

# Analysis of a Verifying Method of Consistency Between CT/ PT Polarity and Directional Protective Relaying

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**Abstract:** The coordination correctness of Nuclear power plant current transformer (CT) / voltage transformer (PT) polarity and relay protection is often verified through the dynamic test on the unit no load / load operating conditions. This paper proposes a test method to prevent and circumvent the failure of the dynamic test abnormality caused by the static power test before the plant power is applied and the whole group is started. Reduce the dynamic test workload and test difficulty, to ensure that the dynamic test safety risk control and control in the state.

**Keywords:** CT / PT loop; Polarity / direction; static / dynamic test; Relay protection

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## 1. Introduction

Nuclear power plant's power transmission and the outside plant spare power supply use 550kV and 220kV access to the power grid. When the system is powered, the relay protection direction of the flow transformer, the voltage transformer (CT / PT) polarity is required to inform at first, and then the grid is allowed to put into normal continuous operation. As the nuclear power plant with a considerable length of time after the test load is very small to reach the instrument measurement and protection device display accuracy, therefore, often the method is taken only to organize the load in the factory to meet the test requirements of the following conditions:

- 1) Since the transmission line is capacitive reactive load, about 10 MVA or so, the construction power load is perceptual active load, the site construction power load must reach 30 ~ 40MVA, offset the line capacitive load, in order to meet the test measurement accuracy;
- 2) The factory 10.5kV bus temporarily increases the reactive load of the capacitor, about the total capacity of 10 ~ 20MVA, then the factory and line capacitive load superimposed in order to meet the test measurement accuracy;
- 3) The grid to organize the grid load, respectively, combines two transmission line load circuitous through the power plant side 220 kV / 550 kV bus, but can only help taking the substation and line system test.

Due to the limited construction power load, transmission lines do not have the conditions and other many unfavorable factors, the implementation of the program may be subject to greater restrictions.

In view of the above factors are objective and difficult to solve the premise, the advance negotiations with the

power companies is needed before taking power, to imply the use of electrical system static power test simulation with load dynamic operating conditions to verify the correctness of the relay protection polarity; With the no-load rated voltage operating conditions, put into protection after the completion of all the no-load test, the power system that is put into normal continuous operation; While follow-up plant test load reach a certain number, do the actual load conditions pharos protection test.

The project implements the standard for the GB/ T14285-2006 "relay protection and grid safety automatic device technical regulations."

## 2. CT Static Flow Test

Static current flow is the test in the CT secondary circuit to apply the test current, the analog protection device flows through the normal load current and fault current ,measure the current value and phase of the inflow protection device, and to observe and determine whether the action is correct.

Test equipment: 2000 A riser, 5kVA line lamp transformer, double clamp digital phase table, caliper ammeter a battery, digital and pointer multicenter, insulation shake table, microcomputer relay protection calibrator, etc.

Using the above test equipment, the specific test method is as follows:

- 1) With a battery and a pointer multicenter CT to do a secondary circuit polarity test to check the CT secondary circuit leads to polarity and protection direction with the polarity is correct, if necessary, the polarity test can be extended to the protection cabinet terminal;
- 2) For the bus and the line, rise directly on first device circuit, input a larger single-phase test current using riser equipment;

3) For the existence of the transformer wiring system, low side busbar short circuit. High-side access to three-phase 380V AC power supply, use "transformer short-circuit impedance current limit" approach into the smaller three-phase test current;

4) For the protection of current / impedance / power direction, there also need to apply the test voltage, in accordance with the "CT / PT static flow / pressure with the test" method, but should check the directional protect current loop in the CT flow test single test.

