IOP Conf. Series: Materials Science and Engineering **366** (2018) 012048 doi:10.1088/1757-899X/366/1/012048

Visualization Research of Smart Substation Secondary Safety Measures

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Abstract. The smart substation adopts the network communication rather than the traditional electric cable, which makes the traditional secondary electric circuit terminal into a loop of virtual terminal and then the entire secondary system became a "black box", thus causes a lot of problems and difficulties into the operation and maintenance of smart substation. However, little attention has been paid to the visualization of secondary safety circuits for smart substations. In this paper, a portable device based on the characteristics of the secondary circuits and needs of the current secondary safety measures for smart substation was designed to realize the visualization of the device information, the control circuits and the safety circuits. Finally, the secondary security measures of smart substation were normalized and illustrated based on the first set protection of 220 kV line space.

1. Introduction

Smart substation is an important part of smart grid. In recent years, with the rapidly developed of smart substation, China has become the country with the largest number of smart substations in operation. The equipment of conventional substation is mainly connected by cable, while the smart substation based on industrial Ethernet technology mainly adopts optical fiber and network to achieve connection between substation equipment[1-2]. In this way, the open-circuit faults in the secondary circuit of current transformers and the short-circuit faults in the secondary circuit of voltage transformer can be avoided effectively. In addition, the network data stream replaces the DC secondary circuits which can eliminate the parasitic circuits and achieve the effective monitoring of DC logic [3]. Therefore, as a hub of 'Power Flow, Information Flow, Business Flow' in Smart Grid, smart substations are key components for Strong Smart Grid.

Compared with conventional substation, smart substation has no visual electrical connections. Through introducing integration units and smart terminals into smart substation, the fiber connection between secondary equipment can be achieved by the transmission of highly coupled network data. Due to the cables replaced by optical fiber, the transmission speed of smart substation is faster and the operation of secondary equipment becomes safer. However, this leads traditional secondary electric circuit terminal into a loop of virtual terminal, thus the entire secondary system becomes a 'black box' and cause difficulties to operation and maintenance of smart substations [4-5]. Therefore, the secondary security measures of conventional substation depending on physics isolation technology such as exiting hard plates of protection is no longer fully applicable to the relay protection in smart substation [6]. Moreover, the optical fiber circuits can be vulnerable in the process of frequently mechanical pull and plug. Thus, besides physics isolation technology, the secondary security measures

of smart substation can mainly be realized by the logic isolation of GOOSE soft plates and maintenance mechanism.

However, the logic isolation measures based on GOOSE soft plates and maintenance mechanism of isolation measures are invisible and it requires highly reliability of secondary equipment. Moreover, the logic isolation measures were mainly realized by software which is error-prone, thus it can lead to mistake operations in the field [7, 8]. In addition, a lack of specific secondary security strategies for smart substation results in lots of problems in the process of operation and overhaul [9]. Therefore, it is essential to realize the visualization and normalization of smart substation secondary safety measures and it plays an important role in the reliable operation and large-scale construction of smart substations.

This paper firstly analyses the characteristics of secondary circuits and presents the current secondary safety isolation technologies for smart substation. Then a portable device is designed to realize the visualization of the device information, the control circuits and the safety circuits. Finally, safety isolation measures of the first set protection of 220 kV line space were put forward for the normalization of the secondary safety isolation measures in smart substation.

2. Secondary Safety Measures

2.1. Characteristics of Secondary Circuits

Compared with traditional substation, the complex secondary circuits were replaced by communication connections. The integration units, intelligent terminal and intelligent components in the process layer achieve all functions of the secondary circuits [7, 10]. The SV transmits sampling value of alternating current and the GOOSE network transmits the information of various switches. The structure of secondary circuits for smart substation was shown in Figure. 1.

