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Internal Assessment Test - I

Sub:	POWER SYSTEM PROTECTION							Code:	18EE82
Date:	30/10/2023	Duration:	90 mins	Max Marks:	50	Sem:	7th A & B	Branch:	EEE

Answer Any FIVE FULL Questions

		Marks	OBE CO	OBE RBT
1.a	Explain the Classification of Protective Relays.	6	CO1	L2
1.b	List the merits and demerits of Electromagnetic relay.	4	CO1	L1
2.a	Explain the importance of automatic reclosing.	5	CO1	L2
2.b	Explain the essential qualities of a protective relay.	5	CO1	L2
3.a	Draw a neat sketch of induction disc relay and discuss its operating principle.	8	CO2	L2
3.b	Define the following term. i. Pick up level ii. Reset	2	CO2	L1

P.T.O

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4.a	What are the various type of over current relay? Compare the time-current characteristics of inverse, very inverse and extremely inverse overcurrent relay.	6	CO2	L1
4.b	Derive an expression for torque produced by an induction relay.	4	CO1	L2
5.a	Determine the actual time of operation of a 5 ampere, 3 second over current relay having a current setting of 125% and a time setting multiplier of 0.6 connected to supply circuit through a 400/5 current transformer when the circuit carries a fault current of 4000 a. time of operation is 3.5 seconds for the estimated value of PSM.	4	CO1	L3
5.b	With a neat circuit diagram explain directional earth fault relay.	6	CO2	L2
6.a	Draw the schematic diagram of numerical relay and briefly describe the functions of its various components.	5	CO1	L2
6.b	Explain phase fault protective scheme.	5	CO2	L2

CCI **HOD**

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CCI **HOD**

Solution

Q.1. a

CLASSIFICATION OF PROTECTIVE RELAYS

→ Protective relays can be classified depending on their construction, function, protective schemes etc.

I classification based on Technology:

* Depending on technology protective relays can be classified as
  (i) Electro magnetic relays
  (ii) Static relays
  (iii) Micro processor-based relay

II Classification based on function:

* Depending on the duty they perform they can be classified as
  (i) overcurrent relay
  (ii) Under voltage relay
  (iii) Impedance relay
  (iv) Under frequency relay
  (v) Directional relays

CLASSIFICATION OF PROTECTIVE SCHEMES

* A protective scheme is used to protect an equipment or section of a line.
* Protective scheme mainly includes one or more relays of same or different type.
* The following are the common protective schemes used:
  (i) over current protection
  (ii) Distance protection
  (iii) Carrier-current protection
  (iv) Differential protection

Q.1.b

Advantages or merits:

- Electromagnetic relays have fast operation and fast reset
- They can be used for both ac and dc systems for protection of ac and dc equipments

- Electromagnetic relays operating speeds which has the ability to operate in milliseconds are also can be possible
- They have the properties such as simple, robust, compact and most reliable
- These relays are almost instantaneous. Though instantaneous the operating time of the relay varies with the current. With extra arrangements like dashpot, copper rings etc. slow operating times and reset can be possible.

Disadvantages or demerits:

-
- High burden level instrument transformers are required (CTs and PTs of high burden is required for operating the electromagnetic relays compared to static relays)
- Requires periodic maintenance and testing unlike static relays
- Relay operation can be affected due to ageing of the components and dust, pollution resulting in spurious trips
- Operation speed for an electromagnetic relays is limited by the mechanical inertia of the component

Q. 2.a

AUTOMATIC RECLOSING

* About 90% of faults on OH lines are transient in nature. ie momentary variations in current or voltage.
* These transients are usually caused by lightning or external bodies falling on the line.
* Such faults are associated with arc. (b/w Ph & ground supporting structure).
* Then the line will be disconnected.
* Now immediately after fault is cleared, the CB can be reclosed automatically.
* Most of the faults on EHV lines is due to lightning. Because of over voltage caused by lightning, flashover occurs on the insulation. This exist only for short time.
* So they use only one instantaneous reclosure in case of EHV lines. Usually reclosure is in 12 cycles.
* On lines upto 33 kV, most faults are due to falling trees on lines. So fault might not be cleared during 1st reclosure. So additional reclosures are required.
* Usually 3 reclosures at 15 - 120 sec intervals.
* If fault is not cleared after 3 reclosures, it is considered as permanent fault.

