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Lecture -3

Differential Relay

A differential relay responds to vector difference between two or more similar electrical quantities. This type of protection is mostly used for transformers as this responds not only to inter turn fault but also provides protection against phase-to-phase faults.

Requirements:

- It must have at least two actuating quantities, say I_1 and I_2
- The actuating quantities should be similar in nature i.e current/current or voltage/voltage
- The relay responds to the vector difference between the two quantities, i.e to (say I_1 and I_2), which includes magnitude and/or phase angle difference. When this vector difference exceeds a predetermined amount, the relay operates.

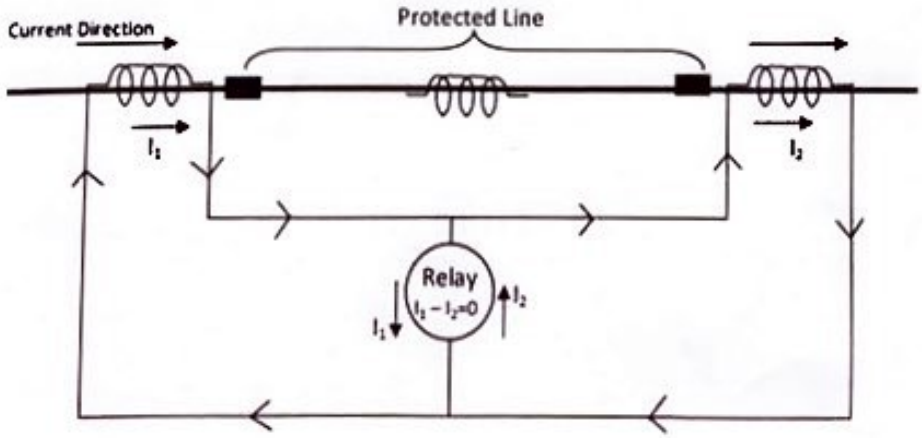
The differentialprotection is frequently called unit protection. The vector difference is achieved by suitable connection of CT and PT secondary. Most differential relay applications are of the current differential type.Relay unit is of over current type

For example: Consider the comparison of the input and output current of the transmission line. If the magnitude of the input current of the transmission line is more than that of output current that means the additional current flows through it because of the fault. The difference in the current can operate the differential protection relay.

Application:

- Protection of generators and generator-transformer unit.
- Protection of Transformer.
- Protection of Transmission line by pilot wire scheme
- Protection of Large motors
- Bus zone protection

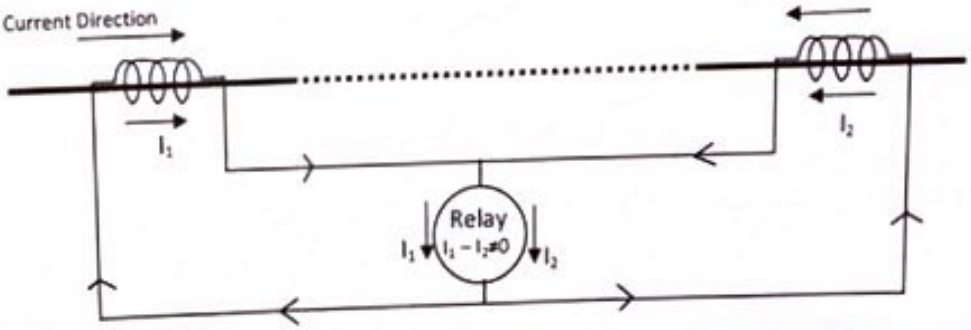
A simple example of circulating current differential relay is shown below…



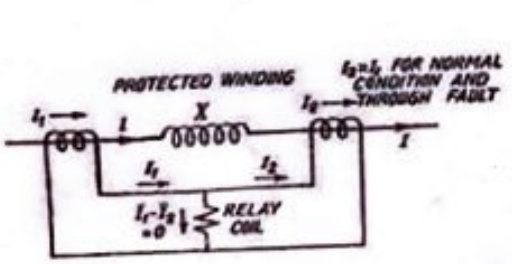
The block represents the system element (transformer, motor, generator, bus etc.) to be protected. Two suitable CTs are connected is series as shown in the figure with the help of the pilot wires. Pilot wire is a communication cable between two relays. Under normal working condition, the two currents at both ends are equal and pilot wires do not carry any current, keeping relays inoperative. Under an internal fault condition, the two currents at both the ends are no longer same, this causes circulating current flow through pilot wires and makes the relay to trip. The relay operating coil is connected between the mid points (equipotential; point) of the pilot wires. The secondary of the transformers is connected in series with the help of the pilot wire. Thereby, the current induces in the CTs flows in the same direction. The secondary current of the CTs will calculate through the combined impedance of the pilot wires and the CTs.