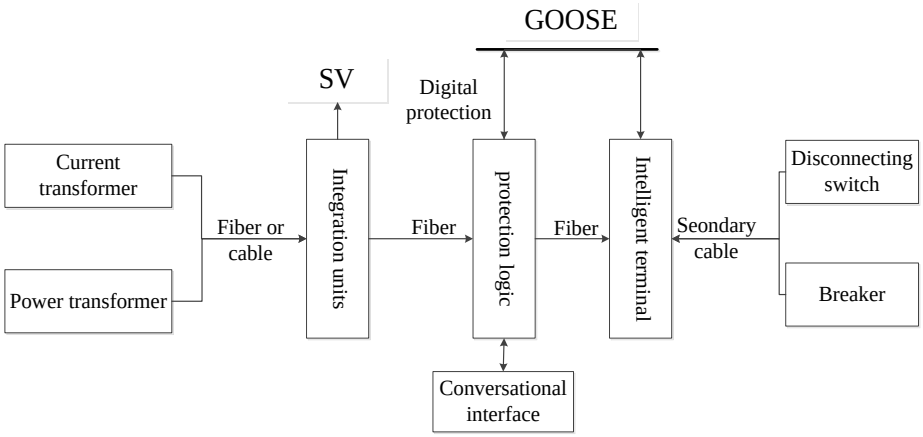

Figure 1. Structure of Intelligent substation secondary circuits

Since the point to point cable connections in the secondary circuits of conventional substations are replaced by optical fiber connections, which causes significant changes in secondary safety measures for smart substation[11,12]. Therefore, it is impossible to achieve effective hardware isolation in the security circuits. The secondary security measures of smart substation can mainly be realized by the logic isolation of GOOSE soft plates and maintenance mechanism. Figure.2 shows the specific safety measures for smart substations.

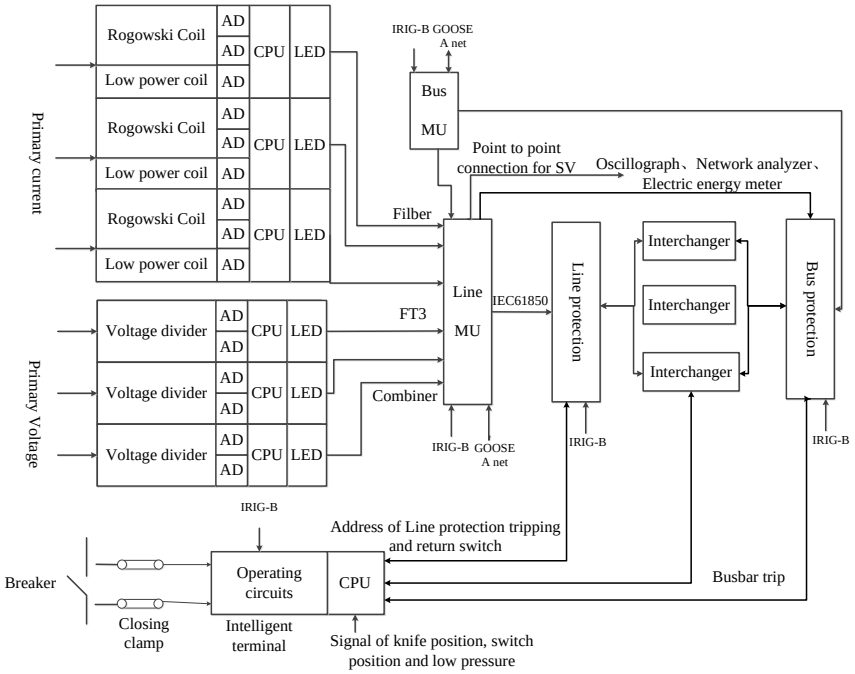

Figure 2. Security isolation measures of smart substation

3. Design of Handheld Device

To improve the work efficiency of repair personnel and improve the reliability of smart substation operation, this paper developed a handheld device to realize the visualization of the device information, the control circuits and the safety circuits, which can better meet the needs of secondary repair.

