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The Design And Implemantation Of The Anti-Misoperation And Safety System For The Secondary Equipment Of The Smart Substation

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Abstract

The paper proposed the automatic technologies such as one-key safety measure, and the examination of the safety measure ticket to solve the safety measure and misoperation problems of the secondary equipment in substation expansion, reconstruction and device maintenance. Firstly, after the analysis of the secondary equipment safety measure information steam and safety misoperation requirement, redesigned the workflow of the safety measure business and offers the misoperation system and contains four function module which include safety measure ticketing, setting misoperation, safety measure monitoring and safety measure execution. Then emphasis on the explanation of the technology roadmap, principle analysis and specification analysis of the key technology of the safety measure examination. Finally, through sampling to conduct an application and verification on safety measure misoperation system.

1 Introduction

The loop structure form of the intelligent substation has a significant difference compare with the traditional substation. The secondary circuit is currently form of the digital packet of IEC61850, the analog sampling use SV packet of IEC61850 9-2 and the protection trip, input/output information use the GOOSE packet of IEC61850 8-1. Accordingly, the secondary safety measures of the traditional substation will not be able to adapt the requirements of the site maintenance and effects elimination

There is already a large amount of researches in the area of secondary device safety operations, and also got a wide approval [1-9]. This essay will have proposed a research on the connection relationship between intelligent substation's secondary system virtual loop and also present a detailed safety measure and operation procedure. In [2] [12], in order to make the virtual loop during the safety operation more specific, a research on virtual loop visualization technology will be deployed and proposed a detailed implementation plan. In [5-8], a deeply research on secondary device online monitoring and operation technology will be discussed. The researches before will enhance the maneuverability during the intelligent secondary system operation and maintenance. However, these researches are limited in afterwards monitoring on secondary system safety measure operation and cannot provide protection on unusual operate during safety operation and maintenance.

In the operation tickets construction process of intelligent substation, because of there is no big differences compare with the traditional substation and the technology is relatively mature, errors will be hard to appear. For the situation include intelligent substation expansion, renovation and equipment maintenance, since the connection loop is achieved by network channel, secondary loop is not intuitive will cause the neglected of the connection. The safety quarantine measure will appear frequent leaks and further cause accident. Like the recent promoted power-off maintenance, if the safety quarantine measure is unappropriate, accidents will be caused [4].

In order to relief the burden of the operator and reduce the mistake, this essay also proposed a research on secondary anti-misoperation and safety measures based on the secondary device online monitoring system. Using the automatic technology to simplify the implementation and verification of the operation step of safety measures and also automatically verify the safety and reliability of the safety quarantine operation ticket of the secondary equipment. This safety measure ticket technology in this paper is already applied in practical project and also applied for a patent.

2 The information flow of the secondary device safety measures

The state grip usually uses three layer and two network architecture in the construction of intelligent substation integrated monitoring system based on the Integration construction standard. The secondary devices are divided into process layer device, bay layer device, and station monitoring and control layer device. The information flow network of integrated monitoring system is divided into process layer network and station monitoring and control layer network. The secondary device safety measures are dependent on the three layer and two network architecture and also typicality.

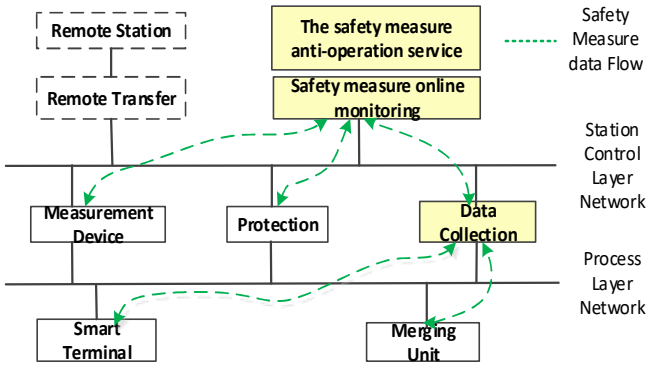

Fig. 1: Data flow chart

In figure 1, the process layer device cannot directly communicate to the station monitoring and control layer device, a data collection device need to be placed and using GOOSE transmission protocol to collect the monitoring information of the process layer devices. The bay layer protection, measurement control devices and the new added devices will transfer the detected information to the online-monitoring server or system through the station monitoring and control layer network. The green dotted line in the figure shows the direction of the detected information flow.