Q.2.b

ESSENTIAL QUALITIES OF PROTECTION :

* The basic requirements of a protective system are :
  - (i) Selectivity or discrimination
  - (ii) Reliability
  - (iii) Sensitivity
  - (iv) Stability
  - (v) Fast operation

(i) Selectivity or discrimination :-

* Selectivity is the quality of protective relay by which it is able to discriminate between a fault in the protected zone & normal operation.
* It should also be able to distinguish whether the fault is in the zone of protection or outside zone of protection. These qualities are known as DISCRIMINATION.

* When fault occur on a power system, only the faulty part should be isolated. Healthy part should remain intact.
* So for this, relay should be able to discriminate between faut & transient conditions. like, power surges or inrush Xmer currents.

NOTE

* power surge: over supply of V for few seconds
* inrush Xmer I: When core become saturated, X mer 1° req : more I to prod flux

(ii) RELIABILITY :

* A protective system must operate reliabily when a fault occurs in its zone of protection.
* Failure of a protective system might be due to failure of any one or more elements of protective system.
* Important elements of a protective system are protective relay, CB, CT, PT, wiring, battery etc.
* To attain greater reliability, more attention should be given to design, installation, maintenance & testing of various protective elements.
* Robustness & simplicity of relaying also contribute to reliability.
* 3 things add to reliability, they are
  - → Contact pressure of relay
  - → contact material of relay
  - → prevention of contact contamination of relay.
* Value of reliability will be 95%.

(iii) Sensitivity :

* A protective relay should operate when magnitude of current exceeds preset value.
* This value of current is called Pick-up current.
* Relay should not operate when magnitude of current is below pick-up current.
* Relay should be sensitive to operate when current exceeds its pick-up current.

(iv) Stability :

* A protective s/m should remain stable even when large current is flowing through the system due to external faults.
* The connected CB in the protective zone is supposed to clear the fault.

(v) Fast operation :

* A protective s/m should be fast enough to isolate the faulty element of s/m.
* It should be quick to minimize damage of the equipments & thus to maintain the system reliability. and stability.
* Operating time should not exceed the critical clearing time, so that connected machines do not lose synchronism.
* Fast operation also reduces damage of equipments from burning due to heavy fault currents, interruption of supply
* & loss of industrial loads.
* Operating time is usually one cycle.
* Half cycle relays are also available.
* Distribution side, operating time is more than one cycle.

Q.3.a

* Fig 2.4 shows an electromagnetic directional relay.
* Direction relay is energized by 2 quantities, namely Voltage & current.