### 2.1 220 kV / 550 kV Bus Differential Protection

1) On both sides new substation case, there is no operation equipment power outage isolation, the test is relatively simple:

(1) Line Auxiliary Transformer / Main Transformer as the inlet and outlet interval, the mother as the I / II , III / IV , V / VI bus differential protection fault current direction selection interval, as I / III , II / IV , III / V , IV / VI bus line between the differential current direction selection interval;

(2) Fix an inlet and outlet interval, select another interval in and out line as a single-phase current application point, the current phase display value measured by the mother protection cabinet should be correct;

(3) Simulate the external fault of the busbar one by one, neither the big differential nor the two small differentials of the bus bar move;

(4) One by one interval mimicking busbar I / II main area fault, bus bar differential does not move, two small differential move according to the main bus current direction, which I / II small difference moves, II / I small difference does not move;

(5) The coordinate bus isolation knife connects to the I / II bus, while the two small differential should be connected to I / II bus circuit breaker.

2) For both sides operation power plant substation, the new expansion of the inlet and outlet interval needs to run equipment, power outages, so the test is relatively troublesome:

(1) Flow test should stop at least one running line, short-term suspension of bus differential protection, with good security isolation measures;

(2) Due to the operation of the interval access the bus differential protection, the polarity direction has been tested with load, there need only to choose a running interval CT wiring as a reference, the new expansion interval and the operating interval CT do the same direction current application, and the test value of the current phase in the bus differential of the interval be the same;

(3) For the new expansion of the power grid to the power plant line spacing, the latter part of the expansion of power plant side applies auxiliary transformers, main trans-

former, bus segment interval, the early and late interface equipment are proposed to imply installation and debugging at the same time.

### 2.2 Transmission Line Protection

220 kV / 550 kV lines commonly use optical fiber differential protection and optical fiber locking distance protection. Unlike high-frequency channels, Fiber Channel cannot use the oscilloscope to monitor the bilateral current phase, thereby adjusting the bi-applied current phase to protect the tone. If without the swap of the opposite side direction of line protection, there will be line fault protection of refuse to move, resulting in auxiliary transformer / main transformer impact test or factory auxiliary machine fault-start problem.

#### 2.2.1 Optical fiber differential protection:

1) Firstly one side of the line ABC three-phase grounds, and the other side of the corresponding grounding test line insulate, then taking tests of bilateral counterparts on the corresponding phase;

2) With a battery and pointer multicenter, bilateral CT side of the bus side for the polarity of the polarity of the terminal, CT secondary polarity and bus side should be the same polarity, and access protection device polarity side;

3) Bilateral select one phase that is not grounded, the other two short-circuit ground, one side take the application of 12 v AC voltage with the street lamp transformer secondary lateral line non-ground relatively, as a bilateral CT first rise test common reference phase voltage;

4) One side of the series converter phase shifter, according to the reference phase voltage to adjust the bilateral current phase, because the phase shifter capacity is small, the current up shift size should at least meet the instrument and protection device measurement accuracy requirements;

5) Bilateral current apply both from the bus side of the isolation switch knife, and come out of the line side of the isolation switch knife, then adjust bilateral currents to the same phase and at the same time disconnect test power supply to reset protection;

6) Use communication tools, set on the test power supply both at the same time to simulate the two sides fault current flow both to the line, fiber longitudinal differential protection should be act correctly, with one side switching current direction ;Simulate fault line bilateral flow Passing current, optical fiber longitudinal differential protection does not act;

7) While doing the above tests, the protection cabinet should be measured by a high precision phase meter measurement to check the correctness of the secondary current phase, and check the secondary current phase of the protection device be consistent with the phase table measurement results;

8) Optical fiber lock distance protection: involving a number of pilot projects, the test is the most difficult, if the whole project test is completed, after the nuclear power plant is taking into operation until with the test conditions with a long period of continuous operation with load, the protection as the main line protection and Power plant side backup protection can be put into. The main tests are:

(1) When taking CT static flow test, the fiber longitudinal differential / optical fiber blocking distance protection and bus differential protection CT are located in the line interval on both sides of the circuit breaker, and at the same time of the test, complete the alignment of optical fiber locking Test of distance protection current loop in accordance with the bus differential protection current loop;

