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Internal Assessment Test - I

Sub:	POWER SYSTEM PROTECTION							Code:	18EE82
Date:	21/10/2022	Duration:	90 mins	Date:	21/10 /2022	Duration:	90 mins	Date:	21/10/2022

Answer Any FIVE FULL Questions

		Marks	OBE	
			CO	RBT
1.a	With a neat diagram explain zones of protection in a power system.	6	CO1	L2
1.b	List the merits and demerits of static relay.	4	CO1	L1
2.a	Explain the various methods of back-up protection.	5	CO1	L2
2.b	Explain the essential qualities of a protective relay.	5	CO1	L2
3.a	With a neat sketch explain directional over current relay.	6	CO2	L2
3.b	Define the following term. i. Operating force ii. Pick up level	4	CO2	L1

P.T.O

<table>
<tr><td>4.a</td><td>Discuss a protective scheme for i) Protection of parallel feeders. ii) Protection of Ring Mains</td><td>6</td><td>CO2</td><td>L2</td></tr>
<tr><td>4.b</td><td>Derive an expression for torque produced by an induction relay.</td><td>4</td><td>CO1</td><td>L2</td></tr>
<tr><td>5.a</td><td>The current rating of an over current relay is 150% and the time setting (TMS) of 0.4.the C.T. ratio is 400/5. Determine the operating time of the relay for a fault current of 6000 A. At TMS=1 operating time at various PSM are given below table
<table>
<tr><td>PSM</td><td>2</td><td>4</td><td>5</td><td>8</td><td>10</td><td>20</td></tr>
<tr><td>Operating time in seconds</td><td>10</td><td>5</td><td>4</td><td>3</td><td>2.8</td><td>2.4</td></tr>
</table></td><td>4</td><td>CO1</td><td>L3</td></tr>
<tr><td>5.b</td><td>Draw the schematic diagram of numerical relay and briefly describe the functions of its various components.</td><td>6</td><td>CO1</td><td>L2</td></tr>
<tr><td>6.a</td><td>With a neat circuit diagram explain directional earth fault relay.</td><td>5</td><td>CO2</td><td>L2</td></tr>
<tr><td>6.b</td><td>Write note on overcurrent protective schemes.</td><td>5</td><td>CO2</td><td>L2</td></tr>
</table>

CCI CI HOD

PSP-IAT I –solution

Q.1.a

ZONES OF PROTECTION :

* Protection zone is that part of a power system, which is protected by certain protective scheme.

* Power system contains generators, transformers, bus bars, transmission & distribution lines etc. There is separate protective scheme for each of the elements in power system.

* Few of them are generator protection, transformer protection, transmission line protection, bus bar protection etc. Thus the power system is divided into a no: of zones of protection.

* Each protective zone covers one or at the most 2 elements of a power system. Thus the entire power system will be covered by protective zone. No part of the system is left unprotected.

* The various protective zones are shown in the figure below. Always the adjascent protective zones must overlap each other. This overlapping is unavoidable because even if one protective zone fails, always there is one another. If a fault occurs in the overlapping zone more CB's than the minimum necessary would trip.

