Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.

2) The model answer and the answer written by candidate may vary but the examiner may should assess the understanding level of the candidate.

3) The language errors such as grammatical, spelling errors should not be given more importance (Not applicable for subject English and Communication Skills).

4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.

5) Marks may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.

6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate's understanding.

7) For programming language papers, credit may be given to any other program based on equivalent concept.

1 A Attempt any three 3x4 = 12 marks

1 A) a) State different causes of over voltages in power system network

1 A) a) Ans:

Causes of over voltages in power system network

a) Internal causes:
   i) Switching surges
   ii) Arcing grounds, — 3 marks
   iii) Insulation failures,
   iv) Resonance,
b) External causes:
   i) Lighting strokes, — 1 mark

1 A) b) Write essential features of good protective system.

1 A) b) Ans:

Essential features of protective relaying:

i) Selectivity: - It is the ability of protective system to select correctly that part of system in trouble and disconnect the faulty part without disturbing the rest of the system. — 6 points = 4marks,

ii) Speed: The relay system should disconnect the faulty section as fast as possible to prevent the electrical apparatus from damage and for system stability. — 4 to 5 points = 3 marks

iii) Sensitivity: - It is the ability of the relay system to operate with low value of actuating quantity.

iv) Reliability: - It is the ability of the relay system to operate under predetermined conditions. — 2 to 3 points = 2 marks

v) Simplicity: - The relay system should be simple so that it can be easily maintained.

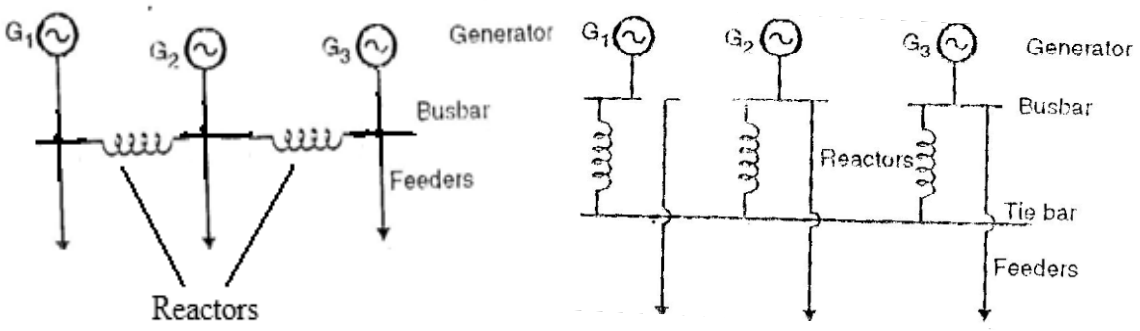
vi) Economy: - The most important factor in the choice of particular protection scheme is the economic aspect. The protective gear should not cost more than 5% of the total cost of equipment to be protected. — 1 point = 1 mark

1 A) c) Draw diagram of a) Bus bar reactor, b) Generator reactor, c) Feeder reactor.

1 A) c) Ans:

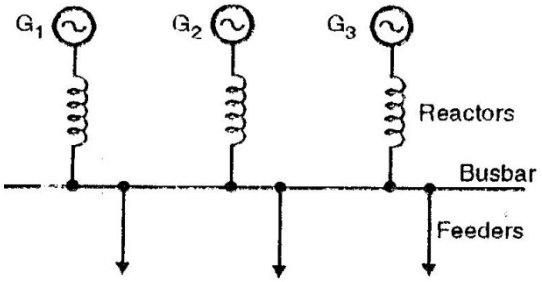
a) Busbar reactors:

(ring system) (tie bar system)



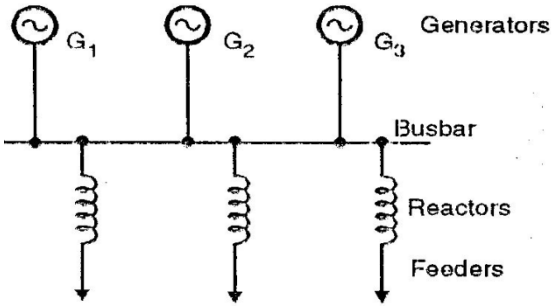
1 mark each = 2 marks

b) Generator reactors:



1 mark

c) Feeder reactors:



1 mark

1 A) d) Define: a) pickup current b) relay time c) plug setting multiplier d) reset current.

1 A) d) Ans:

a) **Pickup current:** the threshold value of operating current above which the relay operates.

b) **Relay time:** time interval between occurrence of fault and closure of relay contacts.

c) **Plug setting multiplier:** PSM = (Fault current in relay coil) / (Pickup current)

d) **Reset current:** The value of current below which the relay resets and comes back to its original position is called as reset current or dropout.

1 mark each = 4 marks

1 B Attempt any one: 6 marks

1 B a) Fig 1 shows single line diagram of three phase system. The percentage reactance of each alternator is based on its own capacity. Find short circuit current that will flow into a complete three phase short circuit at A.