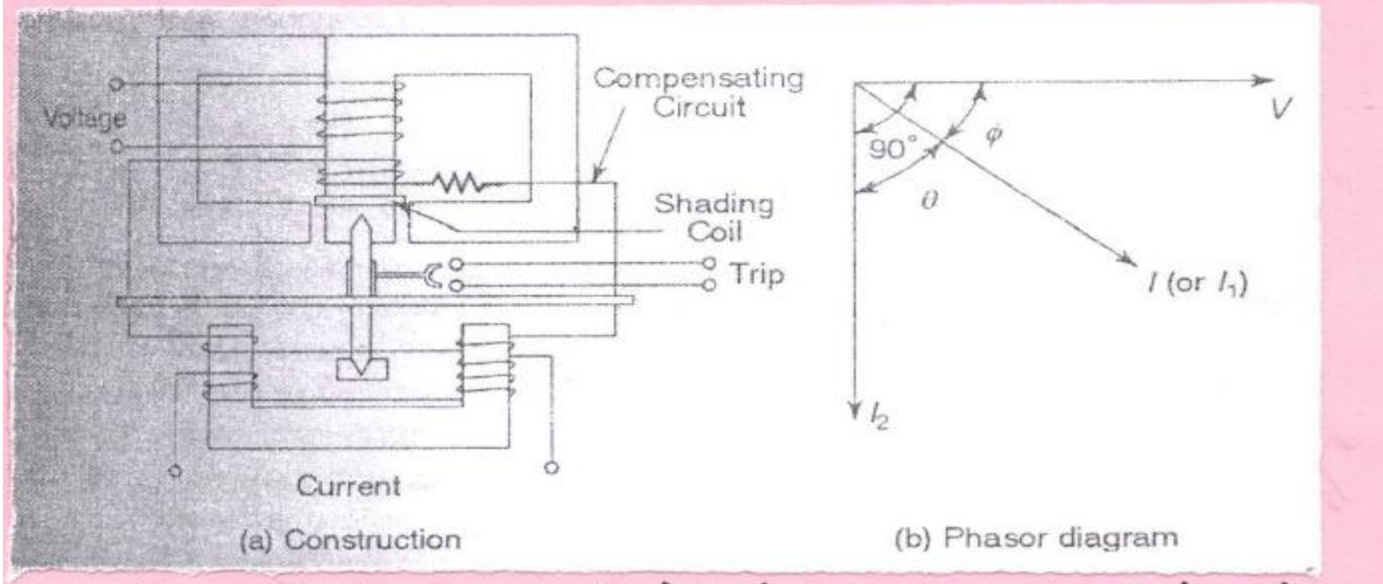


Fig 2.4 Induction Disc type directional relay

* Fluxes ϕ_1 & ϕ_2 are setup by voltage & current respectively.

* Flux ϕ_1 induces Eddy currents, these interact with ϕ_2 and thus produces Torque.

* Similarly flux ϕ_2 induces Eddy currents in the disc, which interact with ϕ_1 and produce a Torque.

* This resultant torque rotates the disc.

* Torque is proportional to $VI \cos\phi$.
  where $\phi \rightarrow$ Ph angle b/w V & I.

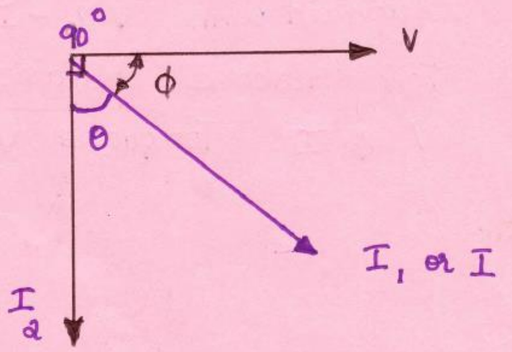
* So from equation we can say Torque is maximum when $\phi = 0$, $\therefore$ $\cos 0 = 1$ ie when there is no Phase difference between V & I. (ie in phase).

* To produce maximum Torque during fault conditions, when Pf is very poor, a compensating winding & Shading is provided.

* We have already discussed in previous chapter that Torque produced by induction relay is given by
  $T = \phi_1 \phi_2 \sin\theta \propto I_1 I_2 \sin\theta$ where ϕ_1 & ϕ_2 are flux produced by I_1 & I_2.

The angle b/w ϕ_1 & ϕ_2 or I_1 & I_2 is θ as shown in pr

$\angle$ b/w ϕ_1 & $\phi_2 \rightarrow \theta$



→ Load current I or I_1 lags behind V by angle ϕ

→ I in voltage coil (I_2) lags behind V by 90°

$$T = I_1 I_2 \sin(90 - \phi) \propto I_1 I_2 \cos\phi \propto VI\cos\phi$$

Q.3.b

Reset:

This is the value of the current or voltage, etc. below which a relay opens its contacts and comes back to its original position. The ratio of the drop-out voltage or reset value to the pick or operating value is called the drop-out or reset ratio.

Current setting:

The **current setting of relay** is expressed in percentage ratio of relay pick up current to the rated secondary current of CT.

