7PG23 5B3

Restricted Earth Fault

Document Release History

This document is issue 02/2010. The list of revisions up to and including this issue is:

Pre release

02/2010	Document reformat due to rebrand

Software Revision History

Contents

1. THEORY OF HIGH IMPEDANCE CURRENT BALANCE PROTECTIVE SCHEMES AND THEIR APPLICATION

1.1. Determination of Stability

The stability of a current balance scheme using a high impedance relay circuit is based on the fact that for a given through fault condition, the maximum voltage that can occur across the relay circuit is determined by means of a simple calculation. If the setting voltage of the relay is made equal to or greater than this voltage, then the protection will be stable.

In calculating the required setting voltage of the relay it is assumed that one current transformer is fully saturated and that the remaining CTs maintain their ratio. In this condition, the excitation impedance of the CT is negligible and the resistance of the secondary winding, together with leads connecting the CT to the relay terminals, constitute the only burden in parallel with the relay as shown in fig. 1.

Thus the voltage across the relay is given by:
V = I x (X1 + Y1) for CT1 saturated
V = I x (X2 + Y2) for CT2 saturated
where,
X1 and X2 = the secondary winding resistances of the CTs.
Y1 and Y2 = the value of the pilot loop resistance between the relative CT and the relay circuit terminals.
I = the CT secondary current corresponding to the maximum steady state through fault current of the protected equipment.
V = the maximum voltage that can occur across the relay circuit under through fault conditions.

For stability, the voltage setting of the relay must be made equal to or exceed, the highest value of V calculated above. Experience and extensive laboratory tests have proved that if this method of estimating the relay setting voltage is adopted, the stability of the protection will be very much greater than the value of I used in the calculation. This is because a CT is normally not continuously saturated and consequently any voltage generated by this CT will reduce the voltage appearing across the relay circuit.

1.2. Current Transformer Requirements

Experience has shown that most protective CTs are suitable for use with high impedance relays and that where the CTs are specifically designed for this protection their overall size may be smaller than that required for an alternative current balance protection.

The basic requirements are:

a) All CTs should, if possible have identical turns ratios.
b) The knee point voltage of each CT, should be at least 2 x Vs.

The knee point voltage is expressed as the voltage applied to the secondary circuit with the primary open circuit which when increased by 10% causes the magnetising current to increase by 50%.

c) CTs should be of the low leakage reactance type.

Most modern CTs are of this type and there is no difficulty in meeting this requirement. A low leakage reactance CT has a joint less ring type core, the secondary winding evenly distributed along the whole length of the magnetic circuit and the primary conductor passes through the approximate centre of the core.

1.3. Fault Setting

The fault setting of a current balance protection using a high impedance relay circuit can be calculated in the following manner.

Primary fault setting = N (I + I1 + I2 + I3)
where,
I = the relay operating current.

I1, I2, I3 = the excitation currents of the CTs at the relay setting voltage.
N = the CT ratio.

The fault setting of the protective scheme depends upon the protected equipment and the type of system earthing. For a solidly earthed power transformer a fault setting of 10 to 60% of the rated current of the protected winding is recommended.

If the power transformer is earthed through a resistor rated to pass an earth fault current of 100% or more of the rated current of the protected winding, a fault setting of 10 to 25% of the rated current of the earthed resistor is recommended.
In the case of earth fault protection for feeders terminating in a power transformer, as shown in Figure 5, it may be necessary to increase the basic fault setting to ensure that the capacitance currents of the feeder do not impair the stability of the protection. For stability during an external fault on the system to which the feeder is connected, the fault setting should preferably be greater than three times the residual capacitance current of the feeder. The maximum residual capacitance current is equal to the capacitance current to earth per phase at normal voltage in the case of a feeder in a solidly earthed system, and three times this value for a feeder in a resistance earthed system. Higher fault settings can be obtained as described in the following section

1.4. To give required current setting

The primary fault current setting obtained may be too low and be required to be increased, for example, a feeder terminating in a power transformer. If the relative increase is relatively small, an increase in the relay circuit voltage setting and hence an increase in the values of I1, I2, and I3 may give the required result. Alternatively, when the required increase in fault setting is large, the correct result can be obtained by connecting a resistor in parallel with relay circuit, thereby effectively increasing the value of primary current setting.