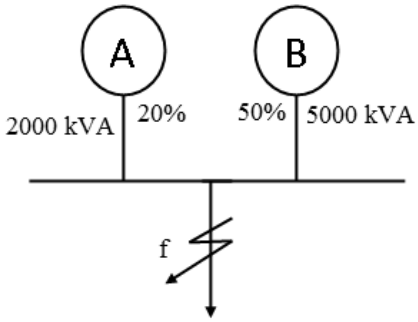


Fig 1

1 B a) Ans:

Assume base kVA = 5000 kVA

% reactance related to base kVA

% X = (base kVA/rated kVA) x percentage reactance at rated kVA 1 mark

Hence X_{GA} = (5000/2000) x 20% = 50 % 1 mark

and X_{GB} = (5000/5000) x 50% = 50 %. 1 mark

Total reactance up to fault at f =

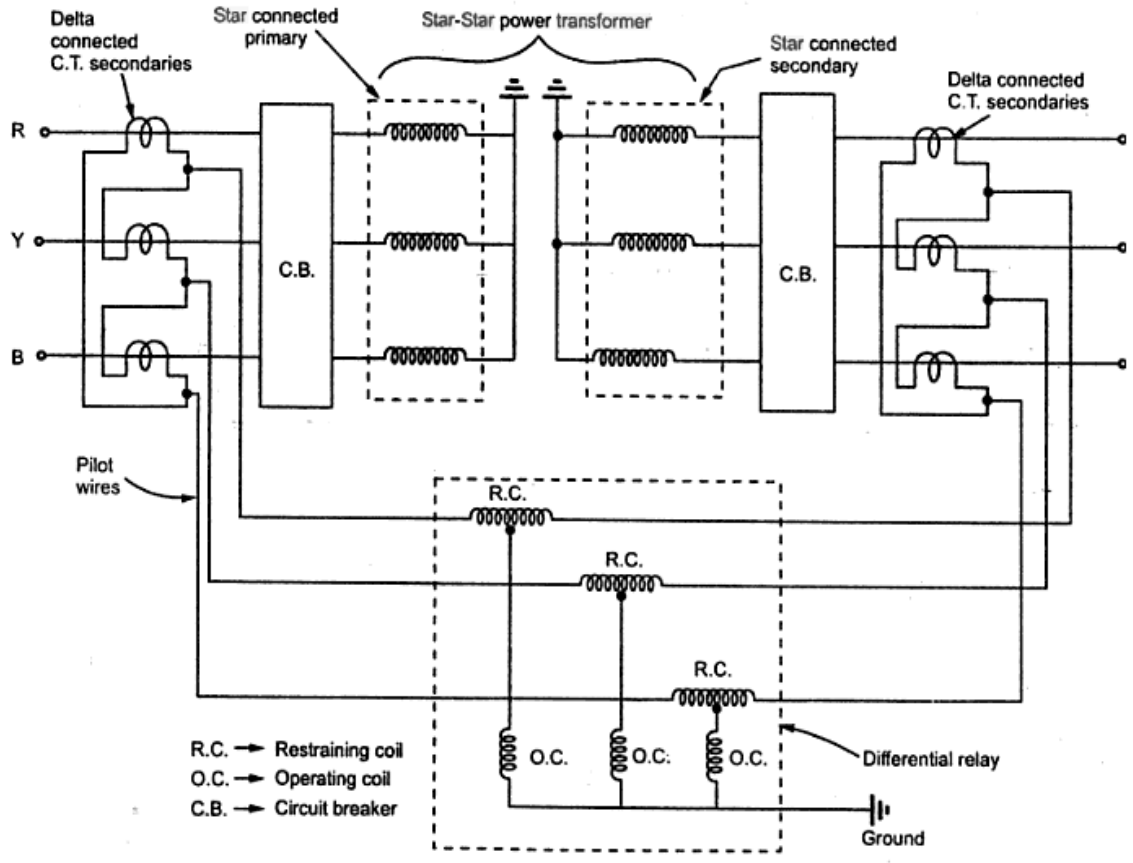
% X_f = (%X_{GA} || % X_{GB}) = [(50 x 50)/(50+ 50)] = 25 %. 1 mark

Short Circuit kVA = base kVA x 100/%X_f = 5000 x100/25 = 20000 kVA = 20 MVA. 2 marks

(Please note that the fault current cannot be calculated from given data as line voltage is not given, hence only short circuit kVA or MVA is expected).

1 B) b) Draw circuit for merz price protection for star – star connected 3 Ø power transformer

1 B) b) Ans:



Merz-Price protection for Star_Star transformer

Or equivalent fully labeled 6 marks,

partially labeled 3 to 5 marks,

Unlabeled 1 to 2 marks

2 Attempt any four 4 x 4 = 16

2 a) Define following terms:
a) Arc voltage b) Recovery voltage c) Restriking voltage d) RRRV

2 a) a) Arc Voltage : - It is the voltage that appears across the contacts of circuit breaker during the arcing period. 1 mark each = 4 marks

b) Recovery voltage : It is the normal frequency (50 Hz) r.m.s. voltage that appears across the contact of the circuit breaker after final arc extinction. It is approximately equal to the system voltage.

c) Restriking voltage : - It is the transient voltage that appears across the contacts at or near current zero during arcing period.

d) RRRV – It is defined as the rate of increase of restriking voltage and is abbrevinated by R.R,R.V. usually, the restriking voltage is in kv and time in microseconds so that RRRV is in kv/usec.

2 b) Compare HRC fuse and kit kat fuse on any four point.

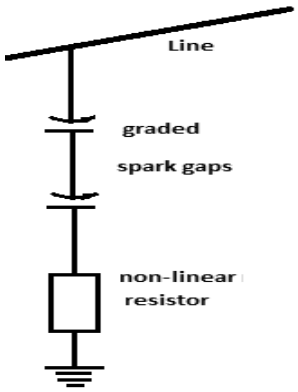
2 b) Ans:

Point of comparison	HRC Fuse	Kit kat Fuse
Construction	Fully sealed housing with arc interruption compound	Not sealed, is in contact with the air outside.
Operation	Fast	Slower
Rupture capacity	Accurately stated	Not as accurate
Operating time	Low & accurate	Not as accurate
Replacement	After every operation	After every operation
Size	Compact	Bigger
Cost	High	Low
Reliability	Higher	Lesser
Deterioration	Characteristics are unchanged with time as fully sealed	Deteriorate with time as not fully sealed.