(2) When taking PT static pressure test, the optical fiber blocking distance protection voltage circuit connected to the common bus PT / line according to "PT static pressure test" method and confirm the PT access phase sequence is correct;

(3) Both sides of the protection cabinet terminal with a computer protection calibrator to simulate the application of fault current and voltage, bilateral adjust the fault voltage phase and the reference voltage with the same phase;

(4) After the completion of the above tests, finally taking the follow-up tests in accordance with the "CT / PT static flow / pressure with the test" method;

(5) Both sides simulate line internal fault and outside the opposite direction of the fault impedance, observe the optical fiber locking distance protection be correctly act or mutual blocking the opposite side for protection;

(6) While doing the above tests, the protection cabinet should be measured by a high precision phase meter measurement to check the correctness of the secondary current phase, and check the secondary current phase of the protection device be consistent with the phase table measurement results.

### 2.3 Medium Voltage 10.5kV Bus Differential Protection

10.5kV bus 8, with the configuration of the busbar protection and circuit breaker failure protection, are the supply hub of high-voltage transformer, auxiliary transformer and diesel generator, through the same period and fast switching to achieve comprehensive defense functions in depth.

In addition, the electrical and technical pre-run test program boundary to break the circuit breaker, fracture below CT are the contents of the process test program. While many 10.5kV branch load CTs apply bus differential protection operation, it is impossible to do load phase measurement. In view of this, the following tests must be carried out:

1) Refer to 220 / 550kV bus differential protection CT flow test, respectively, simulate each bus all outlet branch area outside / area fault, bus protection correctly select to

jump the corresponding circuit breaker test;

2) When the 8 10kV bus has power conditions, auxiliary transformer / high voltage transformer / diesel generators are equipped with power, power supply conditions, all busbar power before the simulation of each branch switch failure protection start Jump the corresponding circuit breaker test to ensure that all horizontal and vertical protection interlock functions are correct.

### 2.4 Generator Transformer Group System

Transformer shave wire group and short circuit impedance, and cannot flow directly, only to use low-voltage transformer side of the transformer short circuit, high-voltage side of the bus to apply three-phase 380V AC power supply, use short-circuit impedance current to limit current. Before the test, calculate the power supply capacity and the high and low side current according to the short circuit impedance. CT primary current  $I_1$  is small, but the variable ratio  $n$  is very large, the protect secondary current  $I_2 \leq 3-5 \text{ mA}$ , protection precise display current  $I_2 \geq 50\text{mA}$ , high precision caliper phase table measurement accuracy  $I_2 \geq 3 \sim 5\text{mA}$ . If the  $I_2$  current is less than the instrument measurement accuracy, string into the wire more than a few turns in the current test terminal, stuck multi-turn and measure.

1) Respectively put 10.5 kV bus short circuit grounding, 220 kV bus on 380 V AC power, measuring auxiliary variable differential protection, lead differential protection, current / impedance / power direction protection phase;

2) Put center point of the generator short-circuit grounding, 550 kV bus plus 380V AC power supply. Machine-side and neutral CT ratio is greater than  $n = 45000 / 1\text{A}$ , if the stator winding affects the input current, put the ABC per-phase winding reactance short-circuits. Measure the main transformer differential protection, lead differential impedance protection, current/impedance/power direction protection phase; generator transformer group large differential protection high-voltage transformer branch phase;

3) Respectively put 10.5 kV bus short-circuit grounding, 550 kV bus with 380V AC power, measuring the main transformer differential protection, lead differential protection, current / impedance / power direction protection phase; high-voltage transformer differential protection, current / Impedance / power direction protection phase; generator transformer group large differential protection high-voltage transformer branch phase;

4) Excitation variable low voltage bus short-circuit grounding, 550 kV bus with 380 V AC power supply, measuring the main transformer differential protection, lead differential protection, current / impedance / power direction protection phase; excitation variable differential protection, current/Power direction protection phase;

generator transformer group large differential protection excitation variable branch phase.