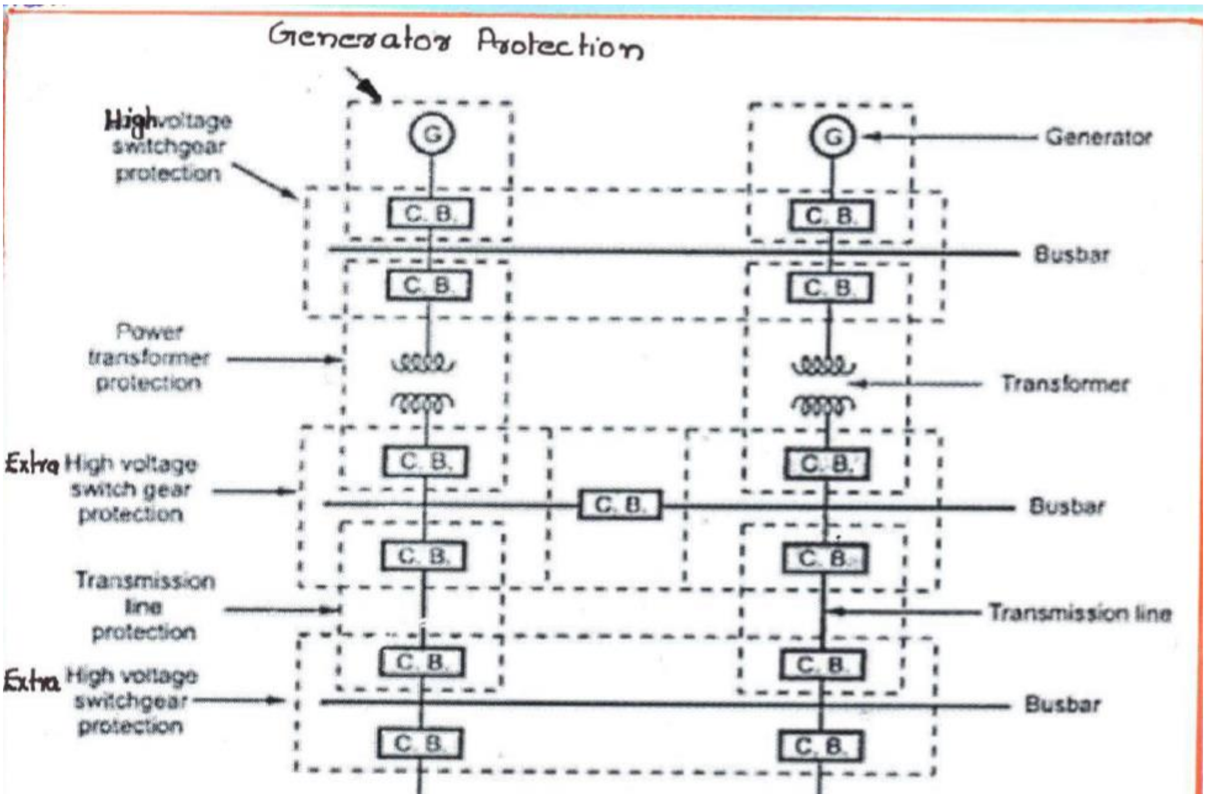

Fig: Zones of protection

Q.1.b

Demerits of Static relay

(i) Static relays are temperature sensitive.

(ii) Sensitive to voltage transients. Semiconductor components may get damaged due to voltage spike. Filters and shielding can be used for protection against overvoltage.

(iii) Static relays need an auxiliary power supply. It can be supplied using battery.

(iv) They have short time overload capacity.

(v) Less robust compared with electromagnetic relays.

(vi) Less overload capacity compared with electromagnetic relays.

(vii) Reliability is unpredictable, because there are large no: of small electronic components.

Merits of static relay

(i) Low burden on CT & PT.

(ii) Static relays consume less Power. Most cases they draw power from auxillary dc supply.

(iii) Fast response

(iv) Long life

(v) High resistance to shock and vibration.

(vi) Frequent operation will not cause any deterioration.

(vii) Less maintenance due to absense of moving parts and bearings.

(viii) Quick resetting and absence of overshoot.

(ix) Compact size

(x) Greater sensitivity as signal amplification can be achieved easily.

(xi) Wide range of operating characteristics can be obtained as the electronic circuits can perform a number of operations.

(xii) They have logic circuits which can be used in complex protective scheme.

Q. 2.a

PRIMARY AND BACKUP PROTECTION

* Power system is divided into various zones for its protection.
* There is a suitable protective scheme for each zone.
* If fault occur in a particular zone, it is the duty of primary relays to isolate the faulty element.
* Primary relay is the first line of defence.
* If the primary relay fails to operate, there is a back-up protective scheme. to clear the fault as the 2nd line of defence.
* Reliability of protective scheme should atleast be 95%. With proper design, installation and maintenance of the relays, circuit breakers, trip mechanism, ac & dc wiring etc, a very high degree of reliability can be achieved.

cause primary relay to fail.

* Back-up relays usually operate after a time delay to give primary relay sufficient time to operate.
* When Back-up relay operates, larger part of the power system is disconnected from power source.
* Back-up relay should be placed at a different station.
* It should be located such that it does not employ components (PT, CT, measuring units) common with primary relays.

* 3 types of Back-up relays:
  - (i) Remote back-up
  - (ii) Relay back-up
  - (iii) Breaker back-up

(i) REMOTE BACK-UP :

* Cheapest & Simplest form of back-up protection.
* Widely used back-up protection. mainly for transmission line.
* They will be located at neighbouring station and they back-up the entire primary protective scheme which [illegible] PT, CT and other elements incase of

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* Reliability of protective scheme should atleast be 95%. With proper design, installation and maintenance of the relays, circuit breakers, trip mechanism, ac & dc wiring etc, a very high degree of reliability can be achieved.
* Back-up relays are made independent of those factors that cause primary relay to fail.
* Back-up relays usually operate after a time delay to give primary relay sufficient time to operate.

includes relays, CB, PT, CT and other elements, incase of failure of 1° protective scheme.