1 mark each any four = 4 marks

2 c) Explain basic principle of lightning arrestor and enlist different types.

2 c) Ans:
The principle of lightning arrester is as follows:
Break down of series spark gaps and non-linear resistors at lightning voltages due to their characteristics of normal behavior (open circuit) at normal system voltages & breaking down to conduct when the voltage across them (to earth) rises due to lightning. On break down the lightning surge is conducted to earth after which when normal system voltage is regained the arrestor stops conduction to become normal. 1 mark



1 mark for figure

Types of lightning arrestors:
(i) Rod gap, (ii) Horn gap, (iii) Multi gap, (iv) Expulsion, (v) Thyrite or valve type

½ mark each, any four= 2 marks

2 d) State meaning of term reactance earthing, list any three advantages of reactance earthing. Explain what is several power protection.

2 d) Ans:

Reactance earthing:

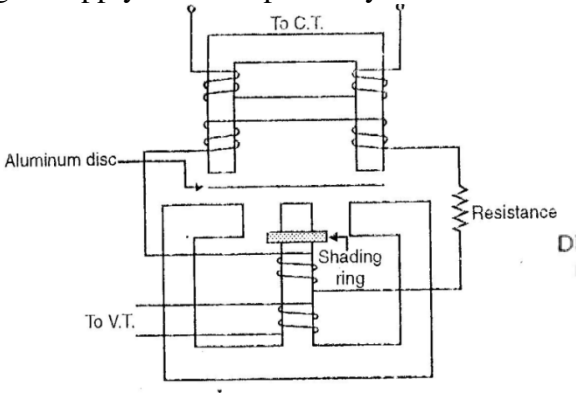
The connection of the neutral point to earth through an inductive reactance is called as reactance earthing. 1 mark

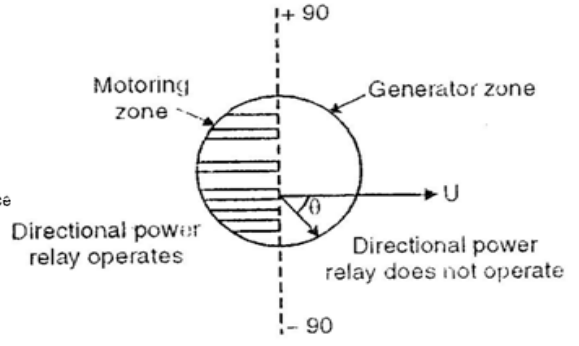
Advantages:

1) Limits short circuit currents in windings for winding to earth faults. 1 mark
2) For cable network the capacitively reactive fault current is neutralized to some extent.
3) CB capacity required is lowered.

Reverse power protection:

In the reverse power protection scheme which is used for alternators the directional relays are used to sense the reverse power (current) flow and trip the relevant CBs. For generators they operate when the machine enters the motoring mode that is the machine gets supply form the power system instead of supplying power. 1 mark





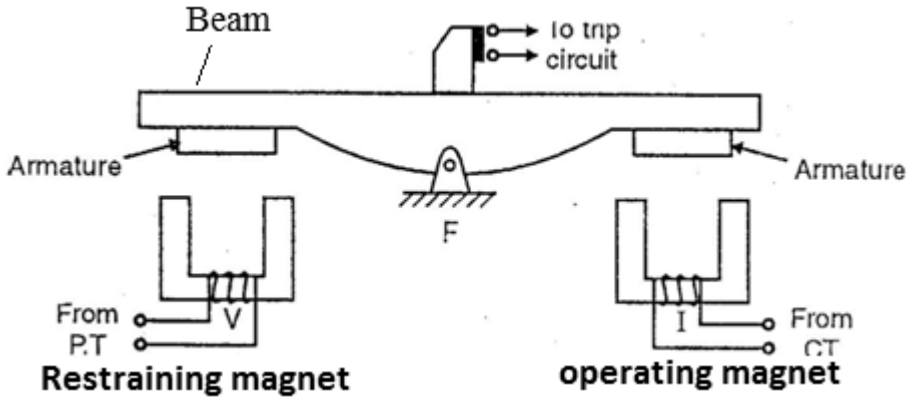
operating characteristics of reverse power relay

1 mark

2 e) Draw ckt. diagram of balanced beam type relay label its parts.

2 e) Ans:

Fully labeled 4 marks, else proportion lesser



2 f) Explain how inter turns faults in alternators is detected and how protection is given?

2 f) Ans:

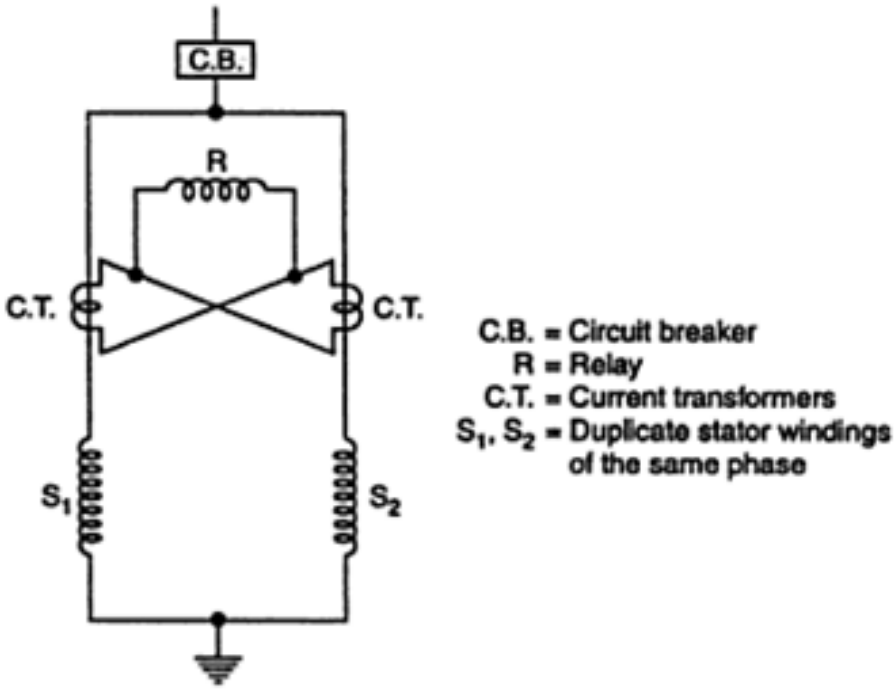


Diagram 2 marks

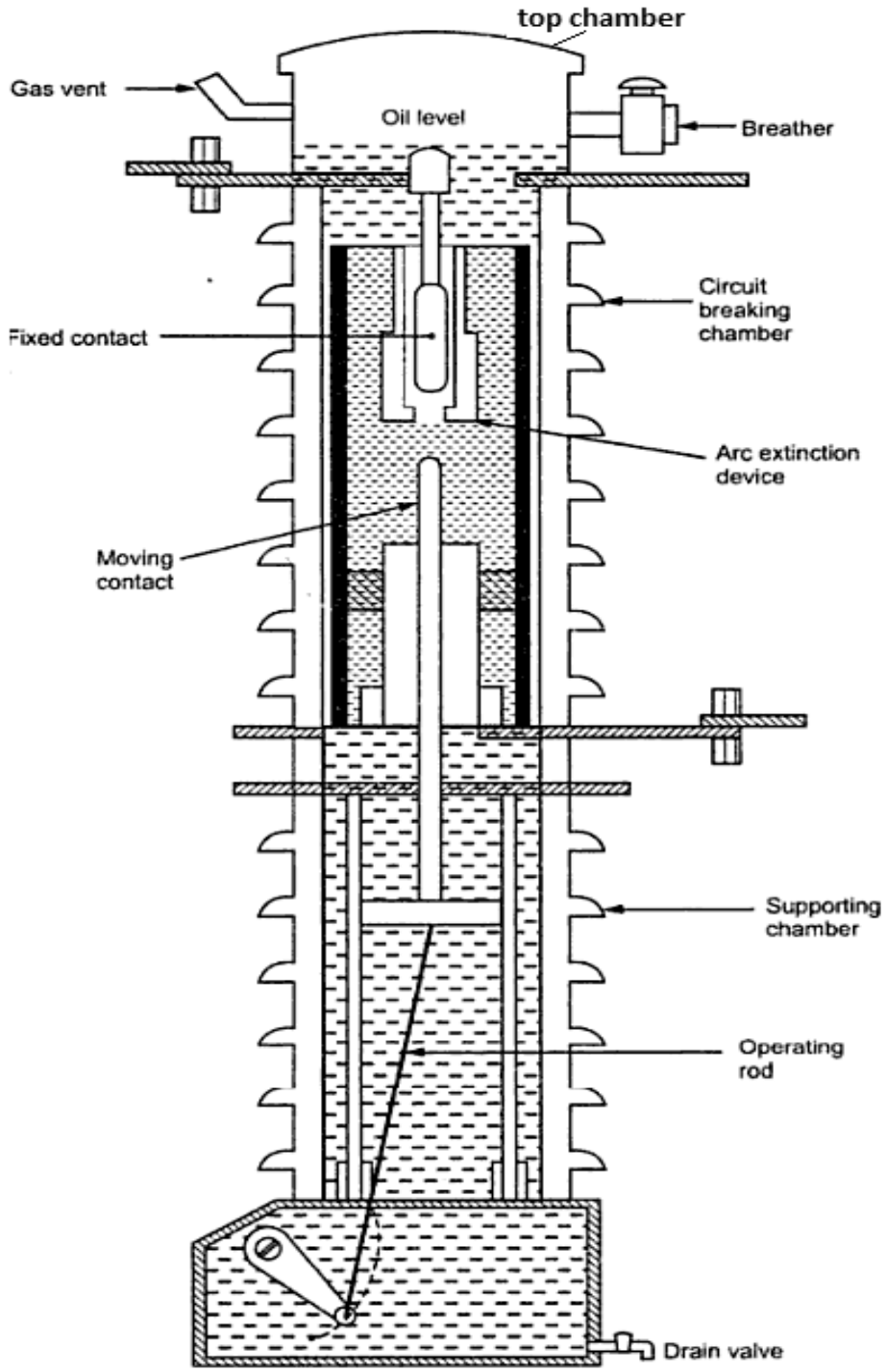
Figure shows scheme for one phase only. It is identical for other phases.
Under normal working conditions the two currents in the stator winding sections S_1 and S_2 are identical and by virtue of the cross connected CT secondaries the relay current is zero, hence no relay operation. But when one of the windings is faulty (inter turn fault) its current differs and hence the two CT secondary currents are different, due which the difference current is diverted through the relay coil to operate it leading to isolation of the alternator from the power system.

2 marks

3 Attempt any four: 16 marks

3 a) Draw neat circuit diagram of MOCB.

3 a) Ans:

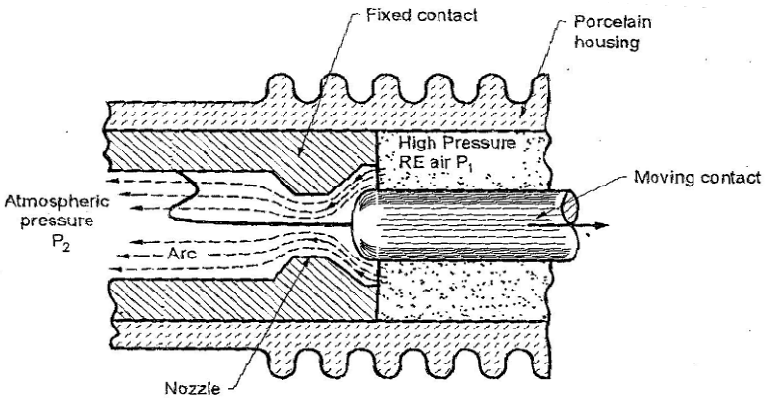


Fully labeled 4 marks, partially labeled proportion lesser

3 b) Explain with neat diagram working of air blast CB.