The safety measure detected information mainly include: the running state, strap state and the self-check information of the secondary device and the control information of the soft strap; The secondary loop state, key node and waring information of the process and station monitoring and control layer; The network port self-checking information of the station monitoring and control layer and data flow information.

From the analysis of the detected information and the data flow, the secondary safety measure anti-misoperation subsystem can be build based on the secondary device online monitoring system because the secondary device online monitoring system fully support the remote control and the data collection of the secondary safety measures.

3 The requirements of the secondary safety measure anti-misoperation

3.1 The analysis of the anti-misoperation safety measure elements

The main operation scene of the safety measure mainly includes: the expansion of the substation; the power-off and power-on maintenance; the maintenance of the secondary device. The safety measures of the secondary device mainly include the operation to the device and secondary loop of related device or the strap considering the special circumstance like the plug of the optical fiber.

The operable elements of the in-loop secondary safety measures mainly include: functional soft strap, GOOSE transmission strap, GOOSE receive strap, SV receive soft strap, maintenance hard strap; the optical fiber connection between the devices; for the smart terminal, there is also an export hard strap to ensure the existing of a breakable point between the electric loop of the smart terminal and circuit breaker.

In the element mentioned before, all the soft strap and maintenance strap can be collected by the secondary device online monitoring system and remote transfer to station monitoring and control layer. The export hard strap, optical fiber need to manually operated and also the online system cannot collect the operate state.

3.2 The requirement of the anti-misoperation safety measures

The selecting of the typical safety measure anti-misoperation and which reliable technology the measure should use need to be thoroughly studied. Mainly include:

1) The safety should provide safety quarantine to power-on and power-off secondary devices;

2) Safety measures need to ensure the verification and warning when maintenance and operation;

3) The safety measures need to ensure the “Three information” can get the correct safety anti-misoperation check (use three aspect include maintenance device, related device and monitoring system to check the safety measure information);

4) Use the automatic technology to achieve one key implement safety measure; one key safety measure implement server can replace manually operate and ensure the reliability of safety measure anti-misoperation, the inversion of the safety measure implementation and the traceable of the safety measure implementation error;

5) Use the visualization technology to monitor and display the operate state of the protection device and secondary loop (the state of hard and soft strap, AC circuit, tripping circuit, closing circuit and failure circuit) real-time.

4 The design proposal of the safety measure anti-misoperation

In order to satisfy the safety requirement, the operate procedure of the safety measure will be divided into 6 major steps despite the first and last step (shown in Figure 2). Firstly, the safety measure continually monitors the strap state in safety measure loop. In the normal running process, activate the warning immediately when the strap state changes. Also exit the related loop strap state monitoring before the safety measure operate. Secondly, based on the safety measure method to select the appropriate secondary safety measure operation ticket. Third step, the safety measure and related secondary device simulate the implantation of the safety measure ticket to ensure the correctness of the ticket. Fourth, in order to avoid the setting error and the modification error, read the strap state and save it. After that, implement the safety measure ticket one key and remote/local maintenance check the correctness according to the operation ticket in order to proceed maintenance.

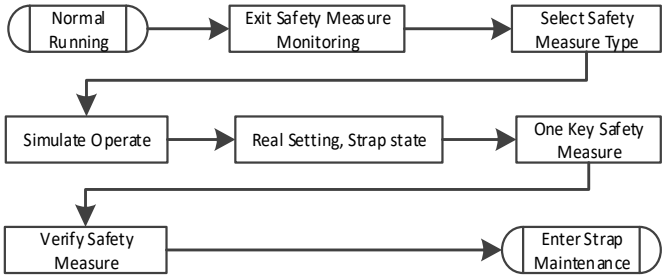

Fig. 2: Business process

According to the new business flow, the safety measure anti-misoperation should include four modular: safety measure ticketing, setting anti-misoperation, safety measure monitoring, and safety measure implementation.

4.1 Safety measure ticketing

The main function of safety measure ticketing is operation ticketing, the verification of operation ticket sequence and also functions like the save, statistic and search of the operation ticket. The operation ticketing mainly have three ways include manually filling, working ticket import and graphical ticketing. For the graphical ticketing, the monitoring interface of the visual secondary loop can be used to directly drag the strap of the secondary loop to the operation procedure list and then determine the target state of the strap. Moreover, the operate procedure can be adjusted based on the situation.

