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Analysis on Transformer Protection Potential Fault Trip Resulting from CT's Wrong Connection

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Abstract. On account of Main transformer CT (current transformer)'s wrong connection leading to additional circuit, differential loop's circuit is calculated according to transformer's load status. Detail analysis is made. In conclusion, potential fault trip exists in RCS-978E stable ratio differential protection. Measures are brought forward to avoid fault trip, so that reliability of transformer protection is improved.

Keywords. CT, ratio differential, transformer protection, impacted bolt

1. Introduction

Transformer main protection differential protection [1] can quickly, sensitively and reliably remove internal faults. At present, the main transformer protection with ratio brake is a kind of main transformer protection which is widely used in our country, whose main characteristics are that the reliability and non-action in the malfunction outside the zone, and sensitive action in the malfunction inside the zone.

RCS-978E is a transformer relaying protection device, it has steady-state ratio differential [2], power frequency variation ratio differential, zero sequence ratio differential and differential fast break protection, and determine the cast or cancel of the above-mentioned various protection according to the actual situation. In this paper, the possibility of misoperation of RCS-978E steady-state ratio differential of the main transformer protection is found in the case of a compression connection error of transformer which caused an additional circuit, and the measures to avoid such accidents are put forward, which will help to improve the operation stability of the main transformer protection.

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2. The Process of Abnormality

The main wiring mode of a 220kV substation is changed to three-turn transformer, and the primary wiring diagram is shown in figure 1. At that time, the main transformer was outage, and the current transformer CT2 at 110kV side was replaced. After finishing sending main transformer, it is found that the there's A tank C-phase current, which is thought to be caused by zero drift, but it is found that the C-phase current of main transformer A cabinet from CT2 is 10% smaller than A-phase and B-phase, so test in the application of load six angle diagram [3], the result is the same, and seal CT in the terminal block of the protection screen, it is found that the C-phase current disappeared, so it can be sure that it is not the problem of the protection device itself. We decided to measure from the CT junction box, but the result was still 10% less, which could rule out the secondary problem. After examination, it was obviously found that the C-phase difference was caused by the error of the primary impacted connection.

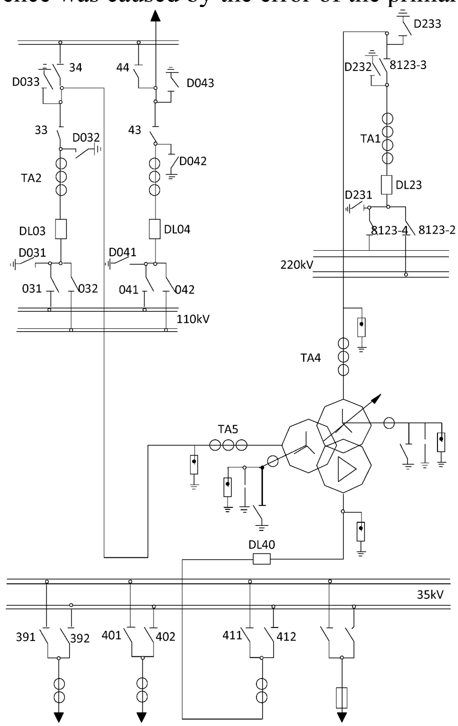

Figure 1. 220kV Substation Primary system.

3. The Checkup and Analysis of Abnormality and Conclusion

It can be seen by the main wiring diagram that the CT of the two sets of protection cabinets A and B of the main transformer are respectively taken from the three-side circuit breaker CT and the main transformer bushing CT of the transformer, Therefore, there is no influence on the Split phase ratio differential [4] of cabinet B. However, for cabinet A, protection misoperation will be caused by a wrong wiring, and the primary wiring diagram of CT2 replaced by power failure is shown in figure 2.

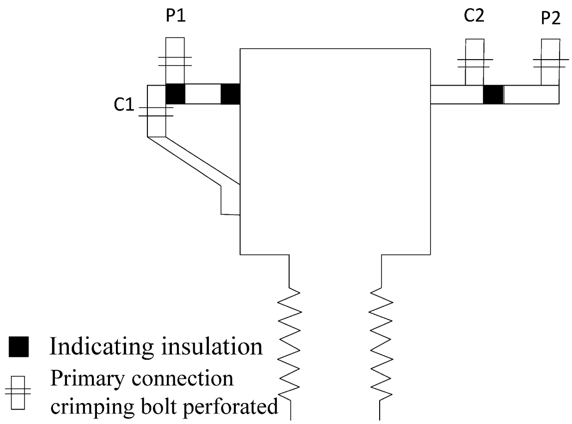

Figure 2. 110kV CT2 Primary figure.

