Part VII

Differential Protection

(Unit protection)

Differential Protection

- Differential protection is the best technique in protection. In this type of protection the electrical quantities entering and leaving the protected zone or area are compared by current transformers (C.T.s). If the net difference equal zero, it means no fault exist.
- This system is operating in either of the two following principles:
  1. **Current balance principle.**
  2. **Voltage balance principle.**
- Differential protection is applicable to all parts of the power system:
  1. Generator.
  2. Transformers.
  3. Motors.
  4. Buses.
  5. Lines and feeders.
  6. Reactors and capacitors

  There are two basic types of differential protection:
  - Current Balance Differential protection
  - Voltage Balanced Differential Protection

1. **<u>Current Balance Differential protection:</u>**

   ➢ <u>Operation during internal and external fault conditions</u>

   Fig.1 shows the basic current differential protection based on current balance principle.

   - At ***normal conditions and for external fault at F,*** CT_1 and CT_2 circulate currents at their secondary's I_{s1} and I_{s2} ($I_{s1} = I_{s2}$) and no current flow through the relay ($\Delta I = I_{s1} - I_{s2} = 0$), hence the relay will not operate.
   - If fault occurs at point ***F*** within the protected zone (***internal fault***) as shown in Fig.2, and the fault is fed from both sides, then current through $C.T_2$ will be reversed. Therefore a current $\Delta I = I_{s1} + I_{s2}$ will flow in the operating winding of the relay. This will cause the relay to trip the circuit breaker connected to the faulty system. Hence the relay trips when

     $| I_{s1} + I_{s2}| > |I|$ $|I|$=> pick up current of relay

     <u>This form of protection is known as Merz-Price protection.</u>

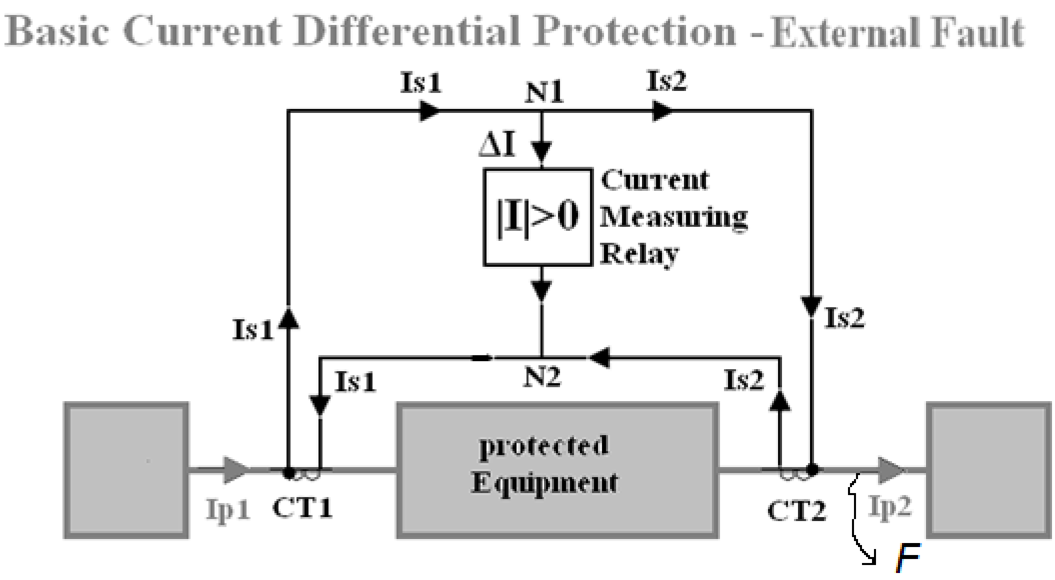


Fig 1

Consider ideal current transformer performance

- $I_{p1} = I_{p2}$
- Therefore $I_{s1} = I_{s2}$
- Therefore $\Delta I = 0$, magnitude of $I = 0$
- Current measuring relay does not operate.