* It is the most desirable protection, because it will not fail due to factors causing failure of primary protection.

(ii) RELAY BACK-UP:

* This is a kind of local back-up, in which additional relay is provided for back-up protection.
* It trips same CB if primary relay fails.
* This operation takes place without any time delay.
* This is costly and can be recomented where remote back-up is not possible.
* They should be supplied from separate current & potential Transf.

(iii) BREAKER BACK-UP:

* Also a local back-up.
* It is needed for bus-bar system where number of circuit breakers are connected.
* When a protective relay operates in response to a fault, but CB fails to trip, then the fault is treated as

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 fault & 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 occur 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 fauls.
* 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

DIRECTIONAL OVERCURRENT RELAY

→ For protection against ground faults, only one directional overcurrent relay is required.

→ It contains 2 elements one directional element and one IDMT element.

→ Directional element has 2 coils, one coil is energized by current and another is energized by Voltage.

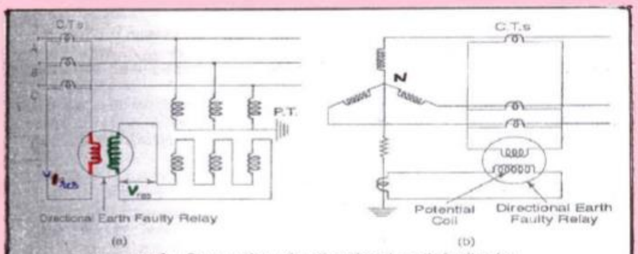


FIGURE 2.14 Connection of a directional earth fault relay

→ Current coil is energized by residual current (I_{res}) & Potential coil by residual voltage as shown in Fig 2.14 (a).

→ Here residual current $I_{res} = I_a + I_b + I_c$

residual voltage $V_{res} = V_{ae} + V_{be} + V_{ce}$

where V_{ae}, V_{be} & V_{ce} are phase V. or 2° voltages of PT

→ This connection is suitable for a place where neutral point is not available.

→ If neutral of an alternator or transformer is grounded, then the connections are made as in Fig 2.14 (b).

→ If N point is grounded through a PT, then potential coil of directional Earth fault relay may be connected to.

Q.3.b

Operating force:

Force required to operate relay.

Pick up level:

The range for operation of relay.

Q.4.a

* Parallel connection is needed to ensure continuity of supply and also for sharing of loads.

* Fig 2.9 shows an over-current Protective scheme for Parallel feeders.

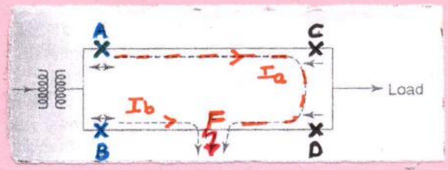


Fig 2.9 Protective scheme for Parallel Feeder

* At sending end of the feeder (A & B), non-directional relays are required. The symbol ⟷ indicates non-directional relay.

* At the load side end of the feeder directional overcurrent relays are used (at C & D). The relay at C & D operates only in the direction as shown by the arrow (←).

* When Fault occur at F, the current direction will be reversed, then the directional relay at D trips. (I_a)

* The relay at C does not trip, as the current flows in normal direction. (I_a)

* Whereas the relay at B also trips because of the overload current (high value of Fault current). Thus the faulty Feeder is completely isolated. And supply through healthy feeder is maintained.

* If non-directional relays are used at C & D, they will not trip for fault. So C & D are directional relays.

* $I_a + I_b = I_f$

* Ring Main system interconnects a series of Power stations. The direction of Power can be changed at will.

* Fig 2.10 a) shows an overcurrent scheme for protection of a ring Feeder.

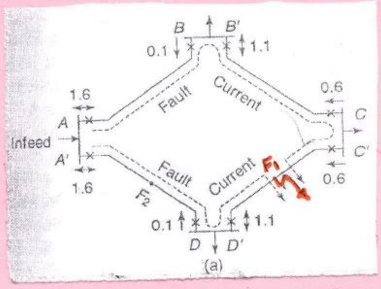
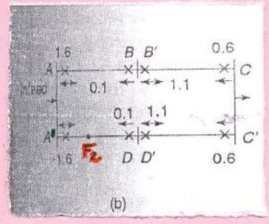


Fig 2.10 Protection of Ring feeder

* Fig 2.10(b) shows another way of drawing the same scheme.