That means,

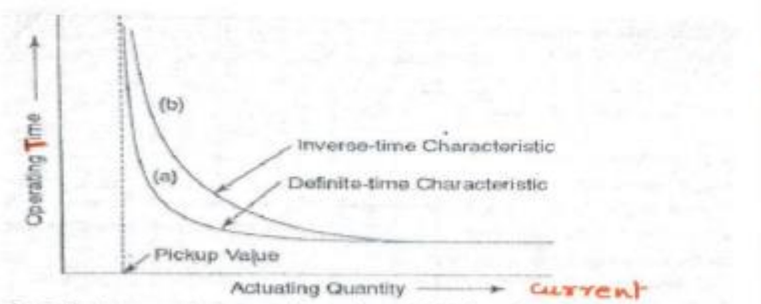
$$Current\ setting = \frac{Pick\ up\ current}{Rated\ secondary\ current\ of\ CT} \times 100\%$$

Q.4.a

→ Variety of time-current characteristics is available.

→ The name assigned to the relay indicates the characteristics as described below

1. Definite-time overcurrent relay:
   * operates after a predetermined time, when current exceeds pick-up value.
   * Fig(a) shows the time-current characteristics
   * The operating time is constant.
   * This definite time is fixed usually with the help of intentional time delay mechanism, provided in the relay unit.



Definite-time and inverse-time characteristics of overcurrent relays

Instantaneous overcurrent relay

* This relay also operates in definite time when the current exceeds the pick-up value.
* Here also the operating time is constant, irrespective of the current.
* Curve is shown in previous Fig.(a)
* Here the only difference is that it is not having any intentional time delay. It operates in 0.1 sec or less.
* Relays having operating time < than 0.1 sec are termed as "high set" or "high speed" relays.

3. Inverse time Overcurrent Relay:

* operates when current exceeds its pick-up value.
* Here operating time is not constant.
* The operating time decreases as the current increases.
* Curve (b) in fig shows inverse time characteristics.

4. Inverse definite Minimum Time Overcurrent Relay (IDMT)

* It gives inverse-time characteristics at lower values of fault current.
* Also gives definite-time characteristics at higher values of fault current.
* Usually inverse-time characteristics is obtained when Plug setting multiplier is below 10.
* For PSM between 10 & 20 characteristics tend to become a straight line.
* Characteristics is shown in Fig (next page).

5. Very Inverse-time Overcurrent Relay:

* It gives more inverse-time characteristics than IDMT relay.
* Its time-characteristics lies between IDMT & extremely inverse-time characteristics.
* This has better Selectivity than IDMT relay.
* When IDMT fails this can be used.
* Standard time-current characteristics is given by

6. Extremely Inverse - time Overcurrent Relay:

* Chara is more inverse than IDMT & very inverse - time.
* When IDMT & very - inverse time relay fails, this is used.
* IDMT relays cannot be graded with fuse.

time charac of fuse,

$$I^{3.5} \cdot t = k \quad ie \quad I^{n} \cdot t = k$$

* Electro magnetic relay have the steepest inverse - time characteri- -stics.
* time current characteristics of extremely Over - current relay

$$I^{2} \cdot t = k.$$

* Most suited for protecting machines against overheat.
* Also used for protection of alternators, power transformers, earthing transformers, cables etc. Because heating characteristics of these are governed by $I^2 \cdot t = k$.

7. Special characteristics:

* time current characteristics greater than extremely inverse relay.
* Used in industrial applications.
* time current chara is $I^{n} = k$. where $n = 2$.
* To protect rectifier transformers $I^{8} = k$ is needed.
* It is suitable to be graded with fuse

DEFINING SHAPE OF TIME CURRENT CHARACTERISTICS

general expression, $t = \dfrac{k}{I^{n} - 1}$

IDMT relay $t = \dfrac{0.14}{I^{0.02} - 1}$

very - inverse $t = \dfrac{13.5}{I - 1}$

Extremely inverse $t = \dfrac{80}{I^{2} - 1}$

Q.4.b

by brief

Theory of Induction Relay Torque

Fluxes ϕ_1 and ϕ_2 are produced in a disc type construction by shading technique. In watt-metric type construction, ϕ_1 is produced by the upper magnet and ϕ_2 by the lower magnet. A voltage is induced in a coil wound on the lower magnet by transformer action. The current flowing in this coil produces flux ϕ_2. In case of the cup type construction, ϕ_1 and ϕ_2 are produced by pairs of coils, as shown in Fig. 2.13. The theory given below is true for both disc type and cup type induction relays. Figure 2.14 shows how force is produced in a rotor which is cut by ϕ_1 and ϕ_2. These fluxes are alternating quantities and can be expressed as follows.

$$\phi_1 = \phi_{1m} \sin \omega t \qquad \phi_2 = \phi_{2m} \sin (\omega t + \theta)$$

where θ is the phase difference between ϕ_1 and ϕ_2. The flux ϕ_2 leads ϕ_1 by θ.

