

Design and Application of Electronic Analog Relay Protection Device with Load Check

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Abstract. This paper designs an electronic substation simulation relay protection device with load check. At the same time, the device is studied and applied in the new substation. First of all, this paper analyzes the primary wiring mode and three-phase symmetrical current and voltage in the primary side of a typical substation, and confirms the transformer ratio, polarity and wiring mode of the current/voltage transformer. Then, by checking the polarity of line protection, metering, bus protection, main variable differential protection and backup protection, the polarity error of metering circuit with load check protection and metering circuit is effectively avoided. Finally, through the field test verification in the new 220kV Fuxing station of Jinzhou power supply company, it is verified that the technology adopted in this paper can fully meet the requirements of substation simulation load test. The relay-protection device with load check designed in this paper solves the problem that the conventional electric-type single-phase large-current generator can only detect the transformer ratio and polarity of the relative single-phase loop current transformer, and the difference loop cannot be detected. It shortened the switching operation time of changing ratio, polarity and phase check of the primary and secondary circuits after passing the load of the substation transmission belt.

1. Introduction

After the installation of the first and second equipment in the newly built substation, vector inspection with load is a very important item in the technical work of relay protection. Vector error will cause the relay protection in normal operation or fault state to misoperate or refuse to operate, so the correctness of vector must be guaranteed before the relay protection is put into operation[1].

At present, the electrical interval in the substation in our country in the practical application process, usually rely on the terminal box secondary circuit source flow, check secondary line and other methods to determine the ac current secondary circuit wiring. However, these methods are difficult to effectively simulate a single load[2]. In this case, the interval is not sufficient to ensure the overall normal operation of the power system before power transmission. In general, when calculating the secondary circuit of the interval bus voltage, the bus brake contact in the analog circuit can be closed. The correctness of voltage switching loop is verified by using the method of verification, and effective line protection support is provided. In the secondary circuit of the interval current transformer, it is difficult to realize the effective simulation of the actual running state, so it cannot be carried out smoothly in the application process[3]. In the conventional power transmission process, a certain bus space should be reserved, and the phasor of current should be tested under the condition of load by charging the bus and intervals.

We have learned, Hebei electric power co., Ltd takes the lead in developing a set of vector check test system. The system adopts the principle of voltage regulator and booster transformer to generate high



voltage and large current, and to pass current and pressure from the primary side of the transformer. The system includes a test power supply and a simulated load[4]. The power supply of the test system comes from the station transformer. The output point is connected to the primary side of the current and voltage transformer, and the transformer transformer and the complete secondary circuit are connected to the relay protection device, which is used as the electric quantity for vector inspection, so as to confirm the correctness of the relay protection vector before the substation is put into operation. But the system has the following problems: 1. The vector check simulation system is actually a three-phase high-power high-voltage source. The current output is affected by the form of load size. Analog load and compensation capacitors are required. Compensation capacitor is used to adjust current output, which is complicated in calculation and operation. 2. Applying the principle of voltage regulator and booster, the voltage output accuracy is poor; 3. The system has a large output capacity of 100 kVA, while the construction power capacity of the general substation is less than 200kVA, which limits its application[5].

Therefore, the goal of this paper is to design an electronic analog relay protection device with load check, and study the application technology of the relay protection device with load check. A miniaturized analog relay protection test device with load check is developed and has a modular structure. The device can be used flexibly according to the test type, and equipped with high-precision wireless phase voltammetry test device. In this paper, the combination unit of intelligent substation and the secondary connection detection of transformer transformer in conventional substation are realized, which has the characteristics of intelligence and easy operation. Therefore, the goal of this paper is to design an electronic analog relay protection device with load check, and study the application technology of the relay protection device with load check. A miniaturized analog relay protection test device with load check is developed and has a modular structure. The device can be used flexibly according to the test type, and equipped with high-precision wireless phase voltammetry test device. In this paper, the combination unit of intelligent substation and the secondary connection detection of transformer transformer in conventional substation are realized, which has the characteristics of intelligence and easy operation. This device can not only meet the requirements of conventional substation, but also meet the test requirements of intelligent substation. It has the functions of test bus protection, line protection, and test differential of main transformer[6].

2. Substation primary system model

2.1. Three communication flow model establishment

The connection mode of single bus is shown in figure 1. Interval I and II circuit breaker is closed, and then close the bus isolating switch and interval II line disconnecting switch. Load was simulated from interval I inflows, by bus from interval II outflow. This method can check interval I, at the same time interval II two interval TA circuits.