C_1 is connected with C_2 through the shell, P_1-C_2 is round pipe, $P_1$is insulated from the shell, C_2 is not; C_1-P2 is embedded in P_1- C_2 (thin). When P_1- C_2 is connected, the CT ratio is 1200/5. This connection mode is normally adopted. When P_1-P2 is connected, the CT ratio changes to 600/5. The schematic diagram is shown in figure 3.

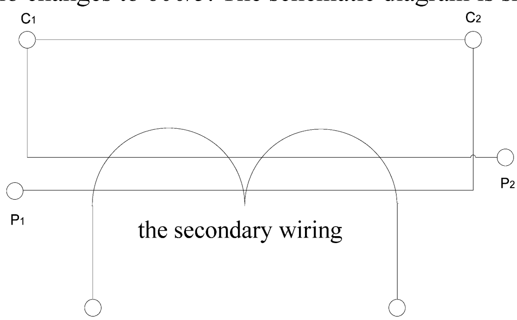

Figure 3. 110kV CT2 principle figure.

After field inspection, it was found that the compression connection bolt of C_2 lead wire in C-phase was reversed and P_2 was touched to cause a primary additional circuit (as shown in figure 4). During power transmission, it was found that the secondary current of A-phase and B-phase was 1.392A, and the secondary current of C-phase was 1.253A, which was 0.139A less and account for about 10%.

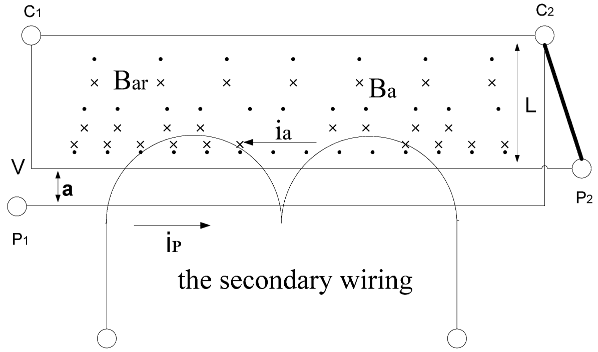

Figure 4. 110kV CT2 wrong connection figure.

It can be clearly seen from figure 4 that a circuit from P_1 to C_2 forms an additional circuit of C_1-V-P_2-C_2-C_1, generating intra-ring induced current, and its action process is as follows: It is assumed that the current at a certain moment of the main circuit, namely the load current, is i_p (direction is shown in FIG. 4), and i_p is in the middle magnetic flux Φ_a in the C_1-V-P_2-C_2-C_1 ring (' • 'in the middle of the figure represents magnetic density B_a, and the direction is outward). The closer it is to P_1P_2, the larger B_a is and the more intensive' • 'is. Conversely, the smaller B_a is, the more sparse the '•' is. According to Faraday's law of electromagnetic induction, C_1-V-P_2-C_2-C_1 ring should generate i_a, which is opposite to I_p direction, to block the change of Φ_a, and i_a generates magnetic flux Φ_{ar} ('×' in the middle of the figure stands for magnetic density B_{ar}, which penetrates inward). For the convenience of calculation, it is assumed that the additional circuit is a standard rectangular region, which can be obtained from the electromagnetic field theory:

$\Phi_{ar} = \int_a^{a+L} \frac{\mu \cdot i_P}{2\pi \cdot r} \cdot L \cdot dr = \frac{\mu \cdot i_P \cdot L}{2\pi} \ln \frac{a+L}{a}$, then $i_a = \frac{\mu \cdot i_P \cdot L}{2\pi \cdot M} \ln \frac{a+L}{a}$, then the actual secondary coil current:

$$i_f = (1 - \frac{\mu \cdot L}{2\pi \cdot M} \ln \frac{a+L}{a}) \cdot \frac{i_p}{n} \tag{1}$$

Where, n is the transformer ratio, μ is the permeability, a is the distance from V-P_2 to i_p at the edge of the additional circuit, L is the width of the additional loop, M is the mutual inductance between the additional circuit and the main circuit.

It can be seen from Eq. (1) that i_f is closely related to μ, L, a and M, where L, a and M depend on the additional circuit structure and the internal structure of CT ontology. For different CT, M is different, so the value of i_f is not determined.

In order to facilitate calculation, the text adopts standard rectangular area for magnetic field calculation. The structure of the additional circuit in the actual field situation is complicated (detailed calculation can be made according to the magnetic field analysis method of finite element, which is not calculated here), and it can be estimated that the secondary current will be smaller than the value calculated in this paper.

For this anomaly, the consequence of its reaction to the secondary current is that the secondary current does not correctly reflect the size of the primary current, which makes the secondary current react 10% less than the actual value under the obstruction of additional circulation.