The most important function of the ticketing module is the operate ticket order correction. Before the save of the operate ticket, the module test the correctness of the new ticket based on the secondary safety measure operate sequence or the strap on/off rule of the safety measure operate.

4.2 Safety measure implemntation

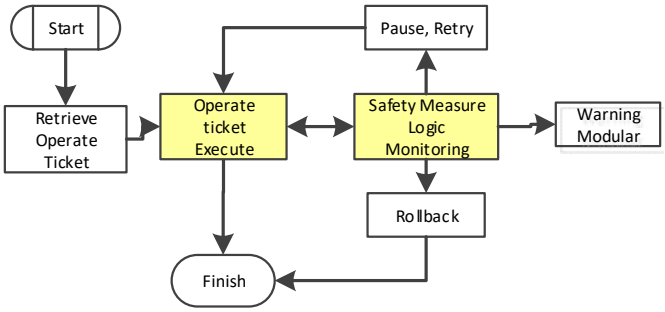

Fig. 3: Security measure process

The business flow of the safety measure implementation module is shown in Figure 3.The module can read the operate ticket, graphically display the ticket and using icon and text to mark the status of the operate ticket (unexecuted, executing, executed, pause and failed etc.). During the execution of the single step operate ticket, use highlight or color to mark the current operate item; in the interval of the operation, allow the executor to pause the execution; if the execution item fails, allow the executor to be able to choose to retry or pause the execution; after the safety measure, the device can be marked as maintenance. The modular can be able to execute one group of ticket to different device instead of execute multiple group of tickets simultaneously.

The modular also need to support the function include operation ticket preview and logging: proceed preview to one key safety measure, if the preview dose not obey the rules, then provide the warning information; for the individual step of the safety measures, be able to record the key step and the interaction inside of the modular in order to easily trace the error during safety measure execution.

4.3 Safety measure logic monitoring

The logic monitoring modular mainly has the following functions: monitoring the correctness of all secondary virtual loop strap on/off sequence, the monitoring of already on/off strap radically change. After the operate execution of the operate ticket, the loop strap should stay stable. As long as the modular noticed the change of the strap, send the strap change warning immediately; Meanwhile, if the warning emerged, the modular should give the waning reason dialog based on the logic of the operate ticket; The warning information should submit to warning client and secondary loop visual modular.

The interaction between the monitoring modular and secondary loop visual modular will make the under monitoring secondary loop in the center of the monitoring interface. The loop module construction of secondary loop visual modular will be detailed discussed in the follow section.

4.4 Setting anti-misoperation

The setting anti-misoperation modular mainly achieve the strap and setting comparison of the before and after related devices to avoid human error. Read the before maintenance strap and setting before operate and backup on the reliable storage in disk; after maintenance and before operation, proceed visual verification, if there is error exists, the visual verification should provide the change location and warning the warning client.

One key safety measure means after the “one key” operation, the system automatically execute the predetermined safety operate ticket to make the target device and related device can automatically exit running status and enter maintenance secure and reliable. The four modular of safety measure anti-operation support each other to make sure the safety measure ticket execute by “one key”.

5 Key technology

In the function development of these four modular, the automatic ticketing and the correction of the operate ticket is system difficulties. The secondary loop and device visual monitoring and graphical ticketing all need the support of the secondary loop visual technology which is the key of the system.

5.1 The safety measure verification plan

The SCD file of the traditional intelligent substation include the following information: 1. the electric topology and primary device module of substation; 2. Functional view; 3. the function description of IED; 4. Communication view and Communication configuration information; 5. Product view; 6. Data flow. In [9][11], the information includes the primary equipment information, secondary equipment information, communication and strap information will be added into SCD for modeling, it successfully used in the running and maintenance support of the secondary loop of intelligent substation.

According to the new SCD module to construct the connection between the primary and secondary equipment and the connection module between the virtual loops of secondary equipment. For the primary equipment that need the power off, automatically obtain the related secondary equipment based on the connection module.

For the secondary device that need maintenance, the related secondary device should be discovered through the secondary virtual loop. According to the safety measure rules of secondary device in power off or power on situation to analysis the safety measure operation that could make the under maintenance secondary reliable isolation and generate safety measure operate ticket automatically.

For the operate ticket that generated by the graphical ticketing, or the imported operation ticket. The safety measure rules can be used to analysis the necessary safety measure step and then examine the existence of the step or operate sequence to finally testify the correctness of the ticket.

