting values, waveform files gathered by the system, and calculate the action quantity to draw the acting track of the relay to determine if the acting point is in action zone or not. By using the method, the tool evaluates action behavior of relays.

![Fig. 3. Compatible model structure.](image)

The system presents customizing approach to customize relay models by a script language. The approach comprises the steps as follows:

1) Define the border, segment, action quantity of relay characteristic with the script language;

![Fig. 4. Relay characteristic analysis.](image)
2) Establish the corresponding relationship between variables in the formula which defines characteristic border and action quantity, and setting values of the relay;
3) Get the setting values from the site on line and instantiate the definition of relays;
4) Get the data from waveform file to calculate action quantity of relays and draw the action track in characteristic graph.

The script language is used to customize the relay characteristic, which includes syntax definition, variable definition, border definition and so on. The graphic key words of the language comprise line, circle, arc, etc. The language describes clockwise direction as positive direction.

After finishing definition of the border and action quantity of relay characteristic, the tool will compile the script code using embedded compiler to instantiate relay model. In running state, the tool will get setting values and some physical quantity such as voltage and current in case of fault to calculate the real value of the action quantity and draw acting track. The relay operators use the tool and other information about acting event of relays to assess the action behavior.

5. Logic Diagram Replaying

The relay characteristic analyzing method orients to relay component in the protective unit, and is based on the relay action principle to analyze exterior feature. As it can’t analyze the logic judgment processing of the relay, the method is like “Black box” analyzing technology. In order to get more information about action behavior, the paper presents an approach to replay the actual interior logic node action of relay’s logic diagram. Nowadays, many protective units are equipped by strong CPUs and large storage capacity. This makes it possible to record all information about state change of logic node and electrical quantities when the relay acts. The master system adopts some communicating technology to acquire the record. Then the master system provides a tool to replay the logic processing procedure in the relay logic diagram by visualization. The method is like “White box” analyzing technology to replay and evaluate action behavior of the relay more transparently.

The communicating technology is based on IEC61850 standard which is to ensure high efficiency and reliability. In detail, the file service of IEC61850 is used to transform the information from protection relays to slave system and to master system through high speed communicating channel.

Different relays have different logic diagrams. In order to ensure the generality, the replaying tool adopts generic logic diagram editor. The editor supports FBD language of IEC61131-3 to create and show various logic diagrams, and to save the diagram as a configuration file.

The replaying tool provides an interface to control replaying process with one step, forward, backward buttons. When replaying, the tool will open relevant logic diagram according to the type of relays firstly. Based on the information about state change of logic node and electrical quantities, the tool explains the information and demonstrates the logic processing procedure with thick line and striking color.

Fig. 5. Logic diagram replay.

To implement comprehensive replay, the tool integrates acting event and waveform file about the same grid fault to show. Relay operators can observe the change of waveform, state of digital quantities before and after startup moment when replaying the logic processing procedure.

6. Conclusion

The paper introduces the protection relay and fault information analyzing system for smart grid. To meet the demand of smart grid, the paper researches the compatible modeling method of secondary devices, and presents two approaches to analyze and assess the action behavior for relay operators in dispatching center. The system has been carried out in many large regional power grid in China. The paper concludes that the system can promote the automatic level of the protection relay management, enhance the ability to monitor and control the power grid. The system will have an active impact on stage of building smart grid.

To analyze grid fault more roundly, the paper recommends that the system should integrate with other automation systems to analyze the complex grid fault comprehensively and do decision more smartly.
References


Ge Liang research interests include power system automation in dispatching center and generic software platform.