2. TYPICAL APPLICATIONS

2.1. Generators and Synchronous Motors

a) The circuit for phase to phase and phase to earth fault protection is shown in fig. 2. It requires two CTs and a single pole relay per phase. If the generator is earthed through a relatively high value earthing resistor, it may be necessary to supplement the high impedance protection by a sensitive earth fault protection.

b) The circuit for phase to earth protection is shown in fig. 3. It requires three line CTs and a single pole relay. A neutral CT is necessary if the neutral of the protected winding is connected to earth.

2.2. Series Reactor

Same as 2.1 (a).

2.3. Shunt Reactor

Same as 2.1 (b).

2.4. Auto Transformers

A scheme for phase to phase and phase to earth fault protection is shown in fig. 4. It requires three CTs and a single pole relay per phase. This scheme does not detect winding short circuits which do not involve earth or another phase. Where a protection responsive to this type of fault condition is required, Duobias protection can be used.

2.5. Restricted Earth Fault Protection for Windings of Power Transformers

A scheme for restricted earth fault protection is shown in fig. 5.

2.6. Earth Fault Protection for Feeders Terminating in a Power Transformer

The arrangement will be the same as on the delta side of the transformer shown in fig. 5 but in this case it may be necessary to increase the basic fault setting to ensure that the capacitance currents of the feeder do not impair the stability of the protection. For stability the fault setting should preferably be greater than three times the residual capacitance current of the feeder for an external earth fault on the system to which the feeder is connected. The residual capacitance current is equal to the capacitance current to earth per phase at normal voltage, in the case of a feeder in a solidly earthed system, and three times this value for a feeder in a resistance earthed system.

2.7. Busbar Protection and Protection of HV Connections

The circuit for phase to phase and phase to earth protection is shown in fig. 6a, and fig. 6b shows the circuit for phase to earth fault protection only. Where the protection is for a busbar installation controlling a number of circuit breakers, it is normally arranged so that two independent protections must operate before tripping of the circuit breakers can occur. The second protection would either be a duplicate of the high impedance scheme shown or, depending on the type of switchgear, a different protection, such as "leakage to frame" protection.

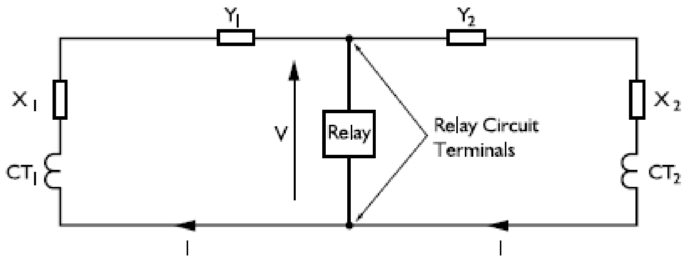

Figure 1 Basic Circuit of High-impedance Current-balance scheme

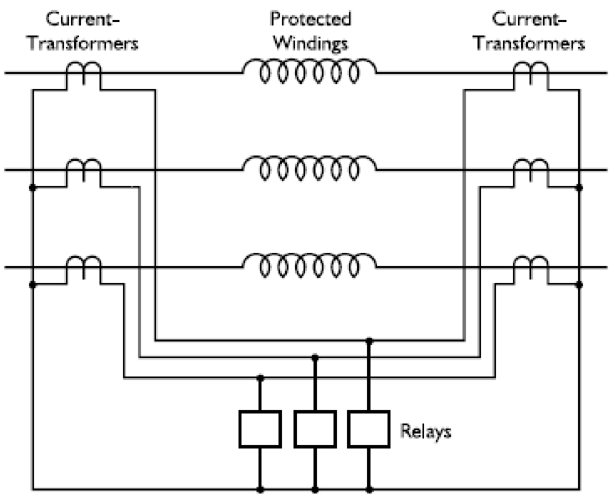

Figure 2 Phase/Phase & Phase/Earth Fault Protection for Generator A.C. Windings, Synchronous-motor A.C. Windings, and Series Reactors