There is also few hardware operate in operate ticket. (Disconnect the vertical fiber or export hard strap). Those ticket that include hardware operate also hard to verify and also cannot automatically ticketing. Therefore, manually analysis and improvement are required frequently.

5.2 The verification of analysis rules

Based on the requirements in chapter 2, the main rules of the safety measure analysis are as follows:

Rule 1. The site operation includes device verification and defect elimination, the connection with the operating equipment in sampling, tripping, closing and start failure circuit to ensure the normal operating of the operating equipment.

Rule 2. When single set of equipment are proceeding verification and defect elimination, the primary equipment should stop. For the dual configuration secondary equipment, the primary equipment will keep in service only when single set of equipment is checking or eliminating. However, the primary device running without protection still need to be prevented.

Rule 3. For the optical fiber that has soft strap in send and receive side, possibly do not disconnect the optical fiber, make sure the soft strap is open before disconnect the optical fiber.

Rule 4. Introduce the dual safety isolation measures for the virtual loop safety isolation. Firstly, consider the send strap of the under maintenance device and then the receive strap of the related sunning device. The maintenance strap the under maintenance device also need to be take into consideration.

Based on the safety measure rules, procced the analysis in the following four steps:

Step 1. Stop the related secondary device or close the maintenance strap when stop the primary device (The related device normally indicate the primary and secondary device in same bay).

Step 2. The to be maintained secondary device should stop running or close the maintenance strap when the primary device is not stop;

Step 3. The safety measure rules of the goose loop for the under maintenance device: Close the maintainence strap of to be maintained device and open the related goose export strap of to be maintained device. Open the goose receive strap of the related to be maintained operating devices. Before stop the primary device, stop the secondary device based on step 1, the goose strap between the stopped secondary devices can keep operating.

Step 4. The safety measure rules of the maintenance device that has the SV send loop: When stop the primary device, despite stop the secondary device based on step 1, also need to open the SV receive strap of the operating protection device that is related to the specific secondary device. For the protection devices that need to stop receive SV when the primary device is stopped, the SV receive strap of the protection device can keep closing.

5.3 The standardization of safety measure verification

In order to provide convenience to the contrast check between the automatically analyzed operate ticket and manually generated operate ticket, based on the safety requirement and operate habit, three types of measures will be proposed to normalized the operate ticket.

Step 1, for the operate ticket, use the simplified operate ticket template in Table 1 to support automatically ticketing and provide standard format to the import of the operate ticket. In the table, if the primary device need to power-off, the safe exit secondary device can be determined based on the connection between the; If the primary device need to keep power on status, determine the other secondary device that need to isolate safety based on the maintenance secondary device. In the third row, the change of the value indicated the status value change of the operate ticket. The device type often explains the type of the related elements. The virtual loop APPID is the mark of the secondary virtual loop, the APPID in the table shows the loop which the strap belongs to.

Primary power off device	XX Line			
Maintenance Secondary Device	Line protection device, Smart Terminal			
No.	**Safety Measure Content**	**Value Change**	**Device Type**	**Virtual Loop AppID**
Line protection device				
1	Close XX Maintenance Strap	0->1	Soft Strap	XX Loop
2	Open XX SV Strap	1->0	Soft Strap	XX Loop

Table 1: The example safety sheets of XX station

Step 2, grouping the operation elements according to the belonging device. Normally according to the order include major protection, circuit breaker protection, control cabinet (merging unit and smart terminal), and related device. The table only shows the line protection device.

Step 3, after grouping the operation elements according to the belonging device, in each group, based on the safety requirement to each operate task to order the operate elements. For instance, for the same device, the elements operate in accordance with order: export hard strap, maintenance hard strap, SV strap and goose strap. For the operate elements of the related device, can also use the order of the device group and then the order of the specific device.

6 Safety measure application

6.1 The discussion of the typical safety measure

In the actual application, because of the improper device maintenance isolation measure, the accident happened from time to time [4]. Against [4] the line bay configuration circumstance in this paper, if the safety measure anti-misoperation system can be used to generate ticket, the all station power off failure can be eliminated because of the closing maintenance strap of the merging unit.