### 2.5 Diesel Generator, Motor / Low Voltage Transformer / Cable System

1) Diesel generator neutral point short-circuit grounding, ABC each side of the winding reactance short-circuit, 10.5 kV bus ABC phase to the ground to apply single-phase AC current, measuring diesel generator differential protection and current / impedance / power direction protection Phase.

2) High-voltage motor and cable lines can refer to the diesel generator flow test method;

3) Low-voltage plant transformer can refer to the auxiliary transformer flow test method;

4) For high-voltage motors, low-voltage transformer and cable lines and other branch load, due to the relative independence of the system involved in a small range, static flow test can be taken with load test conditions.

### 3. PT Static Pressure Test

Static pressure is to apply voltage in the PT secondary circuit test, analog protection device to apply the normal rated voltage and fault voltage, measure the voltage and phase of the application of protective devices, observe and determine whether the protection test act correctly.

Test equipment: 10kV three-phase step-up test PT, high-precision dual-card phase table, battery, digital and pointer multicenter, insulation shake table, microcomputer relay protection calibrator, computer synchronization device calibrator, Wave equipment and so on.

Using the above test equipment, the specific test method is as follows:

1) Taking PT secondary circuit polarity test with a battery and a pointer multicenter, and check whether the CT secondary polarity and protective treatment polarity is correct, if necessary, the polarity test can be extended to protect the cabinet terminal;

2) 10.5 kV PT / 24 kV PT directly apply three-phase 380 V test voltage, 220/550 kV PT take 10 kV test voltage applied using the step-up test PT, by measuring the sequence of secondary voltage phase sequence between PT groups, take the secondary phase test between two sets of PT or multiple sets of PT, the test voltage phase loss can check PT open triangular output voltage. Test in the PT local control or control the protection of the cabinet terminal to measure the voltage phase sequence phase to ensure that the power of PT a secondary voltage step-down transmission does not appear problems;

3) PT second small switch off, to prevent the PT Reverse transmission to high voltage side of the bus, after the switch apply three-phase symmetrical rated 100V voltage.

Single and multiple sets of PT protection / measurement / metering / opening triangular winding voltage can be pressurized in parallel. The test verifies the correctness of the external cable termination of the control panel by measuring the parameters such as the voltage phase of each control cabinet terminal.

4) 220 / 550kV I / II bus PT voltage Switches the protection / measurement / metering / opening triangular winding voltage into the protection / measurement / metering device through the disconnecter to protect and I / II bus PT secondary voltage parallel by switching the relay contact. Through the actual opening and closing test by the isolation switch, observing whether the action of the switching relay is correct, and measuring whether both sides of the PT voltages before parallel phase are correct, after the parallel phase, verifies comprehensively the correctness of the control cabinet wiring;

5) Nuclear power plants have multiple simultaneous points, with automatic quasi-synchronous / manual synchronization, fast switching / line reclosing check the same period and so on. By operating the isolation switch, circuit breakers and the same point of the line switch, When both sides of the PT parallel to the same name with the same phase voltage into the same device, measuring device terminals on both sides of the voltage phase, observe the same device and control the differential pressure / Frequency difference, phase difference are synchronized to indicate zero;

6) With a computer synchronization device calibrator, select a group of PT secondary application of 100 V system voltage, select another group of PT secondary application of 100 V to be paralleled system voltage, do the same period of the circuit breaker false synchronous grid Wave test, observe the same device differential pressure / frequency difference / phase difference latch, test voltage regulator / FM output pulse width, and adjust the circuit breaker breakage instantaneous slip voltage zero crossing deviation;

7) When the current / impedance / power directional protection also need to put on test current, follow the "CT / PT static flow / pressure test" method, but should check the direction protection before the PT single voltage circuit test.