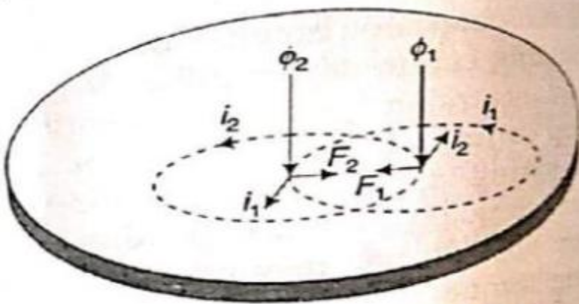


Fig. 2.14 *Torque produced in an induction relay*

Voltages induced in the rotor are:

$$e_1 \propto \frac{d\phi_1}{dt}$$

$$\propto \phi_{1m} \cos \omega t$$

$$e_2 \propto \frac{d\phi_2}{dt}$$

$$\propto \phi_{2m} \cos (\omega t + \theta)$$

As the path of eddy currents in the rotor has negligible self-inductance, with negligible error it may be assumed that the induced eddy currents in the rotor are in phase with their voltages.

$$i_1 \propto \phi_{1m} \cos \omega t$$

$$i_2 \propto \phi_{2m} \cos (\omega t + \theta)$$

The current produced by the flux interacts with other flux and vice versa. The forces produced are:

$$F_1 \propto \phi_1 \, i_2$$

$$\propto \phi_{1m} \sin \omega t \cdot \phi_{2m} \cos (\omega t + \theta)$$

$$\propto \phi_{1m} \, \phi_{2m} \cos (\omega t + \theta) \cdot \sin \omega t$$

Q.5.a

Rated secondary current of CT = 5 A

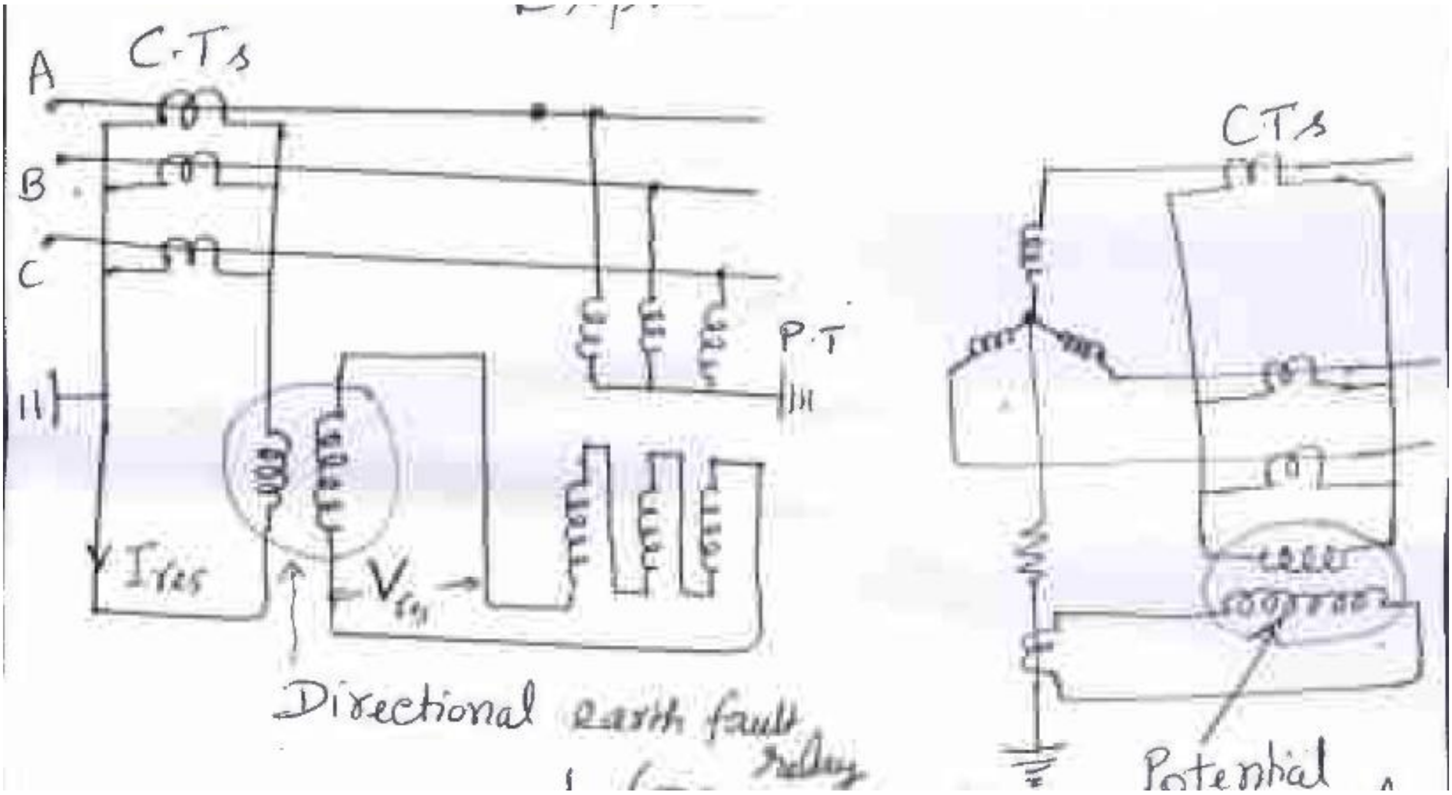
Pickup current = 5 x 1.25 = 6.25 A

Fault current in relay coil = 4000 x 5/400 = 50 A

Plug-setting multiplier (P.S.M.) = 50/6.25 = 8

Given when P.S.M is 8 time operation is 3.5 Sec.