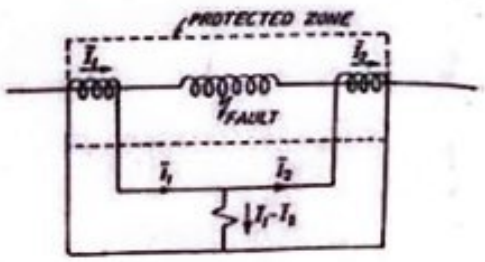
When the operating coil is not connected between the equip-potential points, even though the current through each CT is same, the burden on the two CTs is unequal; This causes the heavily loaded CTs to saturate during through faults, thereby causing dissimilarities in the characteristic of two CTs which result in malfunctioning-operation of the relay. The relay could be any of the ac type that has been discussed but preferably attracted armature type.

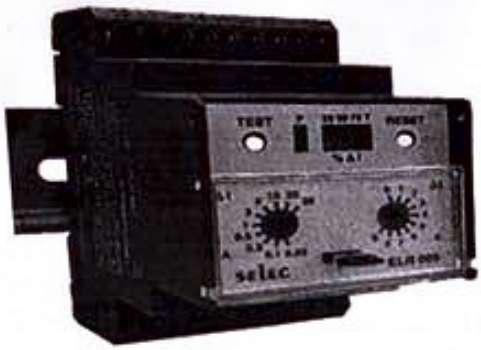
When there is no internal fault, the current entering the protected element is equal in magnitude and phase to current leaving the protected element.The CTs are of such a ratio that during normal operating condition or for external faults (through faults) the secondary current of CTs are equal. These currentssay I1 and I2 circulate in the pilot wires. The polarization of CTs are such that I2 and I2 are in the same direction during normal operation or through fault condition. The differential current (I1-I2) which flow through relay coil is zero means the zero current flows through the operating coil,So the relay does not operate.



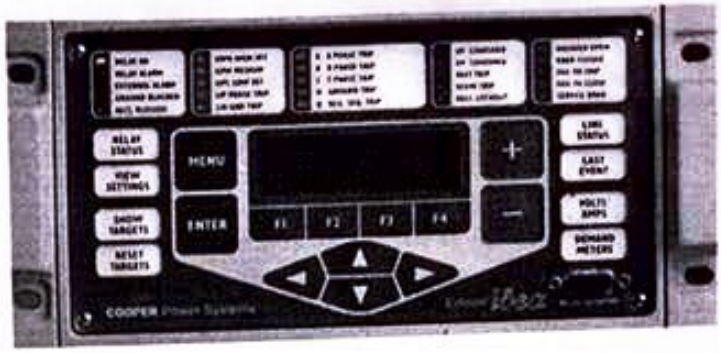
If the fault occurs somewhere in the protection of fault current in the circuit is shown in fig-2. the current entering the protected winding is no more equal to the leaving the winding because some current flows to the faultThe differential current (I1-I2), through the relay coil is not equal to zero i.e. (I1-I2)=0 . If the operating torque due to this differential current exceeds the restraining torque the relay will operate.