#### 3.1 220 kV / 550 kV Bus System PT

1) Bus PT / line PT / auxiliary transformer line PT / main transformer line PT / min - section bus PT, test according to the above methods 1) ~ method 5);

2) 550 kV side of the circuit breaker automatic quasi-synchronous / bus and segmented circuit breaker manual synchronization, test in accordance with the above method 5) and method 6) method of testing;

3) Line reclosing check the same period, take reclosing check same period the situation of the observation test according to the above method 5);

4) When the current / impedance / power directional protection also need to put on test current, follow the "CT / PT static flow pressure test" method, but should check the direction protection voltage in the PT single test whether the circuit is involved in the protective wiring is correct.

### 3.2 10.5 kV Bus System PT

1) Bus PT / High Factory Transformer Operating Branch PT / Auxiliary Transformer Standby Branch PT / Diesel Generator Standby Branch PT Loop test according to the above method 1), method 2), method 3), method 5);

2) Bus PT for auxiliary variable backup branch PT / high change work branch PT take check the same period loop test according to the above method 5) and method 6);

3) Bus PT on the diesel generator spare branch PT, do with the quasi-synchronous test in accordance with the above method 5) and method 6);

4) Simulate 10.5kV bus PT lose pressure, high-plant transformer working branch circuit breaker trip, do fast switching auxiliary backup branch circuit breaker test in accordance with the above method 5) and method 6);

5) Analog high-voltage transformer working branch / auxiliary transformer spare branch circuit breaker full jump, 10.5kV bus PT lose pressure, do 10.5kV bus sweep load protection start jump all bus load, diesel generator start zero boost Closing the bus, test according to the automatic loading program with the branch load circuit breaker.

### 3.3 Generator 24kV Outlet System PT

1) Generator outlet system PT loop, test according to the above method 1), method 2), method 3), method 5);

2) Generator side and main transformer low pressure side PT, do unit automatically quasi-synchronous output circuit breakers test in accordance with the above method 5) and method 6).

## 4. CT / PT Static Flow Pressure With the Test

### 4.1 Protection of the Instrument and CT / PT Polarity Wiring Principle

The CT / PT voltage current circuit input to the current / impedance / power direction protection and power measurement, power meter, must comply with the following wiring principles:

1) PT three-phase secondary voltage  $U_A / U_B / U_C / U_N$  relative to the PT once received bus polarity must be the same polarity wiring leads to secondary voltage;

2) If the direction of protection is pointed from the bus to the line / generator / transformer, the CT three-phase secondary current  $I_A / I_B / I_C / I_N$  should be the same side of the bus side of the bus line leads to the secondary current;

3) If the protection direction from the line / generator / transformer pointing to the bus, the CT three-phase secondary current  $I_A / I_B / I_C / I_N$  should be on the bus side for the reverse polarity wiring leads to secondary current;

4) For measuring power meter / watt-hour meter / centralized control room operation computer screen display direction are to follow the above principles.

### 4.2 Flow / Pressure Test Method

1) According to CT static co-current test results, analysis and determine the correctness of the current circuit wiring;

2) According to the PT static co-current test results, analysis and determine the correctness of the current circuit wiring;

3) The protection cabinet terminal with a computer protection calibrator to apply the fault current and voltage, respectively simulate the protection of equipment within the scope of the fault and outside the scope of the fault, observe the protection action should be correct;

4) Measuring and calculating cabinet terminal with a computer protection calibrator to apply the normal operating current and voltage, observe the power meter positive and negative bias / power meter reversing / centralized control room operation computer screen display direction should be correct.

## 5. Conclusions

The dynamic test of the no-load / load condition of the nuclear power plant is often limited by the operating conditions of the system and the equipment. Thus only the CT / PT polarity and the protection direction correctness of the current voltage circuit can be measured. The static power test can be applied mini operation and abnormal conditions of the current voltage and phase voltage, and the AC / DC circuit control / protection / latching logic test validation. Before the first time the system is powered up / unit, the problems in the design, manufacture, installation and commissioning can be detected by static power test to prevent and circumvent the failure, interruption, damage event of the dynamic test. It can greatly reduce the dynamic test workload and test difficulty, and ensure that the dynamic test safety risk is under control.

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