* Protection of Ring main feeder is more costly. & complex.

* Each feeder requires 2 relays. Usually a non-directional relay at one end and a directional relay at the other end.

* operating time of the relay depends on grading.

* When Fault occur, relays C' & D' trip to isolate faulty feeder

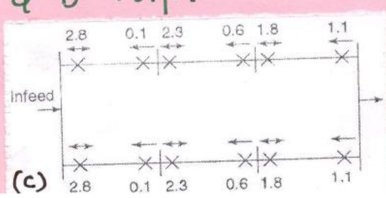
* Relay at C will not trip, as the fault current is not flowing in the tripping direction, though its operating time is same as C' (0.6).

* Same way B & D also will not trip (∵ fault is not in tripping direction), though the operating time is less than B' & D'.

* In Fig 2 (b) which is an alternative way of drawing Here only difference is loads are not shown on B & D. Just to make the diagram simple.

* There if Fault occur at F_2, A' & D trip.

* Fig 2.10 (c) is same scheme with more no. of feeders.



(c)

Q.4.b

by bridge

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.

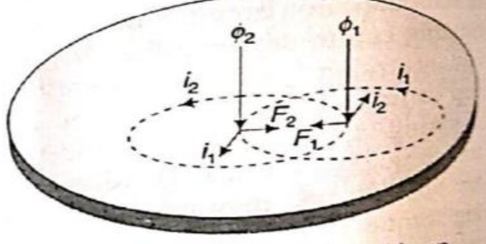


Fig. 2.14 Torque produced in an induction relay

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

Solution: CT ratio = 400/5 = 80

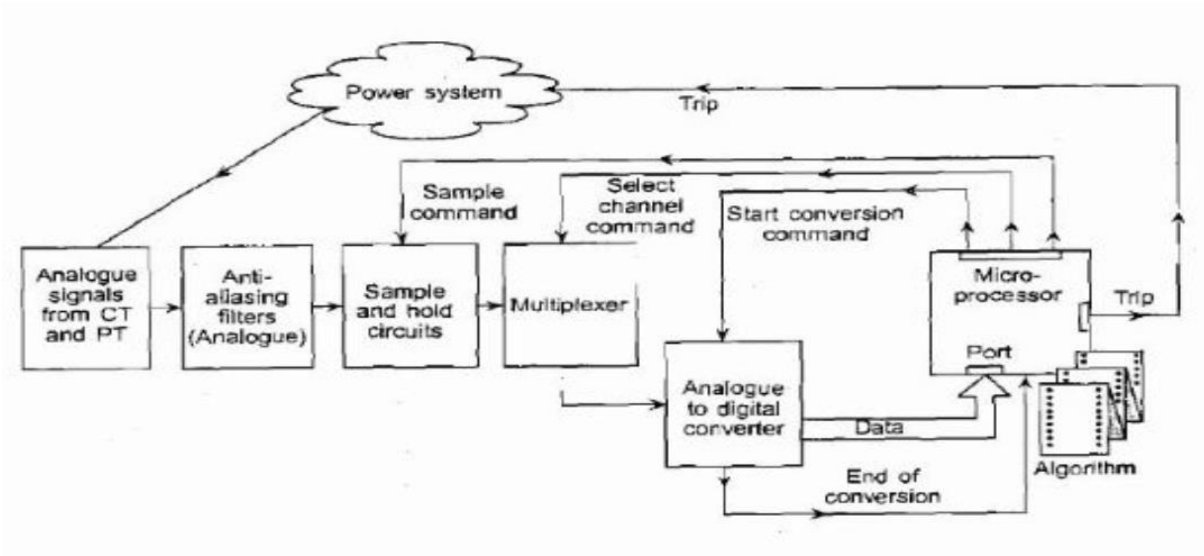
Relay current setting = 150% of 5 A = 1.5 × 5 A = 7.5 A