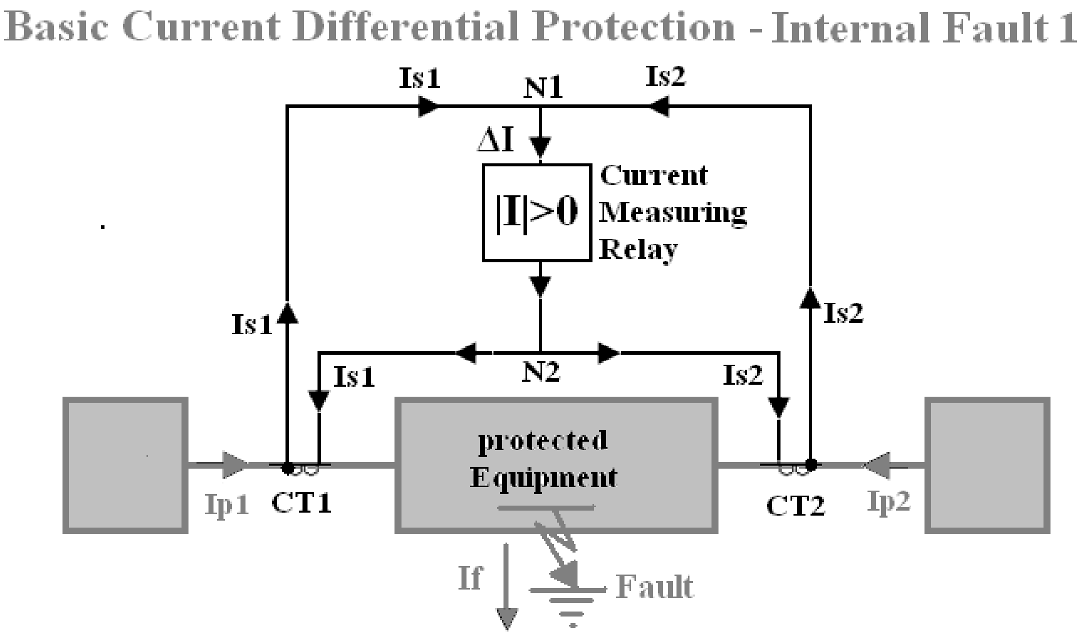


Fig. 2 internal fault with two infeed.

Consider ideal current transformer performance

- $I_f = I_{p1}+I_{p2}$
- Therefore $I_{s1} \neq I_{s2}$
- Therefore $\Delta I= I_{s1}+I_{s2} \neq 0$, magnitude of $I > 0$
- Current measuring relay operates.

-Relay may also operate if the fault in feed is from one direction as shown in fig.3.

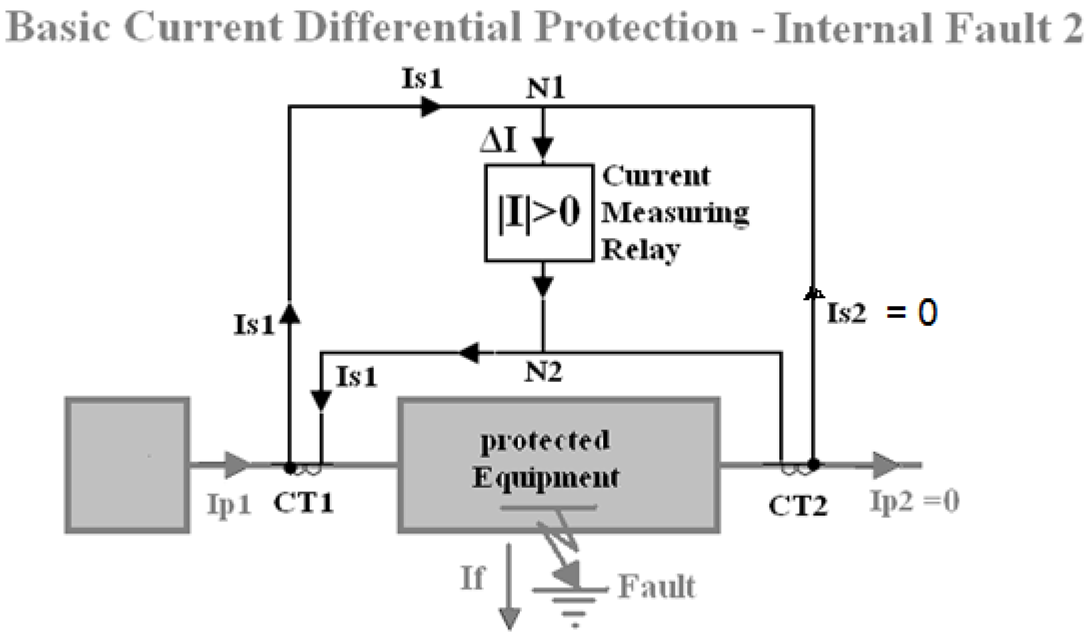


Fig 3 internal fault with one infeed.