3.1. Software Design

Figure.3 shows the system structure of the visual tool. The specific work process can be shown as followings: First, import the SCD file into the system and implement the visualization of SCD file which can display the maintenance status of power equipment, the connect state of secondary virtual circuit and the flow of information between the secondary equipment. Then, the normalization of smart substation secondary safety measures can be used to confirm the implement status of relevant repair work. Finally, a variety of different situations security ticket template were formed to help repair personnel to complete the repair of smart substation. 61850 communication module mainly makes the communication with the maintenance device. Database module achieves the interactions of data with the database. Rights management module can avoid the possibility of wrong operation by grouping operation permissions.

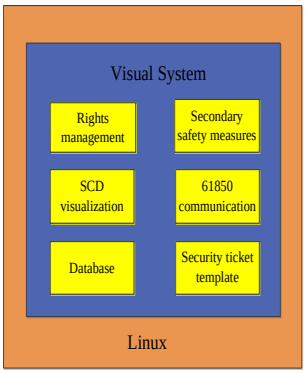

Figure 3. System structure of the visual tool

3.2. Hardware Design

The main parameters of the hardware device can be shown as followings: RJ45 interface, USB interface and touch screen. The RJ45 interface can communicate with the field maintenance equipment conveniently. The USB interface can be used to import and export the information of SCD files and database. The 10 inches touch screen can view the maintenance status of power equipment, the connect state of secondary virtual circuit and the flow of information between the secondary equipment. Figure.4 shows the physical diagram of the handheld device. The handheld device can connected with the relay protection devices automatically in the field which can improve the work efficiency of repair personnel and improve the reliability of smart substation operation.

Figure 4. Figure of Handheld devices

Figure.5 shows the overview of safety circuits of smart substation. Through integration of smart substation network packet analyzer, record information, and protection logic tree, monitoring information system information and so on, it can achieve the visualization of device information, control circuits and safety circuits of smart substation. Thus, the smart protection equipment and secondary circuit security would be simpler and more clearly, which can reduce the difficulties of operation and improve the reliability and safety of substation operation and maintenance.The text of your paper should be formatted as follows:

