Protective Relay Testing –Modified Secondary Injection Method

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ABSTRACT— ***Secondary injection method is used to test the reliability of protective relays and circuits. To avoid any loose connection in the protective relay circuit a continuity test may be carried with DC voltage. But this test is unable to identify any short circuit in the CT secondary. The continuity test should also be carried out with AC voltage to identify any short circuit in the CT secondary or shorting of any other secondary terminals of multiple secondary winding CT. The addition of this low-cost test in the secondary injection method improves the reliability of the protective circuit to a high level.***

Keywords— Protective relay testing, Secondary injection method, Multiple secondary winding CT, Continuity test

1. INTRODUCTION

It is mandatory to perform testing of protective relays and circuits, used in a substation, either on six monthly or on annual basis. This is carried out to guarantee the reliability of the protective system. Generally, secondary injection method [1-3] is used to perform the testing of protective system without taking any shutdown of the substation equipments.

The protective relay, in use, may be tested easily by taking out the relay from its housing and by replacing it with the same type of relay, tested before.

The connection between the secondaries of the protective current and potential transformer (CT and PT) to the relay may be physically inspected. The voltage available at the relay terminal from the PT under normal operating condition may also be measured. Similarly the current flowing through the relay from the CT under normal operating condition may be measured by a tong tester without opening the CT circuit. The trip circuit dc voltage across the relay contact may also be measured to confirm the health of the trip circuit.

But the difficulty arises to confirm the health of the CT and PT secondary connecting circuits in those relays, where the current and voltage appear only during the fault. The current flows through an earth fault relay, connected to the neutral CT of a star connected transformer or a grounding transformer, only during the earth fault. The continuity of the CT or PT secondary circuit in those cases may be tested by an ohmmeter, measuring the resistance of the circuit without the relay. But this test is not able to identify the presence of any short circuit in the CT or PT secondaries. Physical inspection of the PT or CT secondary may not be possible in sealed units.

This paper suggests the necessity of conducting the continuity test with an AC voltage also to identify any short circuit in the secondaries of PT or CT.

The motivation of this paper is the outcome of an actual incident of shorting of CT secondary terminals of a neutral CT of a grounding transformer in a 33 kV substation in a developing country. The shorted CT terminals remain undetected by the normal secondary injection method of relay testing.

2. CONTINUITY TEST WITH AC VOLTAGE

Continuity test of circuit connections is generally carried out by an ohmmeter with a DC supply. Zero or low value of measured resistance indicates healthy connections of circuit components. But this test with DC supply fails to identify any short circuit in CT or PT secondary winding.

It is proposed that the continuity test should also be carried out with AC supply to measure the impedance of the circuit. Under normal operating condition the relay circuit of an over current, impedance and many other types of relay carry normal current and voltage having magnitudes much less than that of the fault condition. In those cases the continuity test with AC/DC voltage should only be carried out with the primary circuit of the equipment disconnected.

The primary winding circuit of the CT or PT of relays, which are actuated only during fault condition, offers very high impedance during normal operation. Therefore, a low value of impedance measured by AC supply from the secondary side indicates a short circuit in the secondary winding of the CT or PT. But a high value of impedance measurement indicates the magnetizing impedance of the CT or PT and no short circuit condition in the secondary winding.

A protective CT, having multiple secondary windings offers a special case to be analyzed.

Single core CT with multiple secondary windings

Multi ratio current transformers are commonly used to protect power system equipments with relays and circuit breaker. A 100:1:5A protective CT may be used to connect a 1A or a 5A relay to one of its secondary. The provision of multiple-winding secondaries in a protective CT helps the customer to choose the proper current rating of the secondary winding to match the protective relay specification. The multi-ratio of the CT may be obtained with tapped secondary or with multiple secondary windings.

Fig.1 shows a double secondary winding CT with one secondary winding shorted and the relay connected to the other second winding. Fig.2 shows the equivalent circuit.

Z_P, Z_1' and Z_2' are the short circuit impedance of the primary, first and second secondary windings of the CT respectively and are referred to primary. Z_M is the very high magnetizing impedance of the CT referred to primary. Z_R' is the relay impedance referred to primary.

I_1' and I_R' are the currents flowing through the shorted secondary and the relay respectively and are referred to primary winding. The total current I is divided into two parallel paths, where the ratio of the relay current to the shorted secondary current becomes equal to the ratio of Z_1' to the sum of Z_2' and Z_R'.