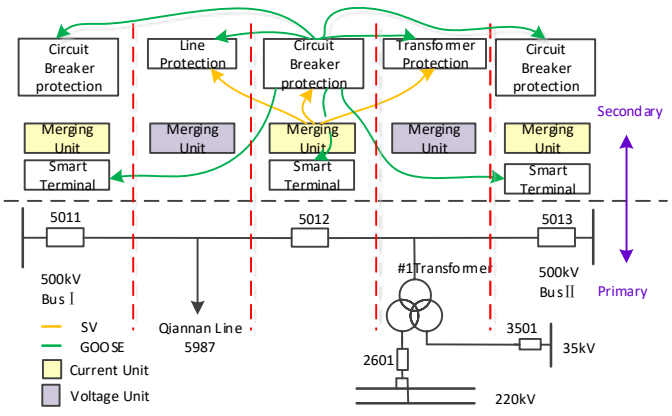

Fig. 4: Virtual loops for the 5012 circuit breaker protection

Figure 4 shows the connection relationship between primary and secondary device of a 500kV line transformer diameter in some certain province. Inside of the figure, above the dotted line are the secondary device, blow is the primary device. The secondary devices that related to the primary device are divided by red dotted line. The merging unit has two kinds which include current and voltage. The orange curve indicates the SV virtual loop and the green curve indicates the goose virtual loop.

For the situation that mentioned in [4], only 5012 circuit breaker power off maintenance will be discussed here. The analysis step and results which based on the safety measure rules in chapter 4.2 is: Based on step 1, the related secondary devices include: circuit breaker protection, merging unit, smart terminal need to close the maintenance strap. Based on step 2, the seven export goose virtual loop send and receive soft strap need to open, the virtual loop strap that related to the smart terminal can stay closing according step 3. The merging unit has three SV virtual loop, the SV receive of the related receiving soft strap need to open. However, the SV virtual strap which related to circuit breaker can keep closing based on step 4 of section 5.3. The export hard strap of the smart terminal tripping loop need to open.

6.2 Automic verification

In the self-developed secondary safety anti-disoperation system, the safety anti-operation analysis and safety measure automatic execution can be implemented to line bay, bus line bay and transformer bay and some certain equipment. For the typical problem in 5.1, using the graphical ticketing to finalize the operation ticketing and then save. In the safety measure ticket management window shown in figure 5, selected the new saved operate ticket on the top left window and the all steps of the operate ticket will be displayed on the center right window in the template of Table 1. Clicked the safety verification button on the down left, the system will proceed safety verification to all the operate ticket. As an example, intentionally forget the smart terminal soft strap operation of the virtual loop between the circuit breaker protection and 5013 smart terminals. After the automatically verify of the ticket, the left option will be highlight in red on the bottom of the safety measure ticket display window.

The bottom left list combination window can be used to manually add optional operation to finalize the operate ticket, and also be able to add some examination or suggestion on some certain circumstance.

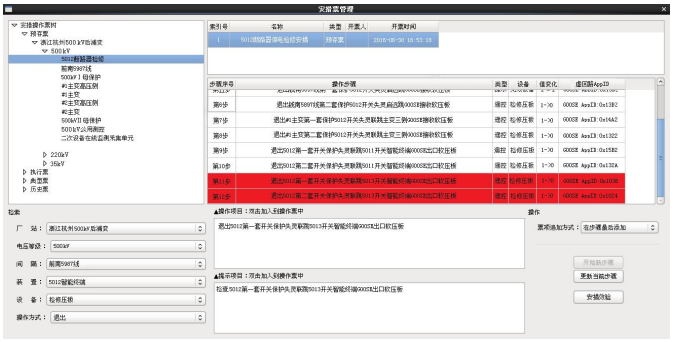

Fig. 5: Security measure management

6 Conclusion

As a conclusion, this paper analyzed the requirements of the secondary safety measure anti-disoperation subsystem. After the detailed research on secondary safety measure operation business flow, the anti-misoperation subsystem modular will be designed. After that, the deeply discuss on the key automatic ticketing design concept and safety analysis rules will be presented. Also the automatic ticketing steps will be demonstrated combine the typical failure example, and finally shows the actual safety measure ticket management window.

In the practical application of the safety anti-misoperation subsystem, automatic ticketing and verification function can ensure the safety isolation of the required devices which can be able to relief the safety anxious of the operation stuff. The one key safety measure function can also improve the work efficiency. In this paper, the promoted safety measure automatic technology is worth to deeply research and promotion.

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