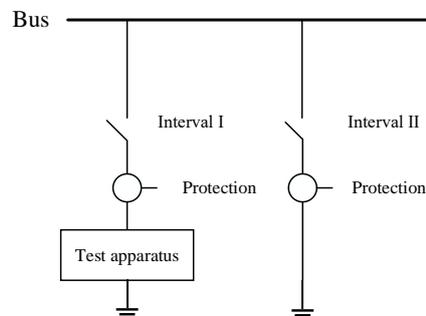


Figure 1. Single busbar connection of a flow

The connection mode of double bus is shown in figure 2. And interval I II busbar liaison between interval of circuit breaker is closed, or on the bus isolating switch and interval II earthing isolator circuit isolating switch breaker side. Load was simulated from interval I is mother inflows, through its wirings

II outflow from vice mother intervals. This method can test at the same time interval II I, interval and busbar contact three intervals of TA circuit[7].

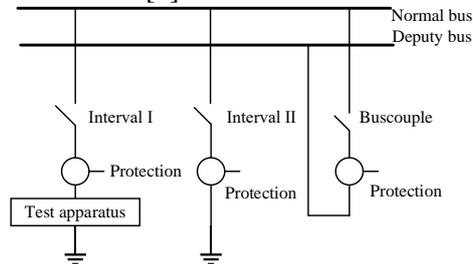


Figure 2. Schematic diagram of primary current connection of double bus connection

The wiring of double bus and double section primary current loop is shown in figure 3. Interval I, interval II, mother is segmented, deputy busbar section contact # 2 bus interval on the circuit breaker is closed. The bus isolating switch and interval II circuit isolating switch breaker side grounding isolating switch is closed. Load was simulated from interval I is mother I period of inflows, by mother is segmented into is mother II section, then through # 2 bus coupler into female vice II section, through vice mother mother segmented from vice II outflow I long intervals. This method can check interval I, at the same time interval II vice mother, mother is segmented, segmentation and # 2 bus coupler five interval of TA circuits[8].

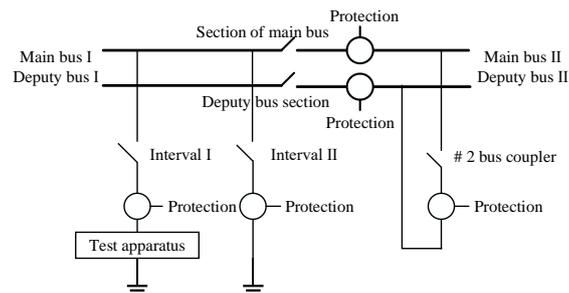


Figure 3. Schematic diagram of double bus and double section connection

Single bus section connection mode of a passage as shown in figure 4. Interval I, interval II and piecewise interval circuit breaker is closed. The bus isolating switch and interval II circuit isolating switch breaker side grounding isolating switch is closed. Load was simulated from bus I period of inflows, are by bus section from bus II outflow. This method can check interval I, at the same time interval II and three intervals are bus section of TA circuits[9].

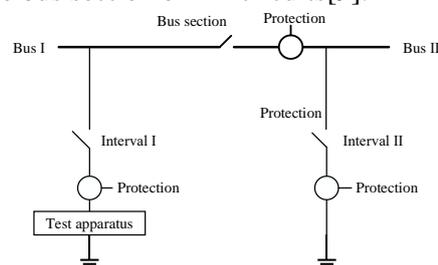


Figure 4. Schematic diagram of single-bus section connection with primary current connection

The connection of primary current is shown in figure 5. Circuit breaker switches are closed. The corresponding isolating switch and outlet II 5022 side of circuit breaker in the earthing isolator has been closed. Load was simulated from qualification I into and II outflow. This method can simultaneously check the TA circuit of 5011, 5021 and 5022 circuit breakers. Circuit breaker switch is closed. The corresponding isolating switch and outlet II 5023 circuit breaker side grounding isolating switch is closed. This method can simultaneously check the TA circuit of 5012, 5013 and 5023 circuit breakers.

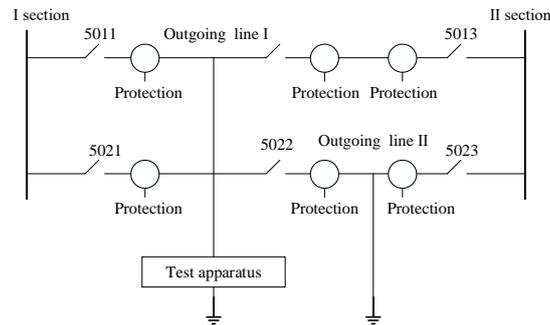


Figure 5. Two-thirds connection mode of a passage wiring diagram

The single-interval one-pass current connection is shown in figure 6. For expansion works, especially single interval expansion works, current is passed in between TA and circuit breaker. The circuit breaker side earth isolator is closed. The TA loop of the relevant interval is checked. Disconnect the appropriate interval circuit breaker, TA is directly carried out flow test. For the bus protection current loop, it is necessary to prevent the current from entering the bus differential current loop. When the bus protection is in operation, the secondary current loop is shorted out at the high-current test terminal, and the secondary current only reaches TA side of the high-current test terminal[10].

