DIFFERENTIAL PROTECTION

Introduction:-

Differential protection is a very reliable method of protecting **Generators**, **Transformers**, **Buses** and **Transmission Lines** from the effects of internal faults. In this system relay operates when the vector difference of two similar electrical quantities exceeds a pre-determined value. Since in this system relay senses difference of similar electrical quantities for its operation hence it is called **Differential Protection**. This means for a differential relay, it should have:

(i) Two or more similar electrical quantities and

(ii) These quantities should have phase displacement of approx 180°.

Basic Principle:-

The most common use of this relay is current differential type. The simple connection for this type of protection is as given in figure-1.

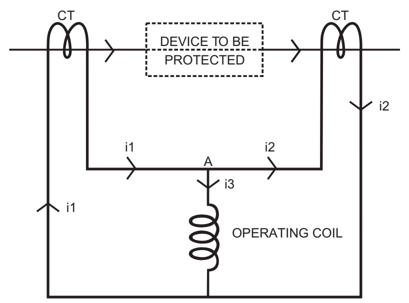

Figure -1

The dotted section shown in above figure can be a **Transformer**, **Alternator**, **Bus** or a **Transmission Line** with identical CTs and symmetry of connection. The basic differential system gives perfect balance on through fault i.e. fault external to protected zone and thus perfect stability. In this scheme two suitable CTs are connected in series as shown in figure-1.

The relay operating coil is connected between equipotential points. The voltage induced in the secondary of CTs will circulate a current through the combined impedance of wires and the CTs.

At node "A", according to **Kirchoff's Current law**, the vector sum of currents leaving or entering the node will be zero.

If we denote the current leaving the node as -ve and current entering the node as +ve, equation at node "A" will be

$$\mathbf{i_1 - i_2 - i_3 = 0}$$

$$\mathbf{i_3 = i_1 - i_2}$$

Where i_3 -current flowing through the relay operating coil

If we assume that CT's have similar characteristics and impedances seen by CT's are equal, then

$$\mathbf{i_1 = i_2} \text{ and hence } \mathbf{i_3 = i_1 - i_2 = 0}$$

Therefore, there will be no current through the operating coil during healthy condition and hence relay will not operate.

Now consider the situation when fault occurs. Fault can be a **through fault** or an **internal fault.**

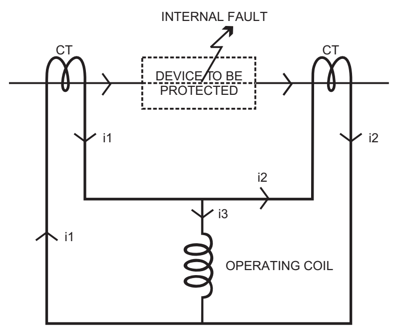

Figure (2)

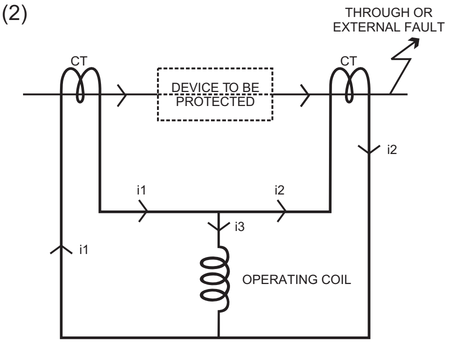

Figure -3

During internal fault condition as shown in figure-2, 1st CT will carry fault current while 2[nd] CT will have only load current and there will be a differential current $i_3 = i_1 - i_2$, flowing through operating coil of relay and if it exceeds the set value of relay then relay will operate and give protection to the protected device.

Now consider the **through fault** condition when fault is external to the protected zone.

In this condition, there will be equal current seen by both CTs and hence there will not be any differential current therefore relay will not operate. **This is the desirable condition**

.Whatever we have discussed above is true with ideal CTs and symmetry of connection, which gives perfect balance & stability on through fault conditions.

But in practice, this is not true. Current transformers of the type normally used, do not transform their currents so accurately especially under transient conditions. This is true because the short circuit current is offset i.e. it contains d.c. components. Suppose the two CTs under normal condition differ in their magnetic properties slightly in terms of different amount of residual magnetism or in terms of unequal burden on two CT's, one of the CT will saturate earlier during short circuit currents and thus two CT's will transform their primary current differently even for a through fault condition.

The stability limits obtainable with an unbiased low impedance relay in practice are rarely sufficient and additional features are necessary particularly with instantaneous schemes. One way of securing stability is to use a high impedance relay. Another way is to use a relay, which has two actuating quantities i.e. biased relay. This is commonly known as **biased differential protection** or **percentage differential protection**.

Biased Differential Protection :-

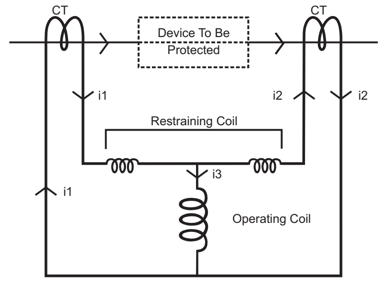

Figure-4

In this scheme Relay consists of an operating coil and a restraining coil as shown in figigure-4. The restraining coil is divided into two parts and operating coil is connected at mid point of restraining coil. Normally no current flows through operating coil under through fault condition but owing to dissimilarities in CT's, the differential current through the operating coil will be $(i_1 \; i_2)$ while average current through restraining coil will be $(i_1 + i_2)/2$.

The torque developed in restraining coil

$$\mathbf{T_1} \text{ á } \mathbf{\frac{(i_1 + i_2)\, n_r}{2}}$$

Where n_r = no. of turns in restraining coil

The torque developed in operating coil

$$\mathbf{T_2} \text{ á } \mathbf{(i_1 - i_2)\, n_0}$$

Where n_o = no. of turns in operating coil

At equilibrium $T_1 = T_2$

i.e. $$\mathbf{\frac{(i_1 + i_2)\, nr}{2} = (i_1 - i_2)\, n_0}$$

or $$\mathbf{\frac{i_1 - i_2}{(i_1 + i_2)/2} = \frac{n_r}{n_0}}$$

If we draw the above equation the operating characteristics of the relay will be as shown in figure-5

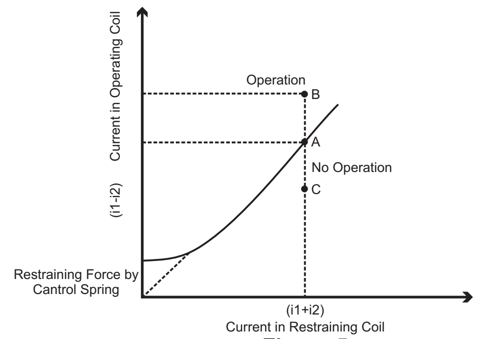

Figure-5

This is clear from the characteristic that except for the effect of the control spring at low currents, the ratio of the differential operating current to the average restraining current is a fixed percentage. That is why it is called **percentage differential protection**.

To have clear understanding of the operation of the relay consider three points 'A', 'B' & 'C' in figure-5. At point 'C' restraining force will be more than the operating force and hence no operation of relay. At point "B" restraining and operating forces are equal and again there will be no operation. But as we move to point "A", operating force will be more than the restraining force so relay will operate.

This is all about basic principle of differential protection irrespective of type of device to be protected.

In Differential protection scheme special CT's are required. The next issue of Tech-Talk will carry article on selection of those special CT's.

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