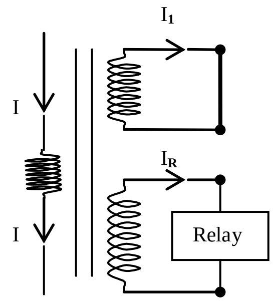

Fig.1 Double secondary winding CT

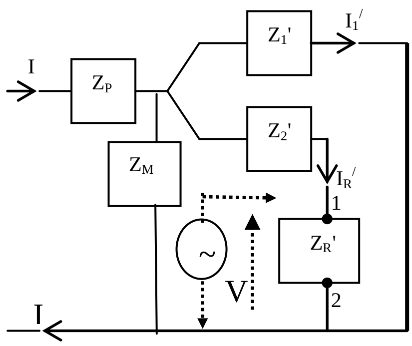

Fig.2 Equivalent circuit of double secondary winding **CT**

$I_R'/I_1' = [Z_1'/(Z_2' + Z_R')]$

As $Z_M >> Z_1', Z_2', Z_R', Z_P$

Both the short circuit impedances, Z_1' and Z_2', of the CT secondaries are very small in comparison to the relay impedance Z_R'.

Therefore, during fault small current flows through the relay, but much higher current flows through the shorted secondary winding. Thus the relay may not operate during a fault condition. Whereas, if the first secondary winding is kept open, the relay current becomes the total current and the first secondary current becomes zero. So the full short circuit current (referred to secondary) flows through the relay.

Continuity test with DC/AC voltage may be carried out from the secondary side by removing the relay and connecting DC/AC voltage source across the terminals 1 and 2 (refer the DC/AC source with dotted line). Low resistance measurement with DC voltage confirms the continuity of the secondary circuit. When AC voltage is connected, with inactivated primary winding, measured impedance becomes ($Z_2' + Z_1'$) and is very small when the first secondary is kept shorted. But the impedance becomes Z_M and is very high when the first secondary is kept open. Thus the continuity test with AC voltage identifies the presence of any shorted secondary in a multi-secondary winding CT.

3. IMPROVED SECONDARY INJECTION METHOD

A 33 kV substation in a developing country was constructed to get its supply from the delta connected secondary of a distribution transformer. A grounding transformer was installed in the 33 kV substation. It had an inbuilt neutral CT with secondary windings rated for 5 A and 1 A. An earth fault relay (electro-mechanical type) connected to the 1 A secondary winding provided the back-up earth fault protection of all the distribution feeders by tripping the 33 kV circuit breaker (CB) of the distribution transformer.

During installation of the grounding transformer the shorted CT terminals of 1 A secondary was opened and the earth fault relay was connected. Due to oversight the 5 A CT terminals remained shorted.

Primary injection method of testing during commissioning tests was not performed for the earth fault relay. Secondary injection method of relay testing was carried out annually and it certified the satisfactory operation of the earth fault relay. During a detailed inspection, after a few years of operation, the shorting of the 5 A CT terminals was noticed. The history sheet of the relay showed that the relay never operated during its use. At that time it was realized that the secondary injection method should be improved to identify the shorting of the secondary of CT. The continuity test with AC voltage was suggested and was performed satisfactorily to identify the shorting of CT terminals.

Test Results: CT rating – 100/5/1 A, 10VA; 1 A secondary terminals were connected to the ground fault relay.

DC Test: Continuity test was carried out using an ohmmeter with 3 V DC supply as shown in Fig.2, with the relay disconnected and no current in the CT primary. The measured resistance is less than 0.1 ohm in both the cases of 5 A CT secondary winding (i) shorted and (ii) open.

AC Test: The test circuit remains the same but the voltage supply is changed to 10 V, 50 Hz. The measured impedance is less than 0.1 ohm and more than 1000 ohm with the 5 A CT secondary terminals shorted and kept open respectively.

4. CONCLUSIONS

Secondary injection method of relay testing should be improved to identify any shorting of the secondary terminals of CT or PT. The continuity test with AC voltage connected to the CT or PT secondary circuit may identify any shorting of the secondary terminals. Therefore, it avoids the mal-functioning of a protective relay during fault and protects the equipment against damage.

5. REFERENCES

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