Earth leakage differential relay



Microcontroller based DR

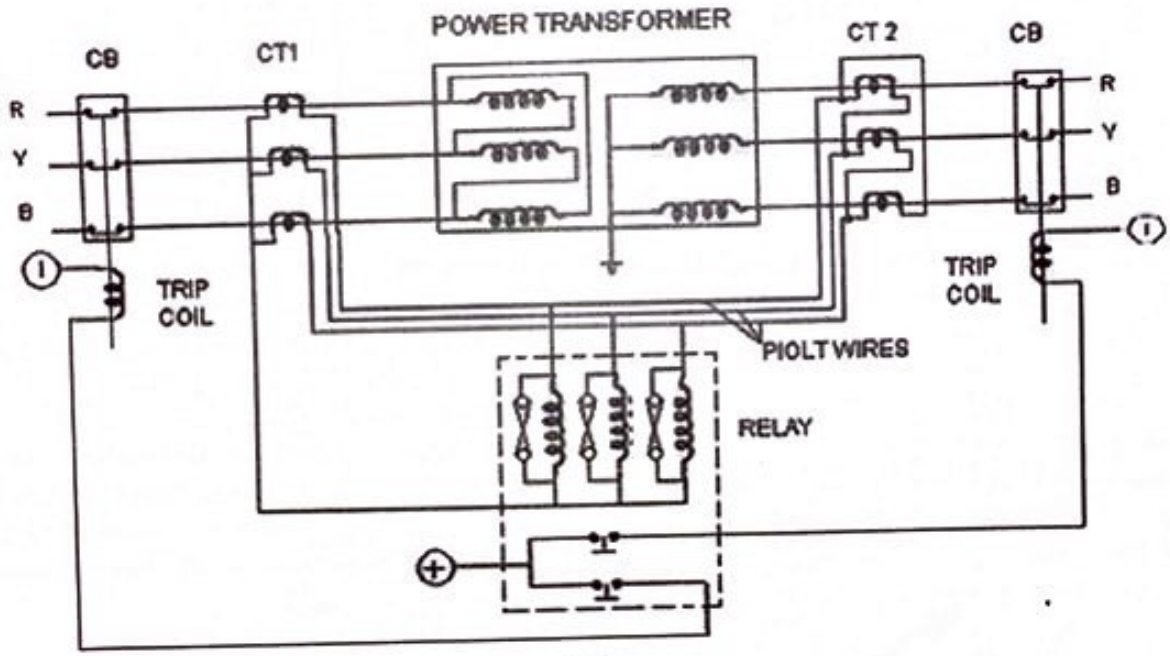


fig 8

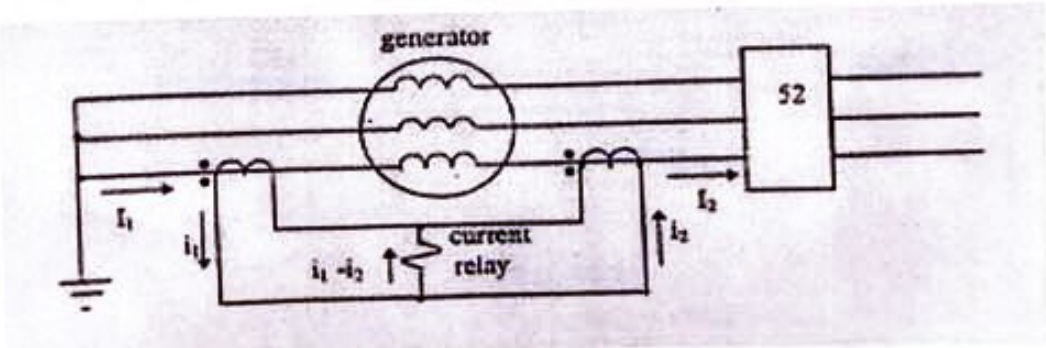


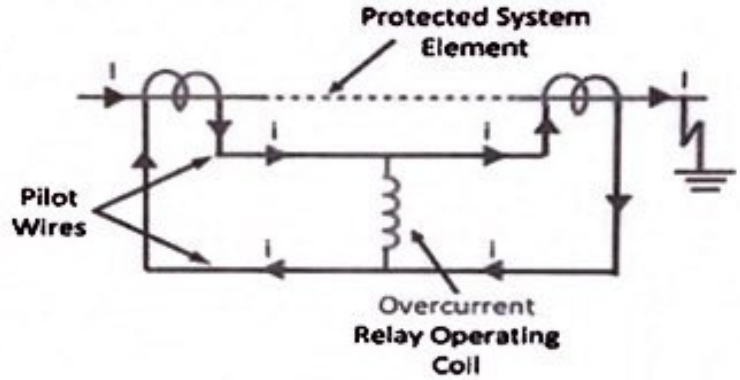
Figure: Differential Protection of a Generator winding

the differential protection relay.

- Current Differential Relay
- Voltage Differential Relay
- Biased or Percentage Differential Relay
- Voltage Balance Differential Relay

Current Differential Relay

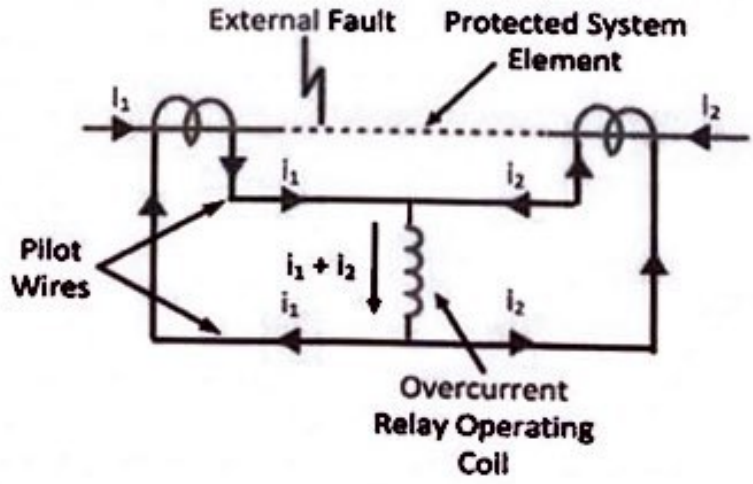
A relay which senses and operates the phase difference between the current entering into the electrical system and the current leaving the electrical system is called a current differential relay. An arrangement of overcurrent relay connected to operate as a differential relay is shown in the figure below.