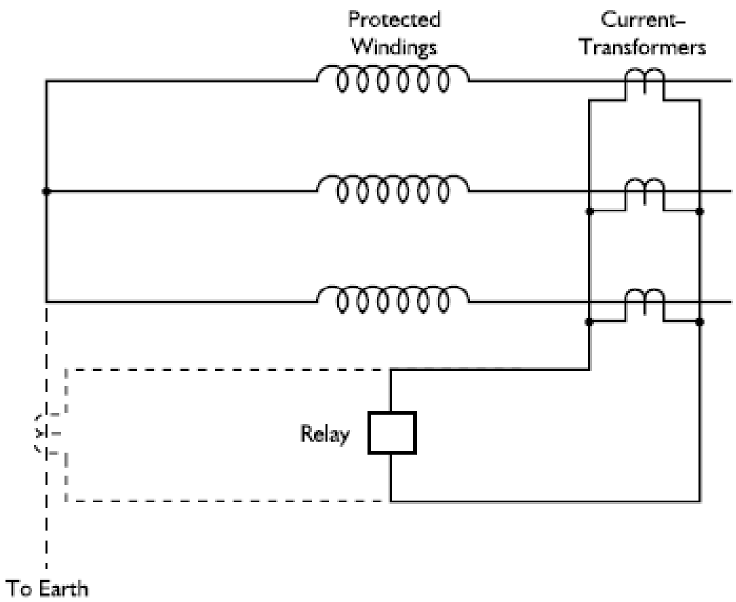

Figure 3 Phase to Earth Fault Protection for Generator A.C. Windings, Synchronous-motor A.C. Windings, and Shunt Reactors