3 b) Ans:

1) Axial blast air circuit breaker



1 mark

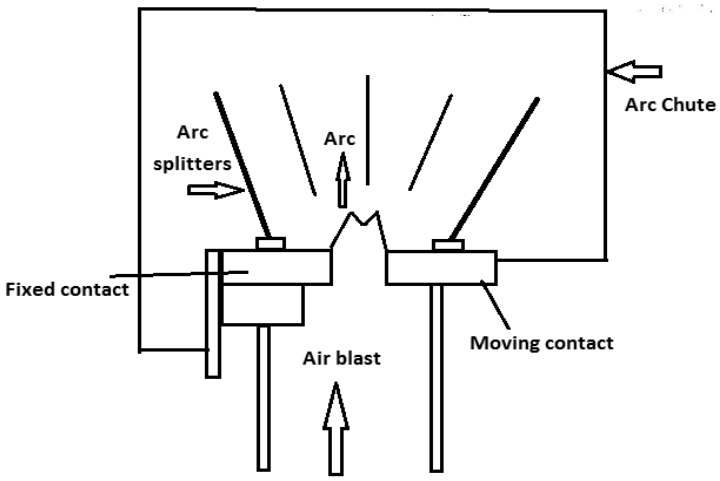
The fixed and moving contacts are held in closed position by spring pressure under normal condition. When a fault occurs, the tripping impulse causes opening of the air valve, which connects the C.B. reservoir to the arcing chamber pushes away the moving contacts against spring pressure. The moving contact is separated and arc is struck. At the same time, high pressure air blast flows along the arc and arc gets extinguished.

1 mark

2) Cross blast air circuit breaker:

As moving contact separates the arc strikes & blast of air is directed across the arc to blow it over arc splitters. In the arc splitters the arc lengthens and gets cooled due to which arc gets interrupted.

1 mark



1 mark

3 c) Write any four safety precautions while using CT & PT.

3 c) Ans:

Safety precautions while using CT & PT:

1) CT secondary terminals should never be kept open. CTs they must be energized

only after connecting the burden across them.

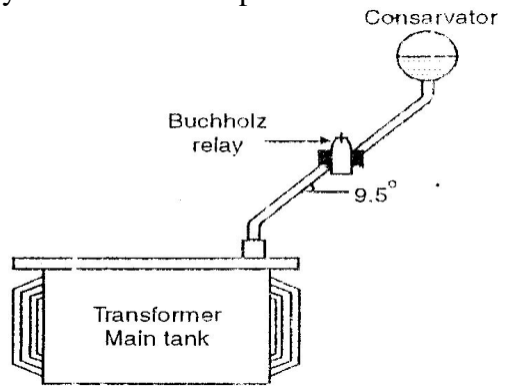
2) PT secondary should never be shorted as they are designed for high impedance burdens (extremely low currents).
3) To be used as per the specified rating of voltage, current & burdens only. The burdens should never be exceeded when multiple ones are connected across one instrument transformer. They are designed to give the highest accuracy at the rated burdens only, else for lower slightly higher burdens, ratio & phase angle errors are present and compensation is needed.
4) CTs for measurement must not be interchanged with those for protection and vice versa.
5) PTs for measurement must not be interchanged with those for protection and vice versa.

1 mark each any four = 4 marks

3 d) Give location of buchholz relay & state application of it for transformer protection.

3 d) Ans:

The relay in located in the path of the oil from transformer tank to conservator.



1 mark

Fluid actuated relay placed between the conservator and the tank containing the components

- to be protected such as the windings of transformers
- where abnormal arcing occurs such as in tap changing chambers (studs/contacts etc.)

1 mark

Applications of Buchholz's relay:

- Normally for transformers of capacities 500 kVA or more
- Detect incipient faults (minor faults leading to decomposition of oil leading to gas formation) (occurring below oil level in oil immersed transformers) such as phase-phase, phase-core and give the alarm signals so that preventive action is taken before the condition leads to a major fault.

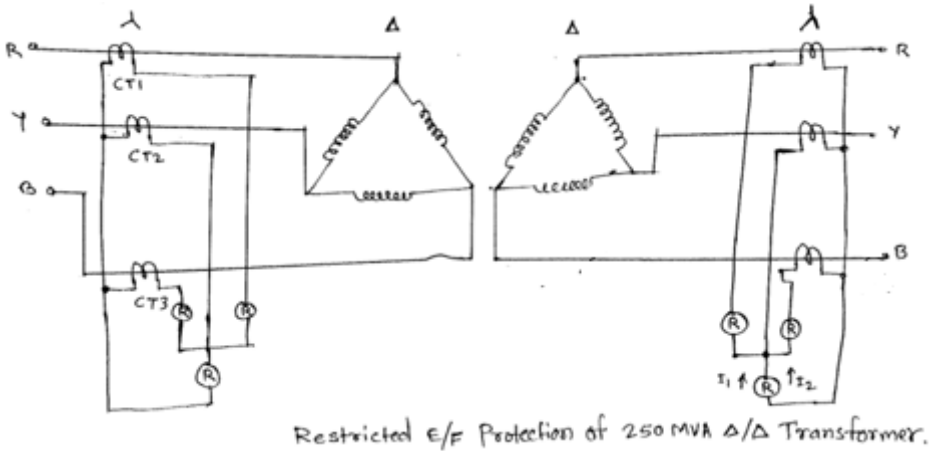
1 mark

- Detect sudden heavy oil movements due to severely violent faults in the tanks and give the trip signals.