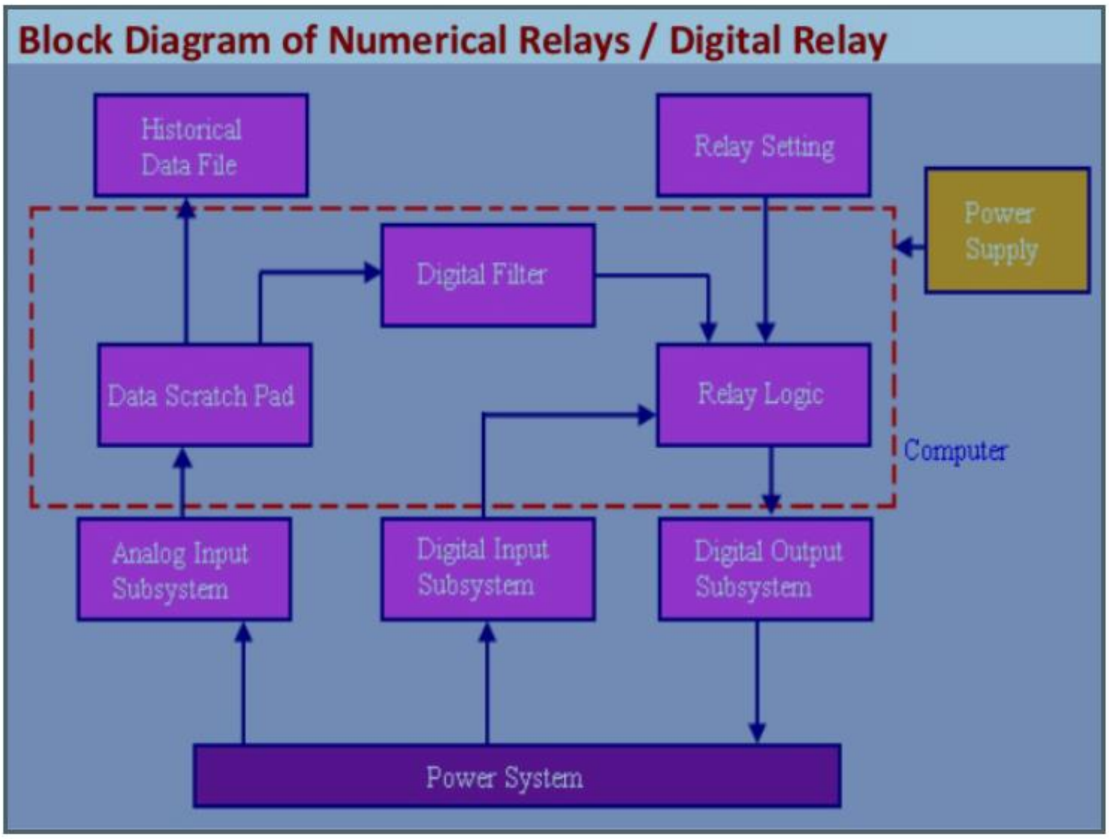
$$\text{PSM} = \frac{\text{Secondary current}}{\text{Relay current setting}} = \frac{\text{Primary current (fault current)}}{\text{Relay current setting} \times \text{CT ratio}} = \frac{6000}{7.5 \times 80} = 10$$

The operating time from the given table at PSM of 10 is 2.8 s. This time is for TMS = 1.

The operating time for TMS of 0.4 will be equal to 2.8 × 0.4 = 1.12 s.

Q. 5.b


Power system
Trip
Sample command
Select channel command
Start conversion command
Analogue signals from CT and PT
Anti-aliasing filters (Analogue)
Sample and hold circuits
Multiplexer
Micro-processor
Trip
Port
Analogue to digital converter
Data
End of conversion
Algorithm


Block Diagram of Numerical Relays / Digital Relay
Historical Data File
Relay Setting
Power Supply
Digital Filter
Data Scratch Pad
Relay Logic
Computer
Analog Input Subsystem
Digital Input Subsystem
Digital Output Subsystem
Power System

- 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.
- Existlng 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.

