Earth Fault Protection

An Online Continuing Education Course for Engineers

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Credit: 2 Hours / 2 PDH / 2 CPD

Earth Fault Protection

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Fault statistics suggests that earth faults are the dominating fault type. Therefore, earth fault protection is of great importance in electrical networks. The type of earth fault protection used depends primarily on the type of earthing method. This course describes protection principles for solidly (effectively), reactance, high resistance, and resonance grounded electrical systems.

Solidly Grounded Systems

In the solidly earthed systems, all transformers are connected to ground. Therefore, they feed earth fault current to the fault. The overall contribution from all earthing locations sets special requirements for the protection arrangement.

Fault Levels and Fault Resistance

In order to obtain fault levels in solidly grounded electrical system, symmetrical components are usually used. Single line diagram of a 132kV electrical system is shown in Figure 1 while its representation using symmetrical components is provided in Figure 2.

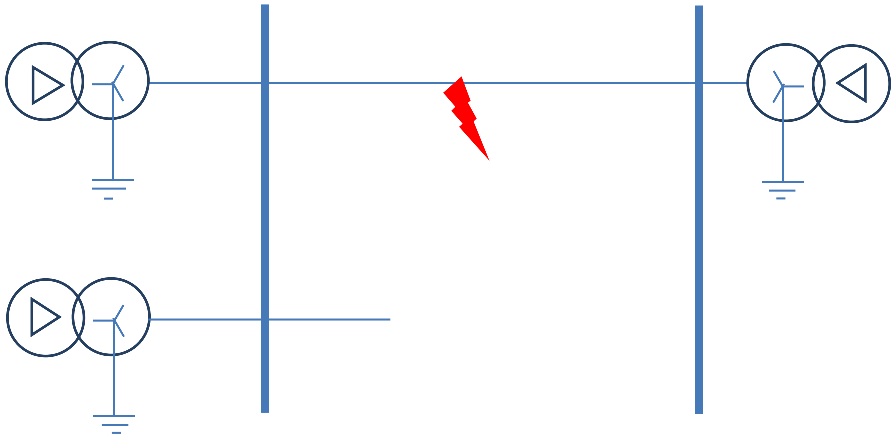

Figure 1. Ground fault in a direct, solidly grounded electrical system

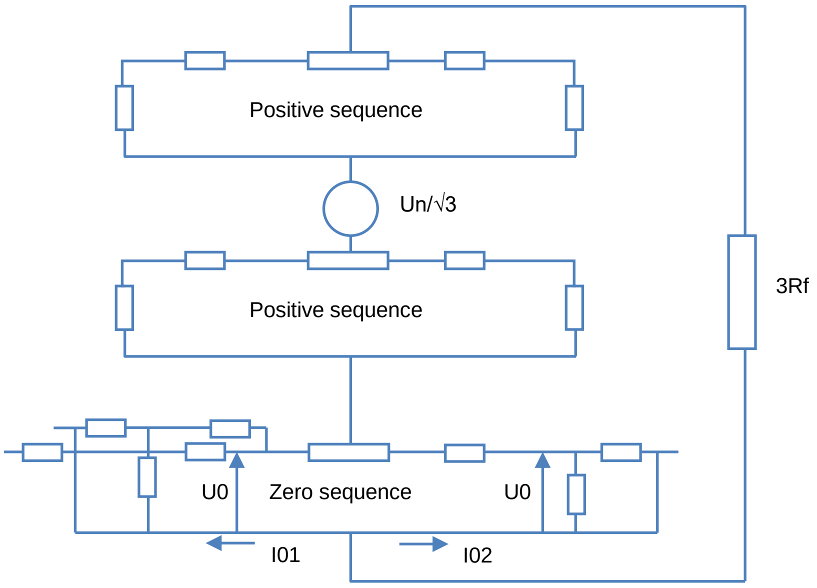

Figure 2. The symmetrical components are used to find the "I0" current

For the line to ground fault shown in Figure 1, "3I0" is the total fault current. Fault current distribution, from the different system grounding points, can be derived from the distribution in the zero-sequence network (as shown in Figure 2). By applying different fault resistances, one can get the fault current level. The fault resistance "R_f," contains the arc resistance and the tower foot resistance. The arc resistance is determined using the following expression:

$$R_{arc} = \frac{28700a}{I_f^{1.4}}$$

where "a," is the arc length in meter, typically the insulator length, and "I_f" is the fault current. A calculation shows that obtained values range from below 1 Ω for heavy faults, up to 50-400 Ω for high resistive ground faults. The tower foot resistance is dependent on the grounding effectiveness of the towers, whether top lines are used etc.