For an External Load or Fault

Circuit Globe

The arrangement of the overcurrent relay is shown in the figure below. The dotted line shows the section which is used to be protected. The current transformer is placed at both the ends of the protection zone. The secondary of the transformers is connected in series with the help of the pilot wire. Thereby, the current induces in the CTs flows in the same direction. The operating coil of the relay is connected on the secondary of the CTs.



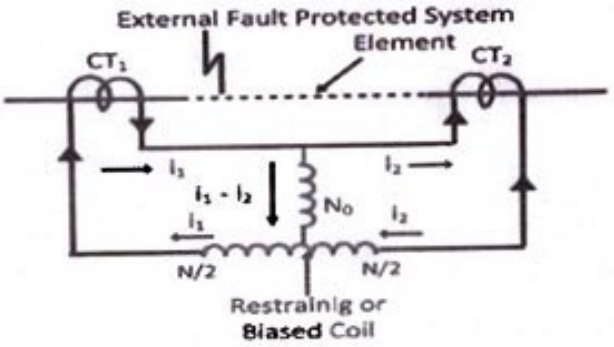
For an Internal Fault

Circuit Globe

In the normal operating condition, the magnitude of current in the secondary of the CTs remains same. The zero current flows through the operating coil. On the occurrence of the fault, the magnitude of the current on the secondary of CTs becomes unequal because of which the relay starts operating.

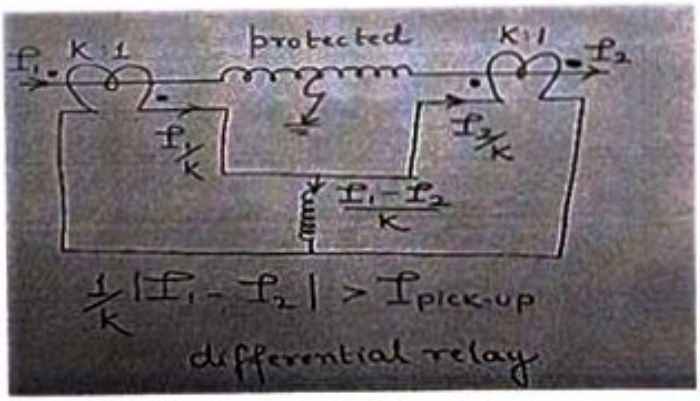
Biased or Percentage Differential Coil

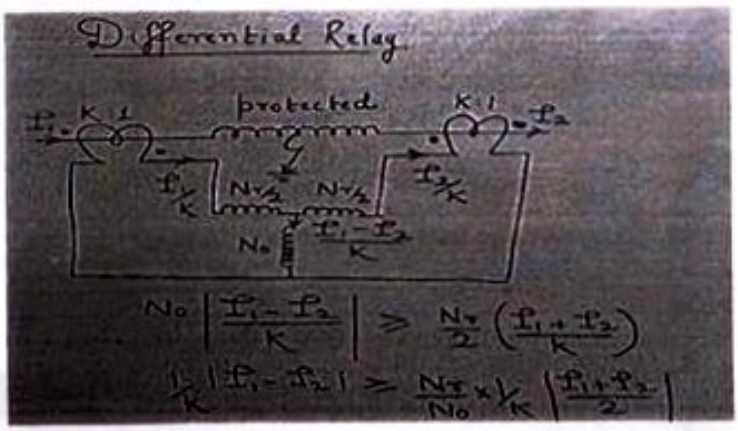
This is the most used form of differential relay. Their arrangement is same as that of the current differential relay; the only difference is that this system consists an additional restraining coil connected in the pilot wires as shown in the figure below.



Biased or Percentage Differential Relay

The operating coil connects in the center of the restraining coil. The ratio of current in the current transformer becomes unbalance because of the fault current. This problem is resolved by the use of the restraining coil.