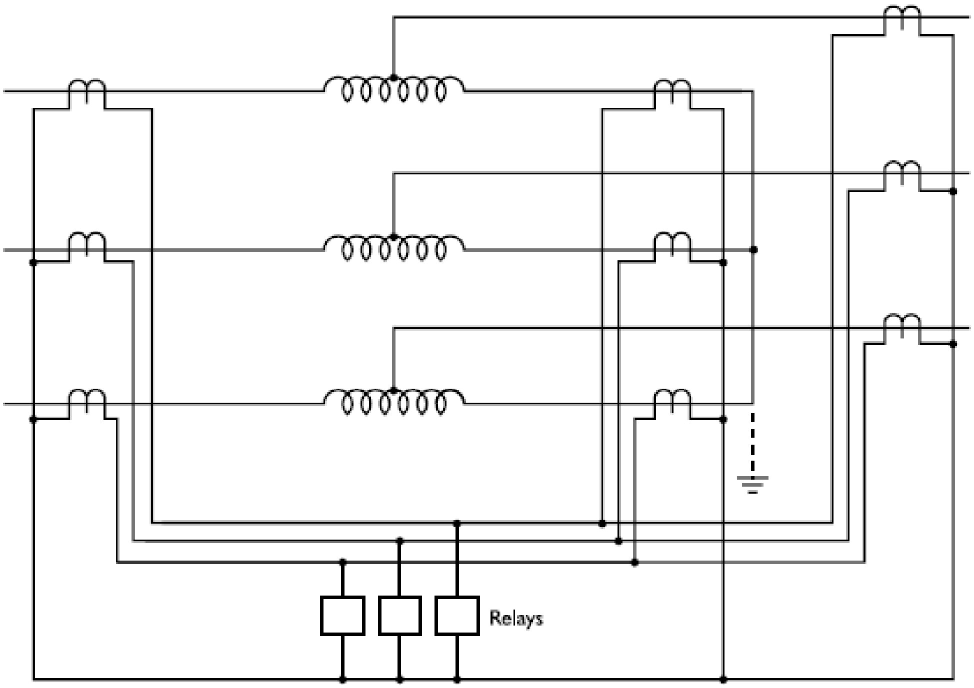

Figure 4 Phase/Phase & Phase/Earth Fault Protection for Auto-transformers

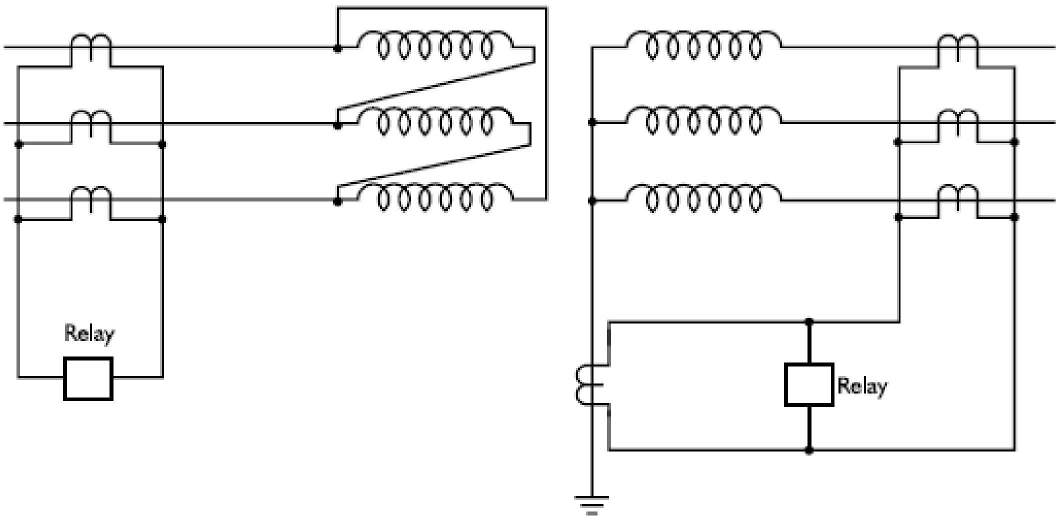

Figure 5 Restricted Earth-Fault Protection for Transformers Windings

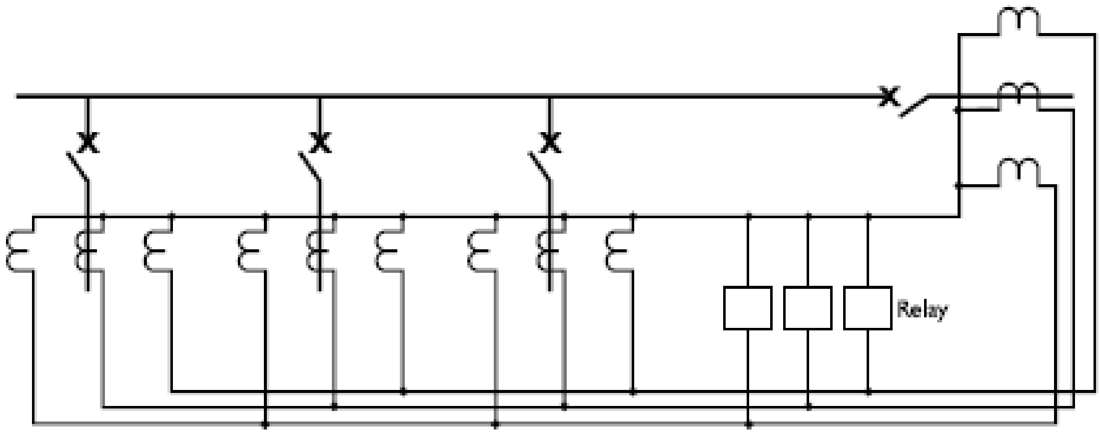

Figure 6(*a*) Phase/Phase and Phase/Earth Fault Protection

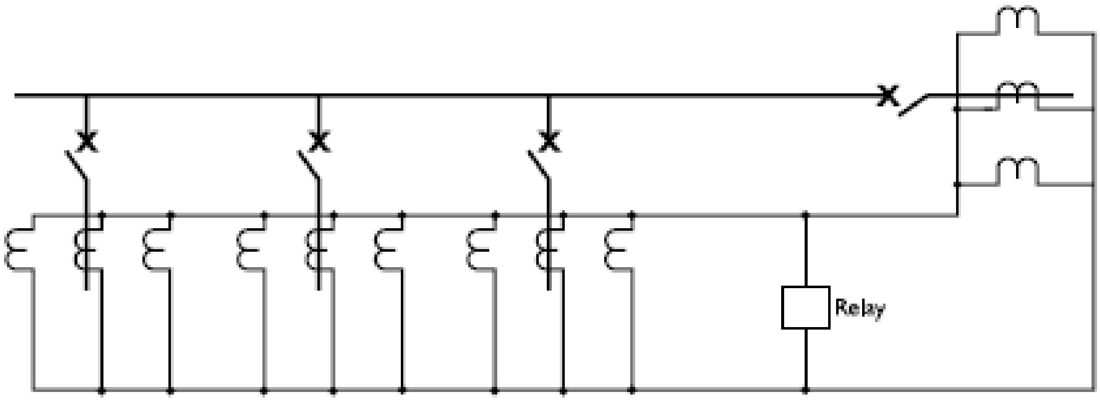

Figure 6(*b*) Phase/Earth Fault Protection