Q.5.b



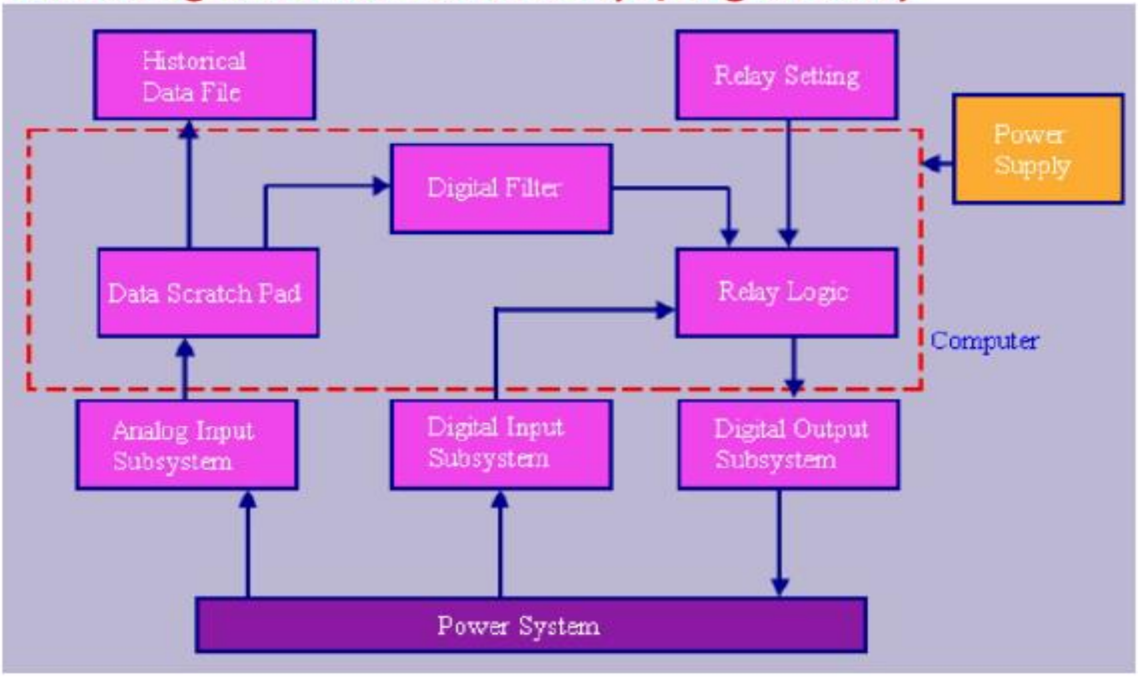
Overcurrent Protection 87

overcurrent relays discussed earlier. It contains two elements, a directional element and an I.D.M.T. element. The directional element has two coils. One coil is energised by current and the other by voltage. The current coil of the directional element is energised by residual current and the potential coil by residual voltage, as shown in Fig. 3.18 (a). This connection is suitable for a place where the neutral point is not available. If the neutral of an alternator or transformer is grounded, connections are made as shown in Fig. 3.18(b). If the neutral point is grounded through a P.T. the potential coil of the directional earth fault relay may be connected to the secondary of the P.T. The I.D.M.T. element has a plug setting of 20% to 80%.

Q.6.a

- Microprocessor-based relay, works on numbers representing instantaneous values of the signals. Hence, they are named **numerical relay.** Other popular nomenclatures for such relays are **digital relay,computer-based relay** or **microprocessor-based relay.**
- In numerical relays, the software, runs in the background and which actually runs the relay.
- What distinguishes one numerical relay from the other generally is the software.
- Conventional relay performs comparison only .
- The numerical relay does not have any such limitation because of its ability to perform real-time computation.
- ExistIng relaying concept can be implemented using the numerical technique.
- The possibilities of developing a new numerical relay are almost endless and there is very little standardization.

Block Diagram of Numerical Relays / Digital Relay



- The signals from the CTs and VTs are first passed through a low-pass filter, which has to be an analogue type of filter, because digital processing can only take place after the frequency spectrum of the signal is properly shaped.
- Next, the analogue signal is sampled and held constant during the time the value is converted to digital form.
- The range of frequencies that can be handled by the analogue-to-digital converter (ADC) without the sample and hold (S/H) circuit is extremely low

- The sampled and held value is passed on to the ADC through a multiplexer so as to accommodate a large number of input signals
- The sample and hold circuit and the ADC work under the control of the microprocessor and communicate with it wlth the help of control signals such as the *end-of conversion* signal issued by the ADC.
- The ADC passes on the digital representation of the instantaneous value of the signal to the microprocessor via an input port.
- The output of the ADC may be 4, 8, 12, 16, or 32 bits wide or even wider.
- The wider the output of the ADC, the greater its resolution

---

- The incoming digital values from the ADC are stored in the RAM of the microprocessor and processed by the relay software in accordance with an underlying relaying algorithm.
- The microprocessor issues the trip signal on one of the bits of its output port which is then suitably processed so as to make it compatible with the trip coil of the CB.
- The microprocessor can also be used to communicate with other relays or another supervisory computer, if so desired.
- The relaying program or the relay software, which resides in the EPROM, can only be upgraded or modified by authorized personnel.
- Thus, new features and functionalities can be added to an existing relay by upgrading its software.
- A numerical relay can be made to run a program which periodically performs a self diagnostic test and issues an alarm signal if any discrepancy is noticed.
- Other features like a watch-dog timer can also be implemented, which issues an alarm if the microprocessor does not reset it, periodically, within a stipulated time of a few milliseconds. This gives an increased user confidence and improves the reliability of the relay.

Q.6.b

4. PHASE FAULT PROTECTIVE SCHEME :

* Fig 2.13 shows three overcurrent relays for protection of 3 Phase s/m
* Mainly used for protection against Phase faults.
* Since there is no scheme of earth fault protection, overcurrent relays will also sense earth fault. But they will be less sensitive.

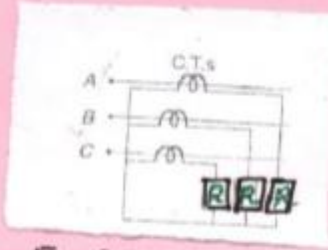


Fig 2.13 Three overcurrent relays