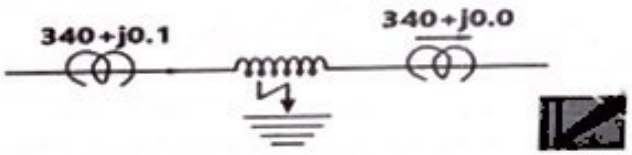
$$\left|\frac{I_1 - I_2}{K}\right| \geq \frac{N_r}{N_o}\left|\frac{I_1 + I_2}{2K}\right| + I_{pick\text{-}up}$$

Biased Differential relay

Bias or slope = N_r/N_o

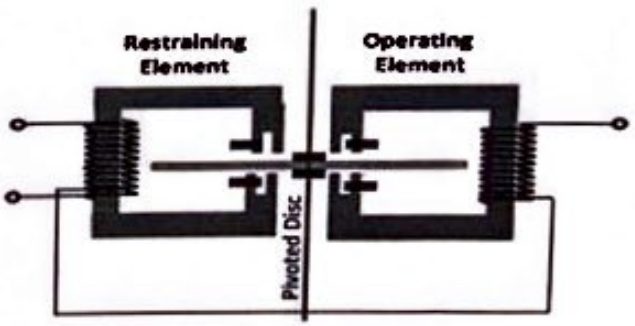
Question

The figure shows the differential relay used for the protection of the synchronous generator winding. Minimum pick up current, percentage slope of the relay are 0.1 A, 10% respectively. Generator winging neutral is grounded. A high resistance ground fault occurs near the grounded neutral end with the current distribution as shown here. Assume a current transformer ratio of 300:4. What do you conclude by this?



Induction Type Biased Differential Relay

This induction type relay consists a disc which freely rotates between the electromagnets. The each of the electromagnet consists the copper shading ring. The ring can move in or out of the electromagnet. The disc experiences a force because of the restraining and the operating element.



Induction Type Biased Differential Relay

The resultant torque on the shaded ring becomes zero if the position of the ring is balanced for both the element. But if ring moves towards the iron core then the unequal torques acting on the ring because of the operating and restraining coil.

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P(26) [Macou]

Induction type Relay

The production of actuating force

Fig (7) → Two fluxes differing in phase
→ Derivation P(27)

$\phi_1 = \Phi_1 \sin \omega t$

$\phi_2 = \Phi_2 \sin(\omega t + \theta)$

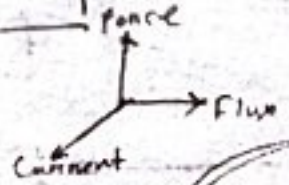
θ = phase angle

Two fluxes ϕ_1 & ϕ_2, produce two voltages

$i_{\phi_1} \propto \frac{d\phi_1}{dt} \propto \Phi_1 \cos \omega t$

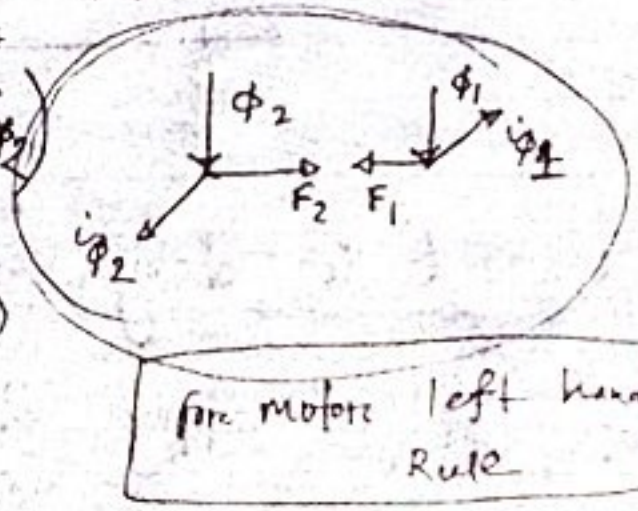
$i_{\phi_2} \propto \frac{d\phi_2}{dt} \propto \Phi_2 \cos(\omega t + \theta)$

* The two voltages circulate current in the Rotor (Aluminum Disc)



Net force

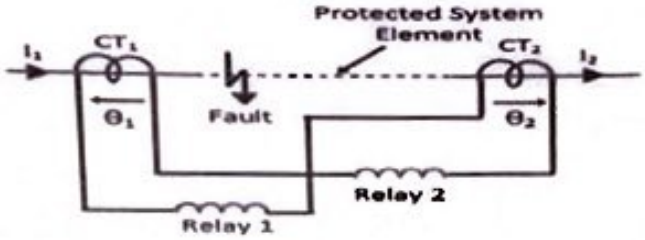
$(F_2 - F_1) \propto (\phi_2 i_{\phi_1} - \phi_1 i_{\phi_2})$



$F \propto \Phi_1 \Phi_2 \sin\theta$ ——(3)

For motore left hand Rule

The relays are connected in series with the secondary of the current transformer. The relays are connected in such a way that no current flows through it in the normal operating condition. The voltage balance differential relay uses the air core CTs in which the voltages induces regarding current.