1 mark

3 e) Draw the restricted earth fault protection scheme for 250 MVA delta/delta transformer.

3 e) Ans:



Restricted E/F Protection of 250 MVA Δ/Δ Transformer.

Fully labeled 4 marks, partially labeled proportion lesser

4 A) Attempt any three 3 x 4 = 12

4 A) a) Explain with neat diagram multi gap type lightning arrester.

4 A) a) Ans:

Multi gap lightning arrester:

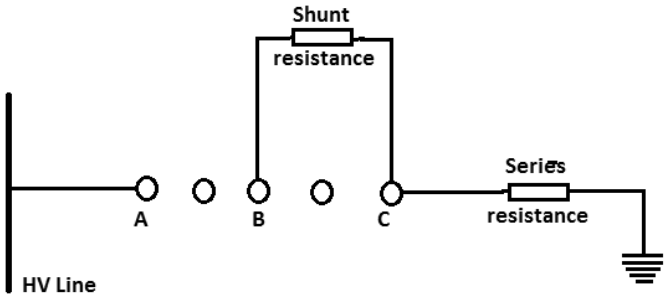


Figure 2 marks

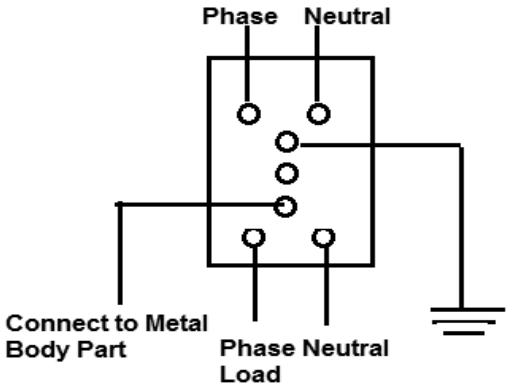
Under normal working voltage the cylinder (zinc made) B is at earth potential, hence series gaps remain open. When over voltage occurs which is sufficient to produce arc between gaps A and B; heavy currents will flow to earth through shunted gap B- C &series resistance, instead of shunt resistance. When surge is over the arc B to C gets extinguished & normal condition is restored. The equipment is protected form voltage surges.

2 marks description

4 A) b) Draw neat connection diagram of ELCB for residential installation.

4 A) b) Ans:

ELCB: here phase line, neutral and earth connections are important.



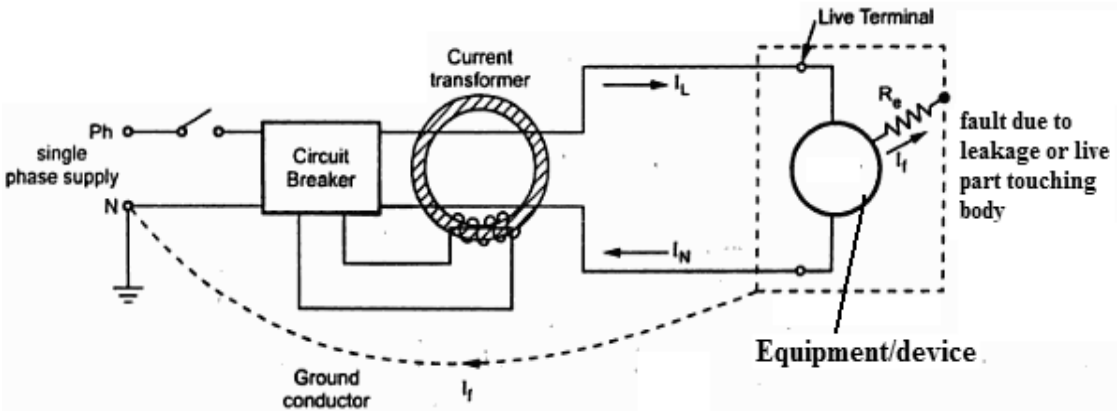


Diagram or equivalent 4 marks, partial proportional lesser.

4 A) c) Write different faults that occurs in alternators.

Ans:

Fault	Description in short
1. Stator winding SC fault (ph & earth)	Phase to phase sc; phase winding to earth.
2. Under frequency	Due to sudden overload, fall in prime mover input power/speed.
3. Rotor earth fault	Field winding insulation damaged leads to short to pole body.
4. Over-voltages	Sudden loss of loads, over excitation.
5. External faults	Terminal short circuit E/F, insulator failure.
6. Over heating	Overloading, cooling defective

1 to 2pts 1mark,

3 to 4 pts 2 marks,

5 pts = 3marks,

6 or more = 4 marks.

4 A) d) How impedance relay used for transmission line protection?

4 A) d) Ans:

Impedance Relay –

Principle: The action of relay depends upon the distance (impedance) between the point where the relay is installed and the point of fault on the transmission line. The operation is dependent on the ratio of voltage and current in the fault path. The relay operates when this ratio falls below a certain value. Higher current indicates faulty condition for a particular distance. 1 mark

From diagram the restraining force F_V due to voltage electromagnet (PT: constant voltage connected) is overcome by force F_I due to current electromagnet (operating force) that is $F_I > F_V$. but these are proportional to respective electric quantities. $F_I = k_1 I_F^2$ and $F_V = k_2 V^2$. From this when $(V/I_F) < \sqrt{(k_1/k_2)}$ or $Z_F < \sqrt{(k_1/k_2)}$ (fault path impedance depends on the distance of fault on transmission line from relay as $Z_F = z\,L$, where z = impedance per unit length of line and L = distance at which fault has occurred) 1 mark