Consider ideal current transformer performance:

- $I_f = I_{p1}$ as $I_{p2} = 0$ i.e no fault current in feed from one side.
- $I_{s2} = 0$
- Therefore $\Delta I = I_{s1} \neq 0$, magnitude of I > 0
- Current measuring relay operates.

2. **<u>Voltage Balanced Differential Protection</u>**

   Instead of current balance, a voltage balance Mertz-Price system, shown in Fig.4, is used for feeder protection or equipment protection (unit protection).

- CT_1 & CT_2 secondary windings are connected in opposition so that there is no current flow in the relay operating coil ($V_{s1} = V_{s2}$ => relay not operate).
  - During internal fault $V_{s1} - V_{s2} \neq 0$, this will drive current through the operating coil of the relay and the relay will operate.Fig.5.

Balanced Voltage Differential Protection - External Fault

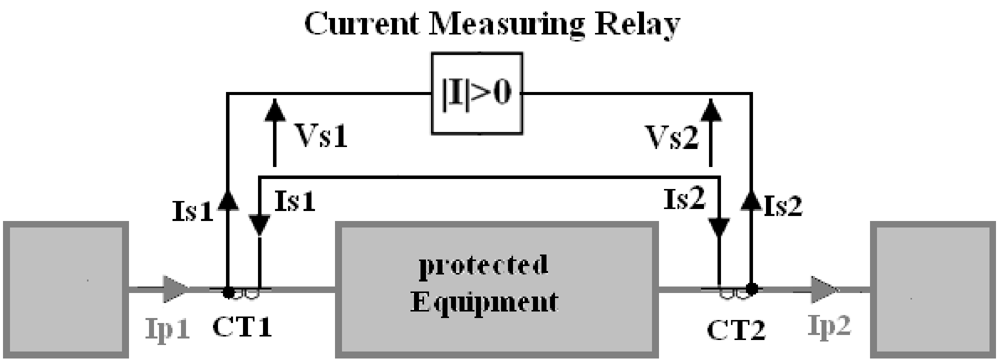


Fig 4

Consider ideal current transformer performance:

- $I_{p1} = I_{p2}$.
- $V_{s1} = V_{s2}$ and $I_{s1} = I_{s2} = 0$.
- Therefore magnitude of I = 0
- Current measuring relay does not operate.

Balanced Voltage Differential Protection -Internal Fault

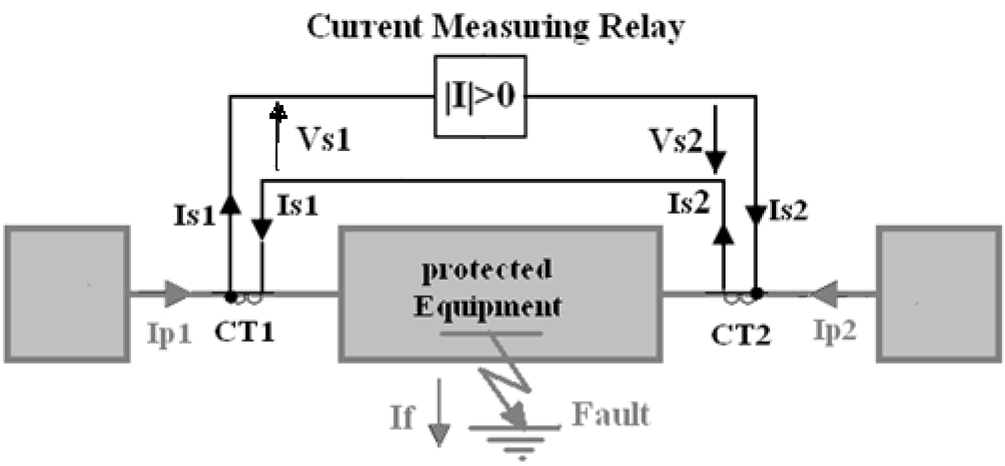


Fig 5.

Consider ideal current transformer performance:

- $V_{s1} \neq V_{s2}$.
- Therefore magnitude of $I \neq 0$
- Current measuring relay operates.