Neutral Point Voltages

The neutral point voltage, at different positions, is shown in Figure 2. The designated "U0", represents the neutral point voltage (3U0=UN). It must be noted that "U0" is generated by the ground fault current "I0" through the zero-sequence source. This means that the angle between "U0" and "I0" is always same as the zero-sequence source angle. This angle does not depend on the fault resistance and the angle between the faulty phase voltage and the line current in the faulty phase. It must be clear that that "UN" will be very low when sensitive ground fault relays are installed in a strong network with low zero sequence source impedances.

For example, we can observe the 132kV network shown in Figure 1 and Figure 2. With an "IN" setting of 120A, the "I0" is 40A and with a zero-sequence source impedance of say 20 Ω, the zero-sequence voltage component "U0" will be 40x10 = 400V and "3U0" will then be 1200V. This will, with an open delta winding with 110V secondary, means a percentage voltage of 1.6%, i.e., the polarizing sensitivity of directional ground fault relays must be high. In an open delta secondary circuit, there is a voltage also during normal running condition due to unbalances in the network. The voltage is mainly of third harmonic, roughly around 0,2-0,5% with conventional VTs and 1-3% together with CVTs. This means that the sensitive directional ground fault protection must be provided with a third harmonic filter when used together with CVTs. The filtering needs to be quite heavy to ensure correct directional measuring for 1% fundamental content also with third harmonic contents of approximately 3%.

Restricted Earth Fault Protection (REF)

For solidly grounded systems a restricted earth fault protection is typically provided as an addition to the normal transformer differential relay. One of the major advantages of the restricted earth fault relays is their high sensitivity. Sensitivities of 2-8% can be accomplished. The level depends on the current transformers magnetizing currents while the normal differential relay will have sensitivities of 20-40%.

Restricted earth fault relays are also very fast due to the simple measuring technique and the measurement of only one winding. The differential relay demands percentage through fault and second harmonic inrush stabilization which always will limit the minimum operating time.

The connection arrangement of a restricted earth fault relay is presented in Figure 3. It is connected across each transformer winding.