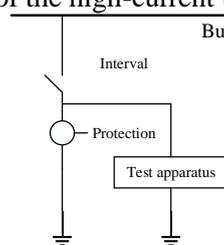


Figure 6. Schematic diagram of single-interval single-pass connection

The transformer interval TA is connected to check the polarity and ratio correctness of the bus circuit. Because the primary current of the used transformer is often very small when it is put into operation, it is difficult to carry out the test of TA access bus circuit polarity and variable ratio with load. Before putting into production, three interlinked current devices can be used to carry out primary current and secondary pressure simulation with load test instead of putting into production with load test, so as to ensure the polarity and variable ratio accuracy of TA access to the mother circuit. The schematic diagram of primary wiring of the current loop is shown in figure 7.

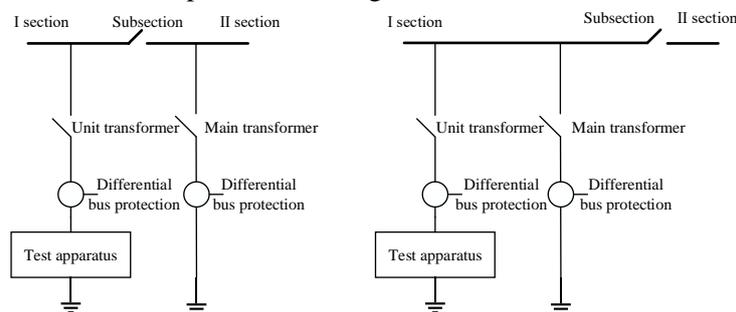


Figure 7. Primary wiring diagram of current loop

It can be proved by the above model that if the differential protection differential current is zero, the secondary current test size of two cells is converted to equal to the current added once and the direction is opposite. In this way, as long as the correct polarity and variation ratio of TA is confirmed by the reference unit after it is officially put into production, the correct polarity and variation ratio of TA can be completely confirmed.

2.2. Establishment of three-phase full station on - voltage model

By using the transformer voltage transformation function, simulate the three sides of the main transformer to be live, and check the wiring of the primary and secondary circuit of the voltage transformer in the whole station. After the correct PT secondary circuit is checked, 50Hz frequency conversion power supply is added to the low-voltage side of the main transformer, and the voltage is induced through the transformer on the medium-voltage side and high-voltage side. The voltage of each PT secondary circuit was measured at the same time to simulate the electrification of the bus on three sides. Since the measurement of line PT secondary voltage requires the main cutter on the outgoing side to be in the coordination position, it is possible to close each line switch and the main cutter on the outgoing side to measure the secondary voltage of line PT under the condition of ensuring safety. And with the bus secondary voltage nuclear phase, check line PT wiring.

3. Research on substation test method

According to DL/T995-2006 test regulation of automatic device for relay protection and power grid safety, the conditions that the transformer substation should have are determined. Including the use of equipment technical requirements, the overall test process, voltage loop testing machine related requirements, current loop testing and related requirements, the whole test process control, test data inspection and other content.

The main research contents are as follows:

- 1. Common system wiring mode of the primary through-current wiring;
- 2. The transformer interval TA is used to check the polarity and ratio correctness of the bus circuit;
- 3. Differential protection hexagon vector graph is drawn by simulating load test with short circuit impedance of compressor;

3.1. Unit module composition

The complete set of electronic tri-intercurrent simulation device with load polarity check detection consists of high-power electronic three-phase double-circuit output power, three-phase high-current conversion output device, three-phase voltage conversion output device, high-precision wireless phase volt ampere tester, wireless forkhead current clamp, etc. This device can realize the protection system wiring detection function of three intercurrent, pressurization and simulated load in substation.

The developed equipment has the same effect as the existing electric-type current riser. In addition, its biggest advantage is that it solves the vulnerable problem of contact voltage regulator by means of high-frequency switch operation, and has the electronic drive switch itself with thermal protection function. Therefore, the equipment can output large current for a long time, which meets the requirements of CT verification on the spot, and the whole equipment has realized miniaturization.

3.2. Function module description

3.2.1. Electronic three-phase power supply. Electronic frequency conversion power supply with two - way three - phase output. Three phase symmetrical voltage is output by three phase large current conversion device. Multiple groups of three-phase CT can be checked simultaneously by variable ratio and polarity at one time. The three-phase high voltage PT boost on the bus can be used to simulate the status of substation with load.