➢ The characteristics of **differential protection** can be summarized as follows:

Simple Concept:

• Measure current entering and exiting the zone of protection

• If currents are not equal, a fault is present

Provides:

• High sensitivity

• High selectivity

Result:

• Relatively high speed

➢ Percentage Differential Current Relay

This relay has an operating winding and two restraining winding connected as shown in Fig.6. The function of the restraining windings is to prevent undesired relay operation should a current flow in the operating winding due to CT during external fault.

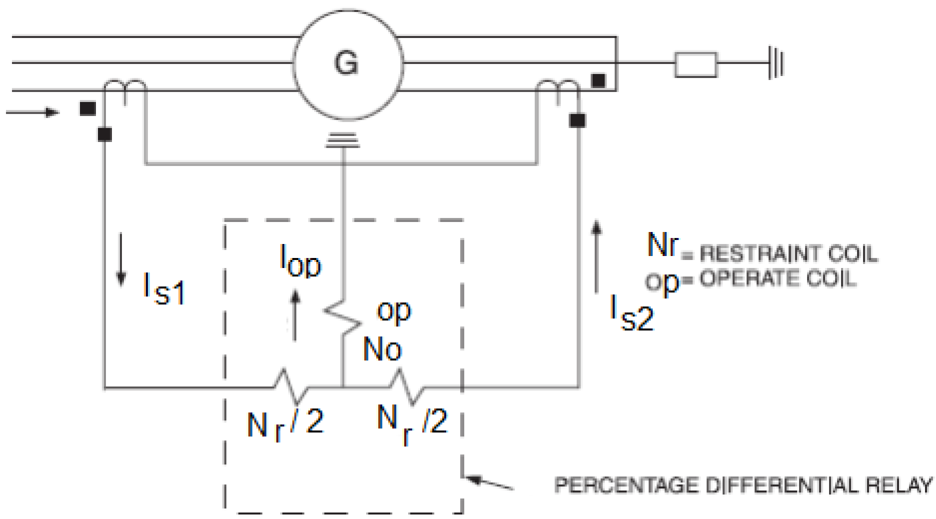


Figure 6—Basic relay connections (one phase) for fixed percentage restraint differential relay.

At Normal conditions:

- The differential current in the operating coil is proportional to Is_1-Is_2.

  ∴ $I_{op} = Is_1 - Is_2$

- The equivalent current in the restrain windings are proportional to ½ (Is_1+Is_2) since the two restrain windings are identical.

  ∴ $I_{rest} = \frac{1}{2} (Is_1 + Is_2)$

- Therefore, the ratio of the differential operational current to the average restrain current is a fixed "percentage". In other word, we can define the **bias** as the ratio between the numbers of turns of the restrain coil to the number of turns of the operating coil, i.e.

$$\%bias = \frac{N_r}{N_o} = k$$

- k is typically (10 – 40%).

- The operating characteristics of the relay is shown in Fig.7

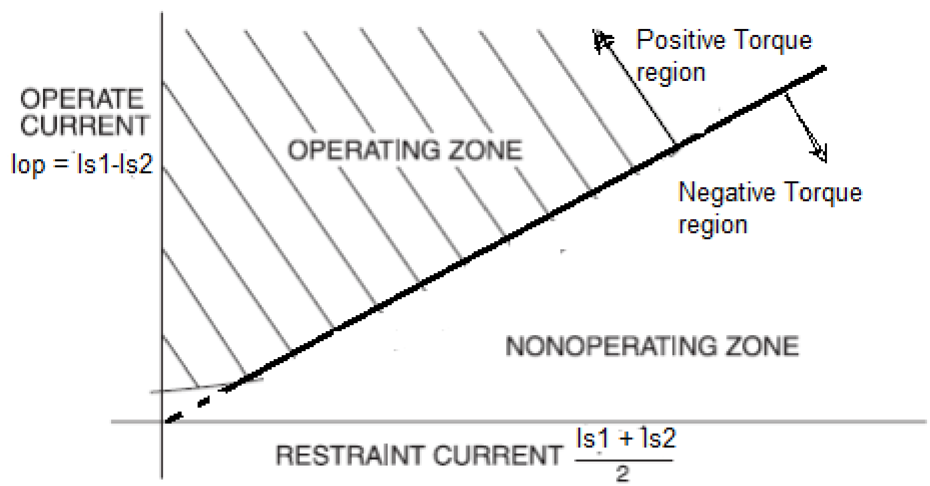


Fig. 7 Typical operating characteristic of a percentage differential relay.