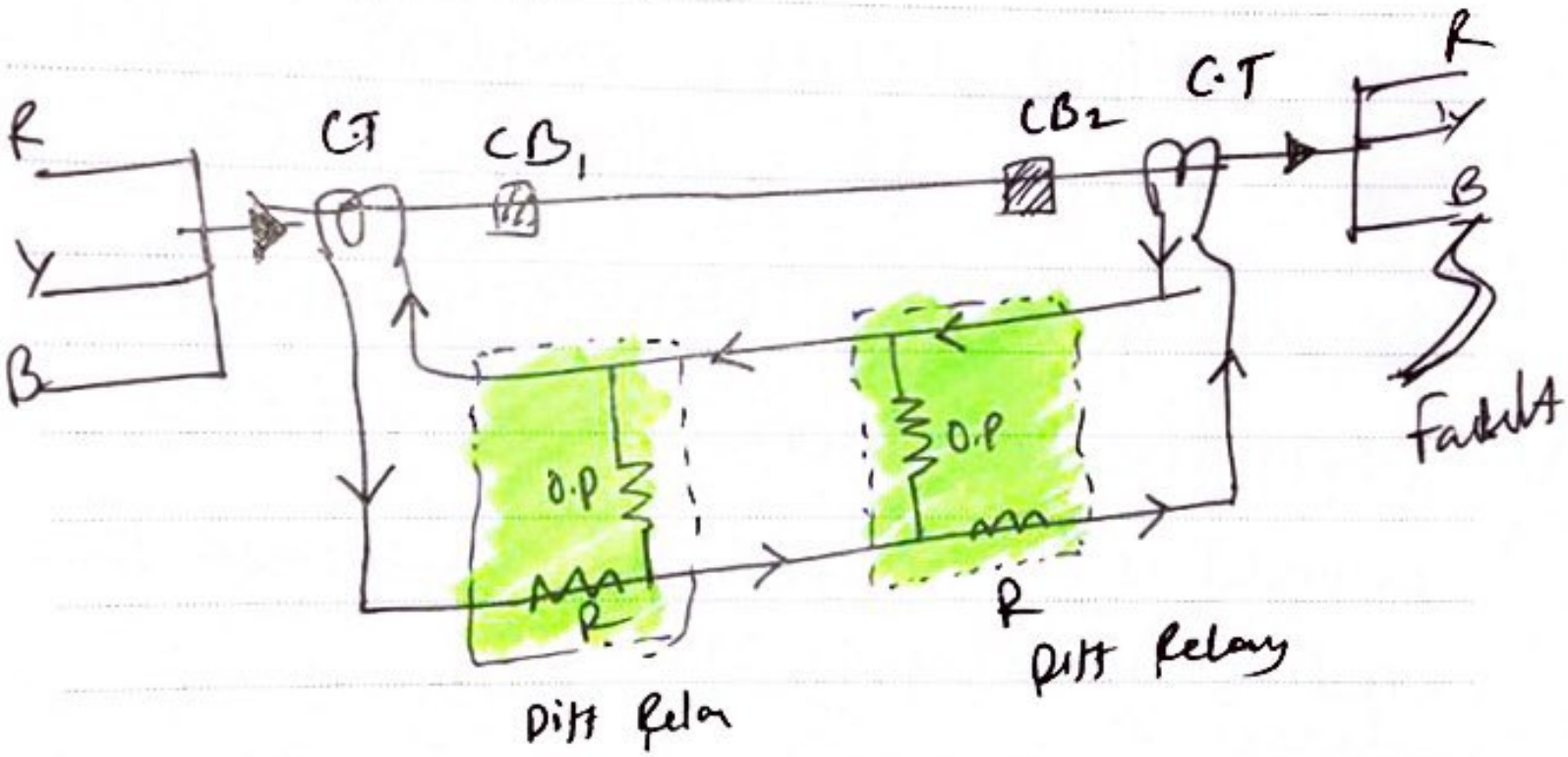


Balance Voltage Differential Protection

When the fault occurs in the protection zone, the current in the CTs become unbalance because of which the voltage in the secondary of the CTs disturbs. The current starts flowing through the operating coil. Thus, the relay starts operating and gives the command to the circuit breaker to operates

Date:

In practice this is not how it is don



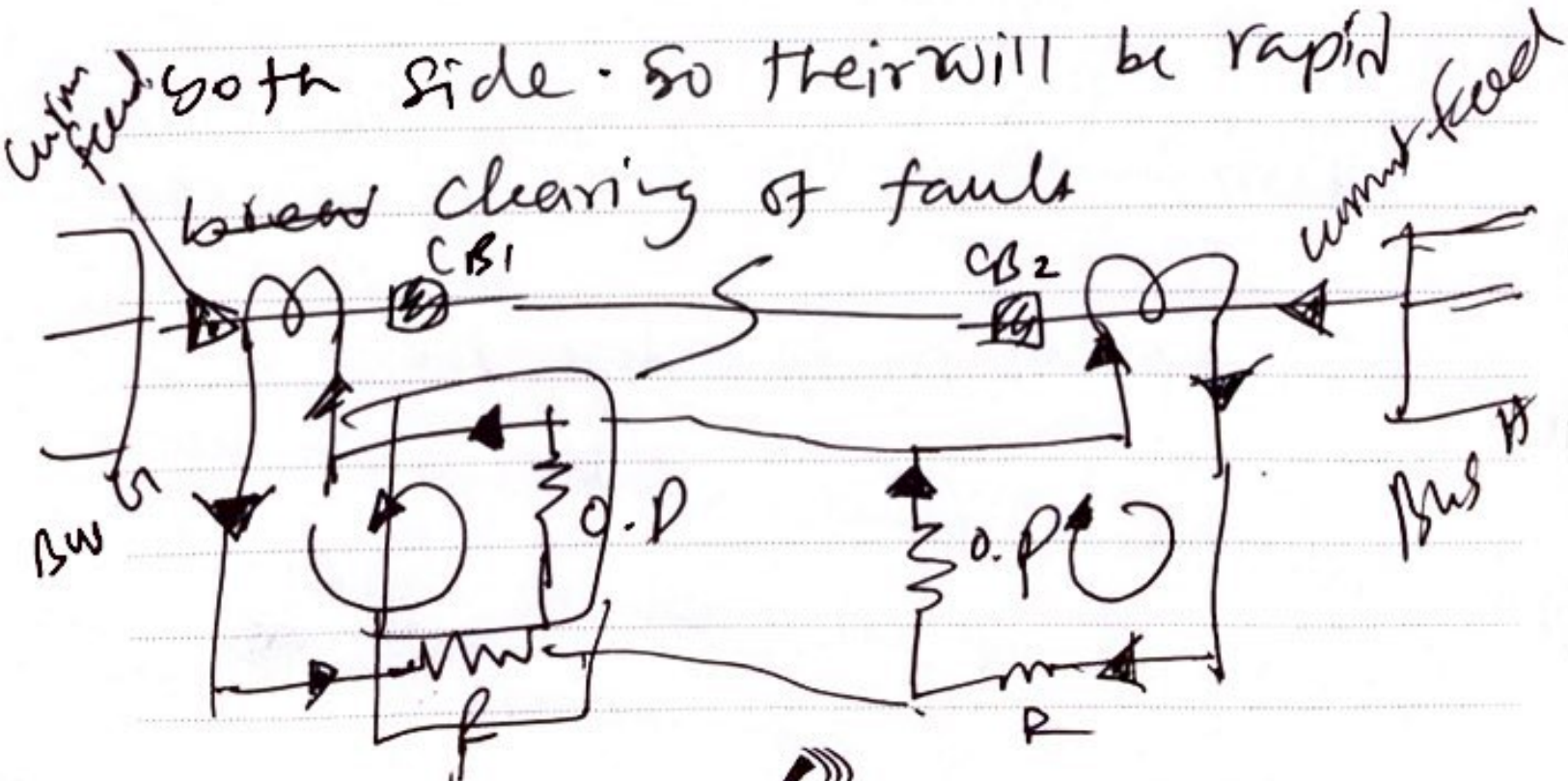
Restraining coil try to hold the O.P coil open

while O.P coil try to close them.

For external fault, small current will flow throug O.P coil which is not sufficient to open the CB or trip the Breker.

Date:

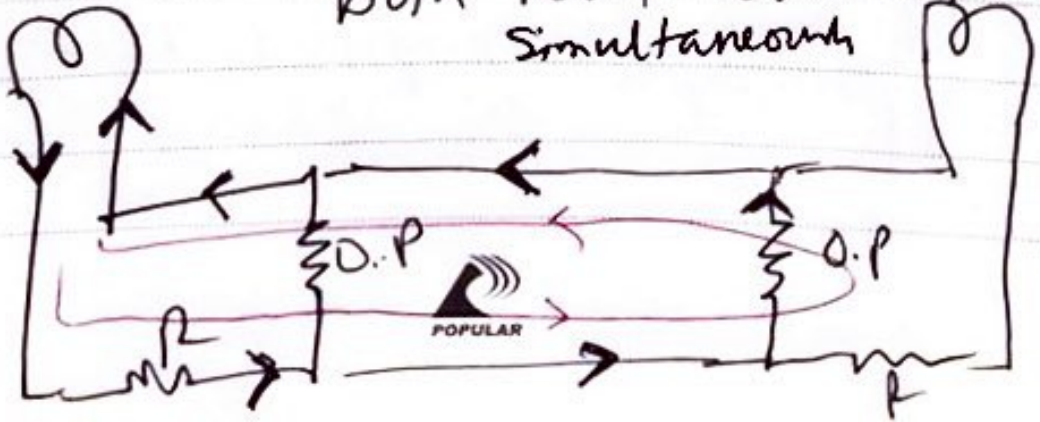
In case of Internal fault within the protected line current will feed from both end and. So large secondary current will flow through the operating coil. This coonts be sufficient to operate the relay and trip the Breaker in both side. So their will be rapid clearing of fault