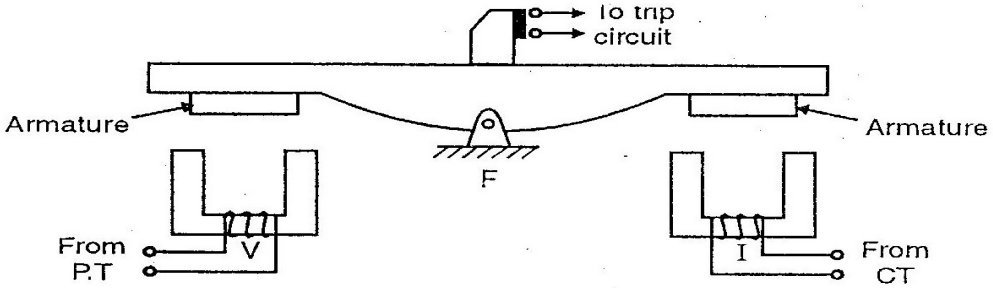


Diagram 2 marks

Definite – distance type impedance relay

4 B Attempt any one. 1 x 6 = 6

4 B) a) Describe differential protection of busbars with neat labeled diagram.

4 B) a) Ans:

Differential protection of bus bar.

Under normal conditions the sum of the currents entering the bus bar zone is equal to those leaving it and no current flows through the relay coil. If a fault occurs within the protected zone, the currents entering the bus will no longer be equal those leaving it. The difference of these currents will flow through the coil causing opening of CB. 2 marks

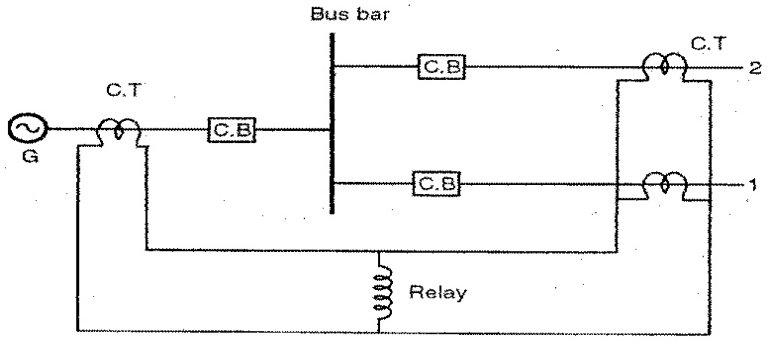


Diagram 4 marks

Differential protection of bus bar

4 B) b) Explain difference between short circuit & overload. Explain how motive is protected from short circuit & overload. 6 marks

4 B b) Ans:

	Short circuit	Overload
1	Sudden flow of heavy current in circuit / device.	Rise in current above rated due to excess load (more than rated load)
2	Occurs due to fault/insulation failure	Non-faulty condition (temporary)
3	Normally protected by fuse	Normally protected by relay system
4	May damage the equipment/machine severely.	Normally does not damage the equipment if for short periods, while if sustained may reduce the life.

1 mark each any four = 4 marks (other valid parallel points may be considered)

Protection of motor from short circuit:
Using fuses such as of HRC type or rewireable. 1 mark

Protection of motor from overload:
Using overload relays of bimetallic thermal or electromagnetic relay type. 1 mark

5 Attempt any four of following: 4x4 =16

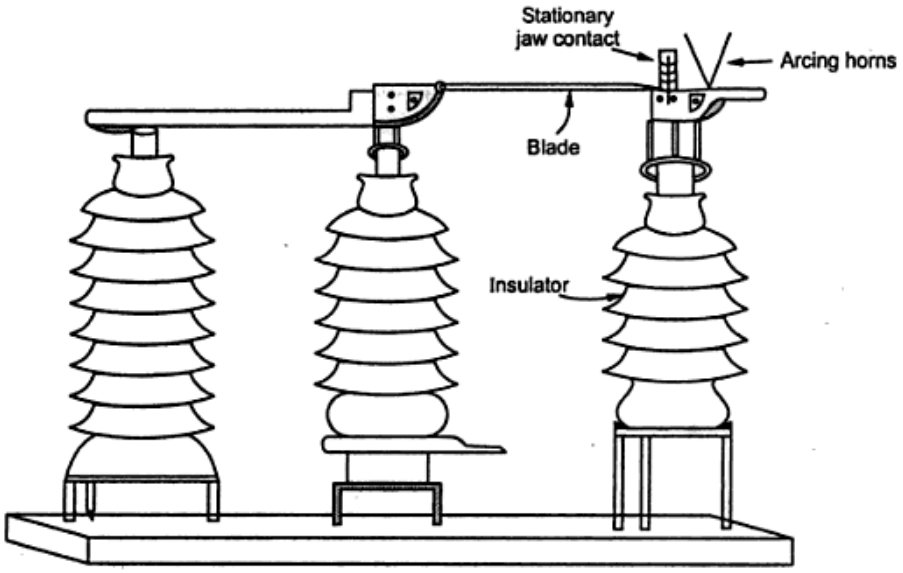
5 a) Give any four properties of SF_6 gas.

5 a) Ans:
Characteristics of SF_6 gas: 1 mark each any four = 4 marks.

1) Stable at high temperature around 500 ^{O}C;
2) Inert;
3) Electronegative;
4) Non-reactive with structured material upto 500 ^{O}C.
5) Low arc time constant;
6) Five times heavier compared to air;
7) Very much better dielectric properties compared to air and oil.
8) Higher rate of rise of dielectric strength.
9) The products of decomposed gas at high temperatures recombine on cooling to form the original gas.
10) For equal pressure the heat transfer capacity is more than twice of air.