The electromagnetic forces are proportional to the square of the magneto-motive force (mmf).
The condition for relay operation is then:

$$(mmf_{op})^2 > (mmf_r)^2$$

$$(I_{s1}-I_{s2})\, N_o > \tfrac{1}{2}\, (I_{s1}+I_{s2})\, N_r$$
$$(I_{s1}-I_{s2})\, N_o > \tfrac{1}{2}\, (I_{s1}+I_{s2})\, k\, N_o$$

$$I_{s1} > (½ (I_{s1}+I_{s2})) k + I_{s2}$$

$$I_{s1} – (k /2) I_{s1} > (½ I_{s2}) k + I_{s2}$$

$$I_{s1} (1 –½ k) > I_{s2} (1+ ½ k)$$

$$I_{s1} > \frac{(1 + ½ k)}{(1 - ½ k)} I_{s2}$$

$$I_{s1} > \frac{(2 + k)}{(2 - k)} I_{s2}$$

These characteristics can be achieved using balanced beam relay shown in Fig.8.

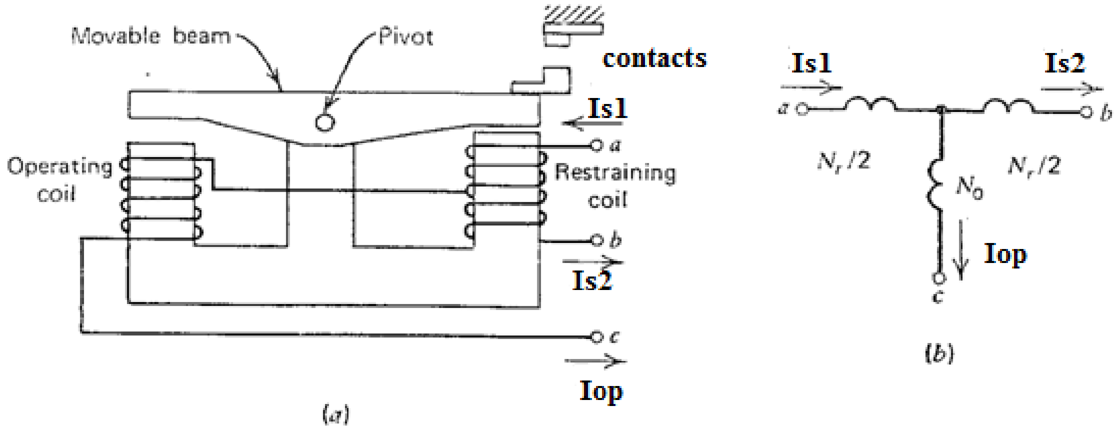


Fig.8 Balanced beam relay with restrain. (a) Balanced beam type relay (b) Schematic

Example : A balanced-beam relay has a pick up current of 0.1 A and a 10% slop. If the restrain coil currents are $I_{s1} = 4.2$ A and $I_{s2} = 4$ A, would the relay operate?

solution:

$I_{s1} = 4.2$ A

$I_{s2} = 4$ A.

The restrain coil has average current of

$$I_{rest} = \frac{I_{s1}+I_{s2}}{2} = \frac{4.2+4}{2} = 4.1 \text{ A}.$$

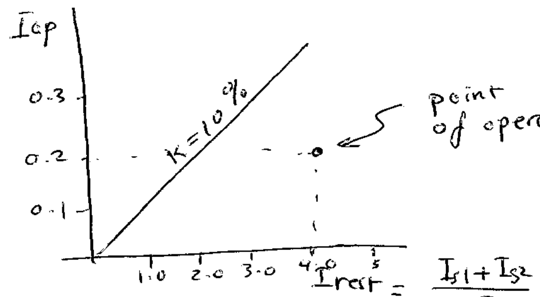
- For the relay to operate, the current in the operating coil must be not less than 10% of Irest :.

$$I_{op} \overset{?}{>} K\left(\frac{I_1+I_2}{2}\right)$$

$$I_{op} \overset{?}{>} \frac{10}{100} \times 4.1 = 0.41 \text{A}.$$

Since $I_{op} = I_{s1} - I_{s2} = 4.2 - 4.0 = 0.2$

Hence the current through the relay operating coil will not be sufficient to operate the relay.



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