In Most case the feed current magnetude is not Identical. Exact valu depends on location of fault and also amount of fault current available from each side. For this reason a small amount of balancing current will flow throug pilot wires.

extrem case

if BUS H does not provide any fault current than, C.T Secondary current will now flow along the pilot wires and past through the both O.P coil so both relay will operate Simultaneously



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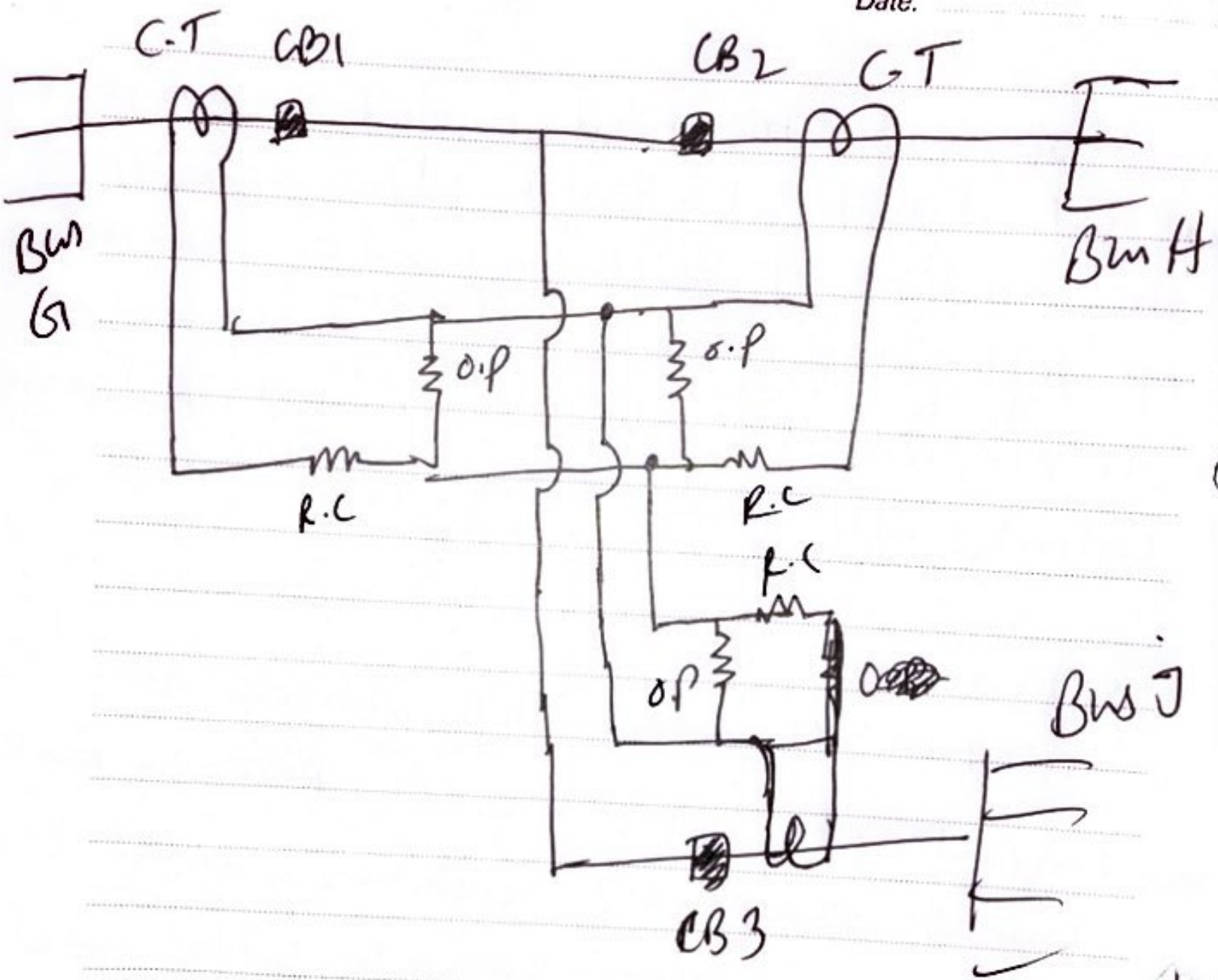

This simplified schematic explain the principle of pilot relays