4. The Impact of CT Wrong Connection on Main Transformer

Since only steady-state ratio differential is used in the main transformer and main protection of this station, only steady-state ratio differential is analyzed in this paper. The differential flow [5] is calculated as follows.

4.1 Differential Flow Calculation and Analysis

Transformer S_e=180 MVA, U_e takes the actual operating voltage, from $I_{1e} = \frac{S_e}{\sqrt{3}U_e}$, $I_{2e} = I_{1e} / n_{TA}$, it is obtained that the secondary rated current I_{2H} of the high voltage side is 3.577A, the secondary rated current I_{2M} of the medium voltage side is 3.575a, and the secondary rated current I_{2L} of the low voltage side is 6.75A. When the protection is abnormal, the secondary current I_{2h} of the high voltage side, I_{2m} of the medium voltage side and I_{2L} of the low voltage side are measured by a clamp meter to be 1.788A, 1.687A and 0.187A respectively. The standard values of I_{2h*}, I_{2m*} and I_{2L*} are respectively 0.5, 0.473 and 0.026. According to the actual value of RCS-978E, differential action Eq. (2) [6] (all variables in the formula are standard values) is:

$$\begin{cases} I_d > 0.2I_r + 0.3 & I_r \le 0.5 \\ I_d > 0.5I_r + 0.15 & 0.5 \le I_r \le 6 \\ I_d > 0.75I_r - 1.25 & I_r > 6 \\ I_r = \frac{1}{2}\sum_{i=1}^{m}|I_i| \\ I_d = \left|\sum_{i=1}^{m} I_i\right| \end{cases} \tag{2}$$

The differential start fixed I_{cdqd} is 0.3, I_{1M} is the current on each side of the transformer, I_d is the differential current, and I_r is the braking current. The ratio differential curve as shown in figure 5 is made according to Eq. (2).

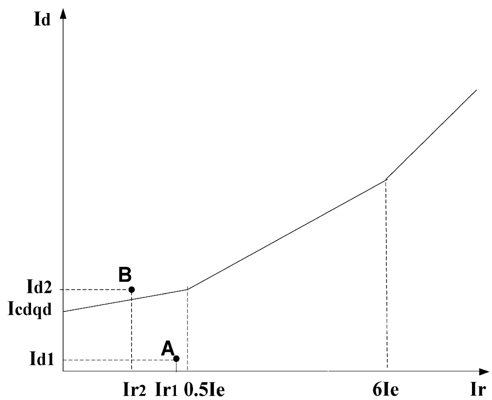

Figure 5. radio differential curve.

The calculation results show that I_d is 0.001 and I_r is 0.449, and the protection will not misoperate at this time. However, as the current of C-phase itself on the medium-voltage side is reduced by 10%, I_{d1} of C-phase phase difference flow is 0.048 and I_{r1} is 0.475, and the protection will not misoperate at this time (point A in figure 5). Due to a single wiring error, we measured that the voltage side current in C-phase decreased by 10%. If the voltage side current in C-phase decreased by more than 10% (assuming that the secondary current was greatly reduced due to a single wrong lead connection), we can calculate by Eq. (2) that if the voltage side current in C-phase is 0.11, a 75% reduction, I_{d2} is 0.364, I_{r2} is 0.318, and the negative sequence current on the medium-pressure side is $0.75I_n$ at this time, and the CT disconnection alarm appears. However, since the protection itself 'CT disconnection differential control word' is' 0 ', there will be no rate differential protection and the protection will misoperate (point B in figure 5).

4.2 Conclusion

Due to the generation of an additional loop caused by a phase current reduction or second generation difference loop break, in light load will not cause differential start, if timely processing at this time, you can avoid the load increase caused by differential protection misoperation (in the case of CT not locking differential protection).

5. Measures to Avoid Misoperation of Differential Protection

The correct sampling of differential circuit is very key to the correct action of differential protection. There are several suggestions for the maintenance of this protection anomaly and the differential circuit in the future:

- When replacing CT, maintenance personnel should carefully check the corresponding relationship between CT variable ratio and CT lead crimping bolt as well as the direct connection relationship of each impacted bolt to prevent the additional circuit formed by misconnection from introducing wrong CT variable ratio into the protection device, resulting in misoperation of the protection device.
- It is suggested that the main transformer protection of all voltage levels should be put into 'CT line-breaking locking differential control word', and its control word value should be ‘2’, which can avoid the misoperation of differential protection caused by CT loop abnormality in case of heavy load and out-of-zone fault.
- This anomaly shows that when the current of a certain phase decreases, the load increases, which leads to the easy differential protection action. According to the calculation of Eq. (2), it is suggested to increase the fixed value Icdqd of the ratio differential starting from the original 0.3Ie to (0.4Ie～0.5Ie), and set the 'CT wire break locking differential control word' to '1'. This kind of situation can be avoided.

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