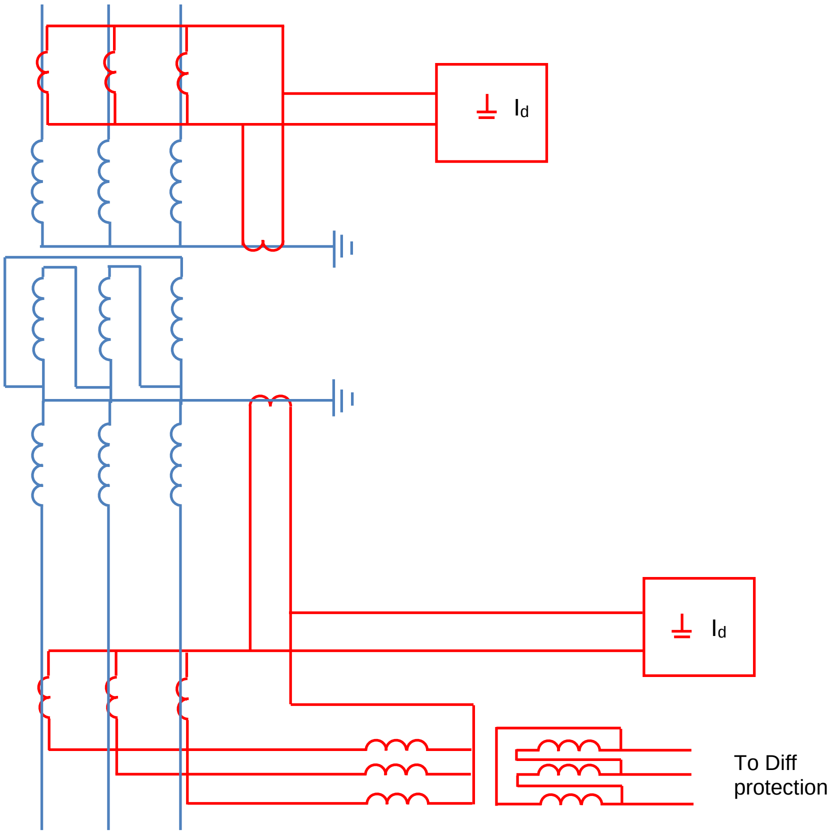

Figure 3. A Restricted Earth Fault (REF) relay for a YNdyn transformer

It is typical practice to connect the restricted earth fault relay in the same current circuit as the transformer differential relay. Due to the differences in the measuring principle, this will limit the differential relay possibility to sense ground faults. Such faults are discovered by the REF. The mixed connection in the transformer low voltage winding is shown in Figure 3.

The typical operating method for restricted earth fault relays is the high impedance principle. This is shown in Figure 4.

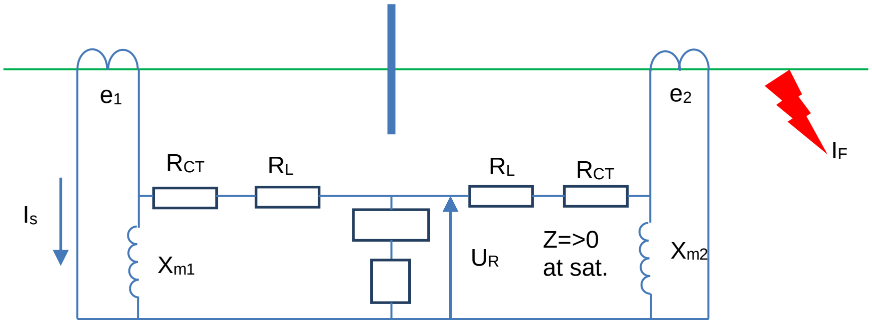

Figure 4. The high impedance principle

The relay gives high impedance to the current. The current will, for through loads and through faults, circulate in the current transformer circuits, not go through the relay. For a through fault one current transformer might saturate when the other will still feed current. In that case a voltage can be achieved across the relay. The calculations are done for the worst possible case and an operating voltage “U_R” is determined using the following expression:

$$U_R \geq I_{Fmax}(R_{ct} + R_l)$$

where

“I_{Fmax}” is the maximum through fault current at the secondary side, “R_{ct}” is the current transformer secondary resistance and “R_l” is the circuit loop resistance.

The maximum operating voltage needs to be calculated (neutral loop and phase loop need to be verified) and the relay set higher than the highest achieved value. For an internal fault the circulation is not possible and due to the high impedance, the current transformers will immediately saturate and RMS voltage with the size of current transformer saturation voltage will be achieved across the relay. Due to the fast saturation, very high voltages can be obtained. To prevent the risk of flashover in the circuit, a voltage limiter needs to be installed. The voltage limiter can be either in the form of a surge arrester or voltage-dependent resistor.

The relay sensitivity is determined by the total current in the circuit according to the following expression:

$$I_P \geq n(I_R + I_{res} + \sum I_{mag})$$

where “n” is the CT ratio, “I_R” is the current through th $_{res}$” is the current through the voltage limiter and “ΣI rents from all CT’s in the circuit. It must b ust be used. The current measurements r rrent AC components in the calculations.

To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.

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Detection of a gro selectivity in a solidly grounded system i urrent from different directions. A specia as been developed. It is appropriate for ult relays in solidly grounded system is se characteristic is presented in Figure the current of the biggest infeed is less , current selectivity is accomplished.