For transformers 220kV and below, the transformer's differential protection hexagon vector diagram can be directly tested through the transformer's high voltage side and medium voltage side (or low voltage side) by using the transformer's short-circuit impedance. Select the pressurized side and the short-circuit side according to the transformer impedance. The short-circuit mode in the simulated load test of substation is shown in Table 1, and the electronic three-phase power supply is shown in Figure 8.

Table 1. Short circuit mode in simulated load test of substation.

Pressure side		Short circuit way	
High voltage side	medium short circuit	low short circuit	neutral-low short circuit
Medium voltage side	high short circuit	low short circuit	high and low short circuit
Low voltage side	high short circuit	medium short circuit	high and medium short circuit



Figure 8. Electronic three-phase power supply diagram

3.2.2. *Three-phase large current conversion output device.* By closing the earthing switch on the side of the bus, the three phase large current conversion device can be used directly to carry out three intercurrent tests on the bus and the circuit interval of the substation. It can detect the ratio, polarity and phase of switch CT secondary circuit.



Figure 9. Three-phase high current switching device

3.2.3. *Three-phase voltage converter.* By applying phase-shifting three-phase voltage to the primary side of high voltage PT, the correctness of voltage loop wiring is detected according to the voltage, current and phase of the display screen of the protection screen.



Figure 10. Diagram of three-phase voltage converter

3.2.4. *High precision wireless phase voltage tester.* In the use of a complete set of equipment for three interflow, pressurization test, you can check the application of the three phase sequence is correct. Adjusting the power output to carry out flow passage and pressure according to the developed field test scheme can meet the convenience of the second test of the traditional substation and the demand of the second simulation quantity distribution measurement of the intelligent substation. The single phase

voltage is selected as the reference by the wireless phase voltage tester, and the polarity, ratio and phase of all test points are checked.



Figure 11. High precision wireless phase voltammetry diagram

4. Experimental verification

4.1. Test instructions

This set of device was tested on site in the 220kV Fuxing switch station newly built by Jinzhou power supply company on November 15, 2018 to test the test ability and effect in the actual site. This set of device is used to pass the high current at each 220kV interval and increase the voltage on the voltage transformer in turn, check the protection phase on the protection device, detect the correctness of line protection, bus protection ac voltage and ac circuit, and verify whether the test method designed in this paper is feasible.

4.2. One three-phase pressurization test

The test voltage is three-phase symmetrical, and the amplitude can be taken as 10% of the rated operating voltage, or less, as long as the measurement accuracy requirements are met. During live operation of the simulation system, the secondary voltage loop inspection can be carried out, including protection voltage loop in the local terminal box, voltage metering loop, open triangular voltage loop and all branch ends of voltage loop.

Test items include: parallel relations of voltage transformers of each voltage level, especially double bus, voltage phase sequence and amplitude inspection, including terminal transformer wiring group. By simulating the actual operation, the correctness of connection of PT and its secondary circuit can be guaranteed, and the problems of short circuit and grounding of PT secondary circuit can be prevented effectively.

4.3. Secondary three flow test

A special test device is used to carry out the primary triple current test. The current amplitude should be greater than 10mA for the secondary current. During the operation of the simulation system with load, a high-precision phase meter is used to check the polarity, ratio, phase and phase sequence of all current secondary circuits at the current passage interval. By simulating the actual operation mode, the correctness of the connection of CT and its secondary circuit can be guaranteed, and the problem of open CT secondary circuit can be effectively prevented when the CT is put into operation. Cooperate with the visual measurement of the primary equipment phase in the substation to prevent the equipment phase of the new station from not corresponding to the system, so as to realize the optimized start-up mode.

4.4. The experimental conclusion

The design and application of the electronic analog relay protection device with load check in 220kV substation shows that the three-phase current conversion device can directly apply the secondary pressure to the bus current and three-phase voltage conversion device to meet the basic test requirements. Even at 4000/1, the secondary current transformer can reach 50mA, which can accurately measure the transformer ratio, polarity and phase.

5. conclusion

This paper presents the design and application technology of simulation relay protection device with load check, and develops a test device for simulation relay protection with load check with three interflow pressurization. The device adopts modular structure and can be used flexibly according to test type. At the same time, it is equipped with high-precision wireless phase voltammetry device, which can realize the ratio, polarity and phase detection of the secondary wiring of transformer in the combination unit of intelligent substation and conventional substation. The device is intelligent and easy to operate, which can meet the test requirements of both conventional substation and intelligent substation. The field application shows that the research content of this paper can greatly shorten the commissioning time of the transformer substation, and it has a good promotion prospect and economic value.

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