- 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.a

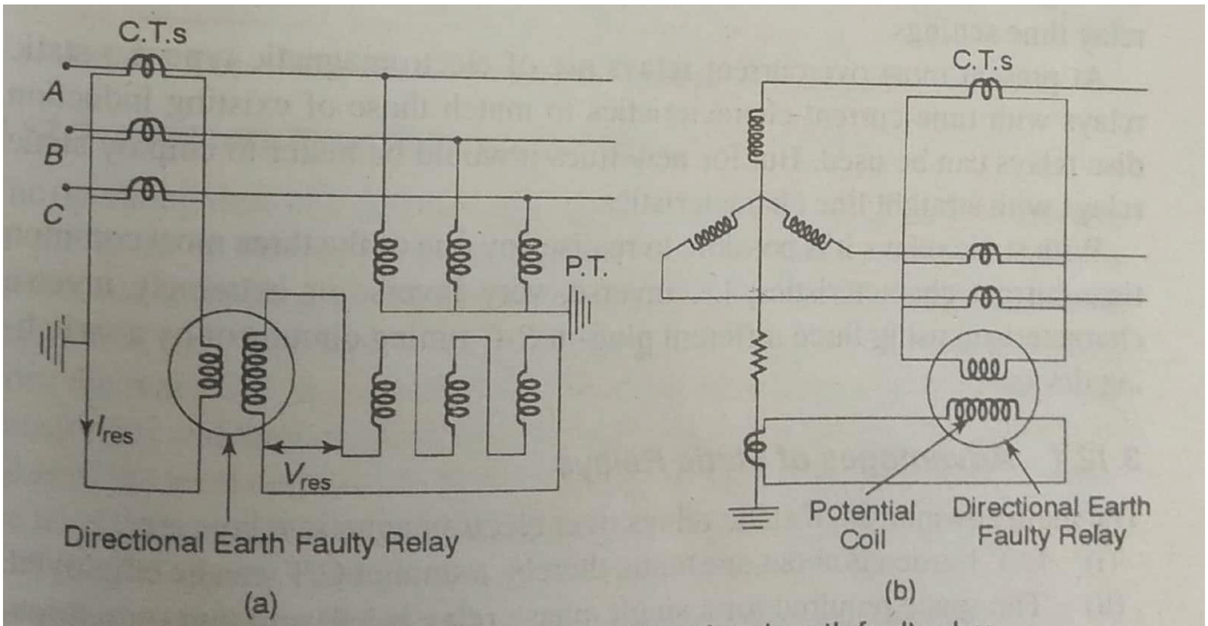


FIGURE 3.18 Connection of a directional earth fault relay

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 b

(i) Time - graded system
(ii) Current - graded system
(iii) Combination of time & current graded system

TIME GRADED SYSTEM

→ In this scheme definite-time overcurrent relays are used.

→ When definite time relay operates for a particular fault current, first it starts a timing unit, this timing unit trips the Circuit breaker only after a preset time.

→ This preset time is independent of the value of fault current

→ The operating time of the relay is adjusted in increasing order from the far end of the feeder.

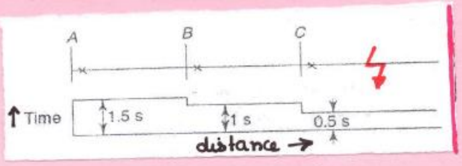


Fig 2.1 Time-graded Overcurrent Protection of a feeder

→ This is shown in Fig 2.1.

→ The difference in time setting is kept as 0.5 sec.

→ This difference is to cover the operating time of the CB and errors in the relay & CB.

→ Now we can reduce this time to 0.4 sec or 0.3 sec, with the help of fast circuit breakers & modern accurate relay.

→ When the fault is beyond C, then all relays come into action as the fault current flows through all of them.

→ Relay at C will have the least time setting. So it operates at 0.5 sec. & after fault is cleared. Then Relay at A & B will be reset.

→ In case if CB at C fails, then the fault remains uncleared, then relay at B operates & will trip CB at B, after 1 sec.

→ Now incase if B also fails, relay at A operates after 1.5 sec and thus CB at A trips.

(ii) CURRENT- GRADED SYSTEM

* In this scheme relays will pick-up the higher values of current.
* Usually that will be towards power source.
* Here we use <u>High- Speed instantaneous over-current relays</u>
* As seen in the figure 2.2, the operating-time is kept the same for all the relays.

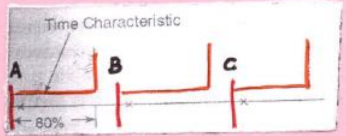


Fig 2.2. Instantaneous overcurrent Protection

* Current - setting of the relay corresponds to fault current level in the feeder section.
* For an ideal relay, The relay A should trip for faults between A & B. B should trip for faults between B & C. And C should trip for faults beyond C. But this ideal operation is not achieved due to following reasons :

COMBINATION OF CURRENT & TIME GRADING :

- Widely used for protection of distribution lines.
- Here also IDMT relays are used. They have combined features of current and time grading.
- IDMT relays have arrangements for current as well as time
- Current setting is made according to fault current level. Higher current levels are towards the source.
- Time - setting is also done increasing towards the source. Here also the difference in operating time is kept 0.5 sec.