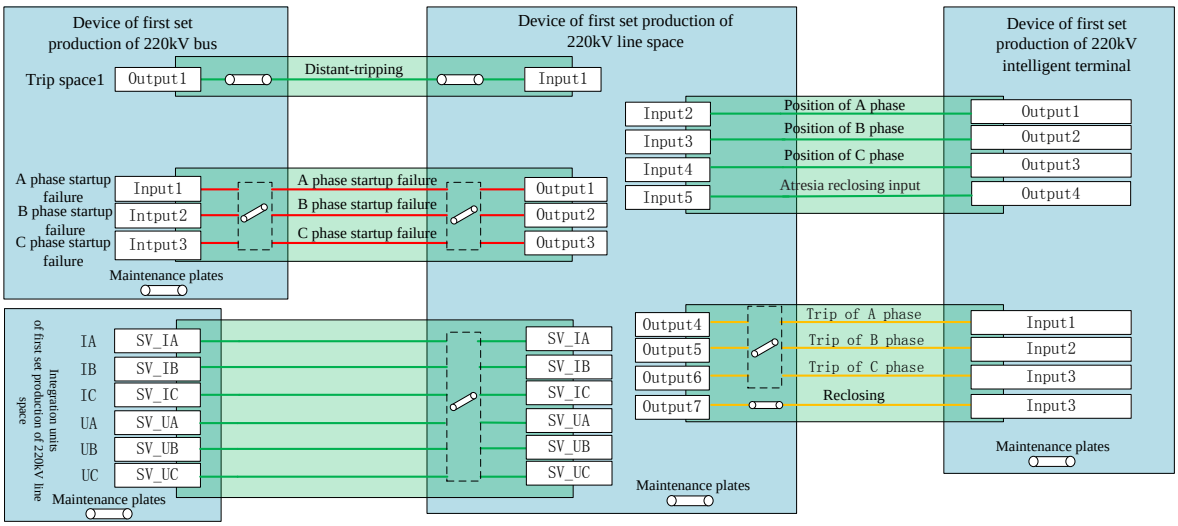

Figure 5. Visualization of safety circuit of intelligent substation

4. Secondary Safety Measures for 220 kV Smart Substation

In the first set protection of 220 kV line space, the typical configuration of SV sampling, GOOSE tripping mode and its network connections are shown in Figure 6. Meanwhile, the secondary security measures of smart substation were normalized and illustrated based on the first set protection of 220 kV line space.

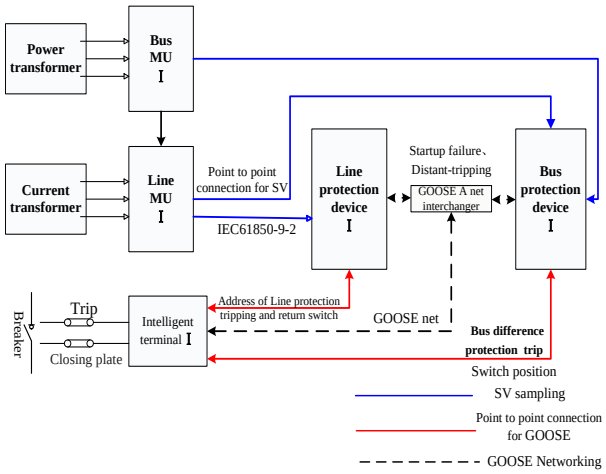

Figure 6. Figure of line space protection for 220 kV smart substation

4.1. Safety measures for outage maintenance of line space blackouts

Under the condition of a power failure of primary equipment, safety measures for the protection of 220 kV lines can be shown as followings:

a) Exit the receiving soft plates for SV and GOOSE of the first set bus protection of 220 kV line space, then input the forced divided voltage soft plates through isolating knife switches.

b) Exit the receiving soft plates for GOOSE of the first set line protection of 220 kV line space;

c) Input maintenance plates of the first set line protection, smart terminals and integration units.

Under the condition of a power failure of primary equipment, the safety measures for checking the failure circuits of the first set of 220 kV bus protection and line protection can be shown as followings:

a) Exit the soft plates for GOOSE and the failure soft plates of first set line protection of 220 kV line space, then input maintenance plates of bus protection;

b) Input maintenance plates of the first set line protection, smart terminals and integration units.

c) Shorted the secondary circuits of current transformer and made the secondary circuits of power transformer open, then separate current transformers and power transformers with the interface of integration unit.

4.2. Safety measures for charged maintenance of line space

Under the condition of charged maintenance of primary equipment, safety measures for the secondary equipment protection of 220 kV line space can be shown as followings:

When defects occurred in merging unit, it is necessary to stop the operation of related relay protection. Moreover, the primary equipment can also be out of service in some degree.

When defects occurred in line protection, safety measures can be shown as followings:

a) Exit the receiving soft plates for GOOSE of the first set bus protection of 220 kV line space;

b) Exit the failure soft plates of first set line protection of 220 kV line space, then input maintenance plate of line protection;

When defects occurred in smart terminals, safety measures can be shown as followings:

a) Exit the hard plate for smart terminals of the first set bus protection of 220 kV line space and input maintenance plate;

b) Exit the receiving soft plates for GOOSE of the first set line protection of 220 kV line space;

c) Input the forced divided voltage soft plate through isolating knife switches;

5. Conclusions

In this paper, a portable device is designed to realize the visualization of secondary safety circuits and the standardization of secondary security measures for smart substations. Therefore, the status of SV/GOOSE transmitting and receiving soft plates and hard plats of maintenance can be displayed directly. What is more, safety isolation measures of the first set protection of 220 kV line space were put forward for the normalization of the secondary safety isolation measures in smart substation.

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