5 b) Explain with neat diagram vertical break isolator with their application.

5 b) Ans:



Vertical break isolator

Diagram 2 marks

During opening & closing operations the blade moves in an arc path vertically. While closing it closes with high precision and makes excellent contact at the jaw of the fixed contact. The contacts are silver coated. Constant pressure is maintained by insulated stainless steel backup springs. The arcing horns divert the current from primary contact and avoid the pitting of contacts.

1 mark explanation

Used in switchyards for isolation of circuit breakers, transformers, surge arresters, line sectioning etc.

Application 1 mark

5 c) State the principle of operation of electromagnetic induction shaded pole type relay.

5 c) Ans:

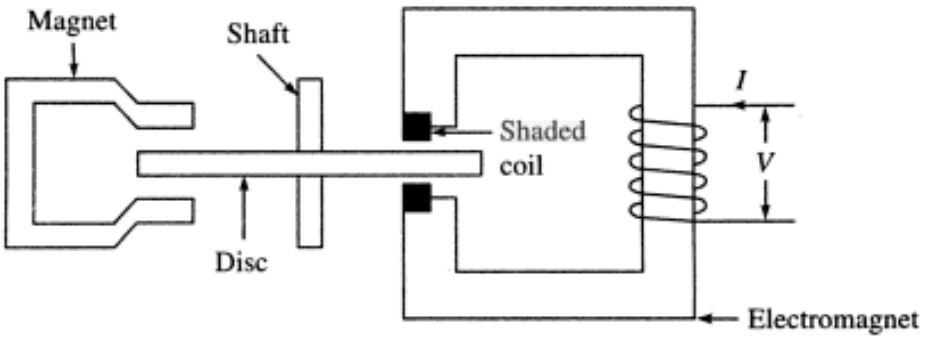


Diagram or equivalent 2 marks

Principle of operation:
The copper shading ring splits the exciting flux into two out of phase components. The shaded pole flux lags behind the un-shaded pole flux by nearly 50 ^{O}. Torque is produced on the disc by interaction of one magnetic field with currents induced due to other magnetic field.

Description 2 marks

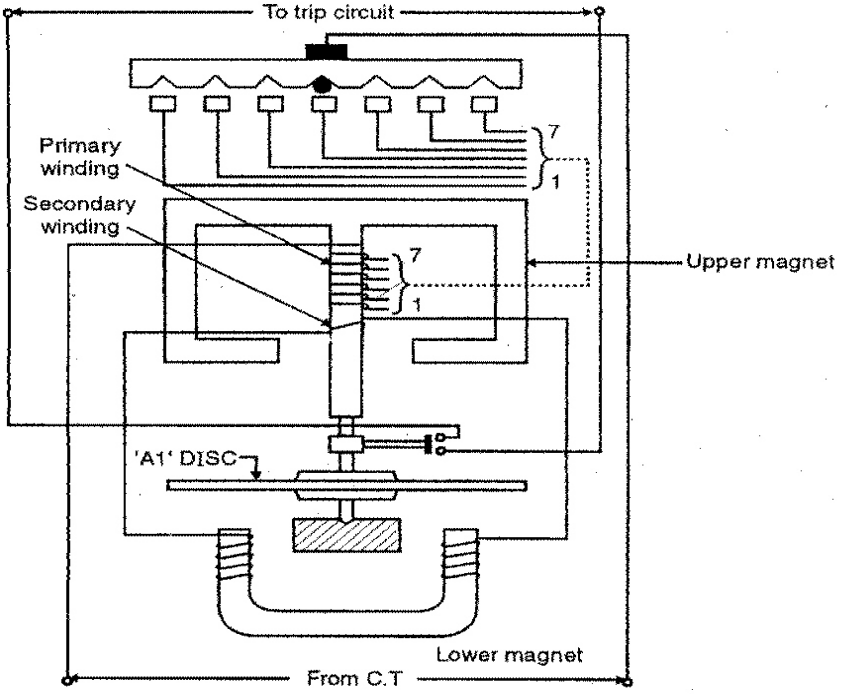
5 d) Define TSM and PSM in relays.

5 d) TSM: the adjustment arrangement provided for setting the operation time of the induction relay is known as TSM (Time Setting Multiplier). TSM dial is calibrated from 0 to 1. 2 marks

PSM: **Plug setting multiplier:** PSM = (Fault current in relay coil) / (Pickup current) 2 marks

5 e) Draw neat circuit diagram of induction type overcurrent relay label its different parts.

5 e) Ans:

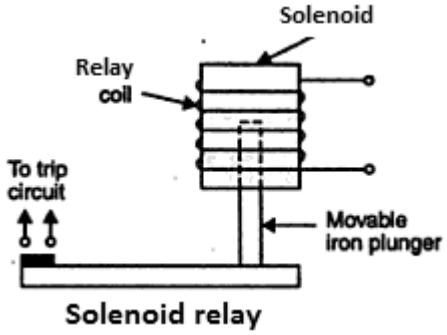


Induction type over current relay (non – directional)

Diagram or equivalent Fully labeled 4 marks, partial proportional lesser.

5 f) Explain with neat diagram solenoid type overcurrent relay.

5 f) Ans:



Solenoid relay

Diagram 2 marks

During the normal operation the current in solenoid coil is not sufficient enough to pull the plunger up by magnetic force, whereas on overcurrent condition (current exceeds pickup value) the magnetic pull of the solenoid coil overcomes the restraining force on the plunger (spring or gravity) and pulls the plunger up to close the trip contacts. This

Operation description 2 marks

operates the relay circuit causing the opening of the CB and disconnecting the overload.

6 Attempt any four: 4x4 = 16

6 a) Explain how differential protection is used in transformers.

6 a) Ans:

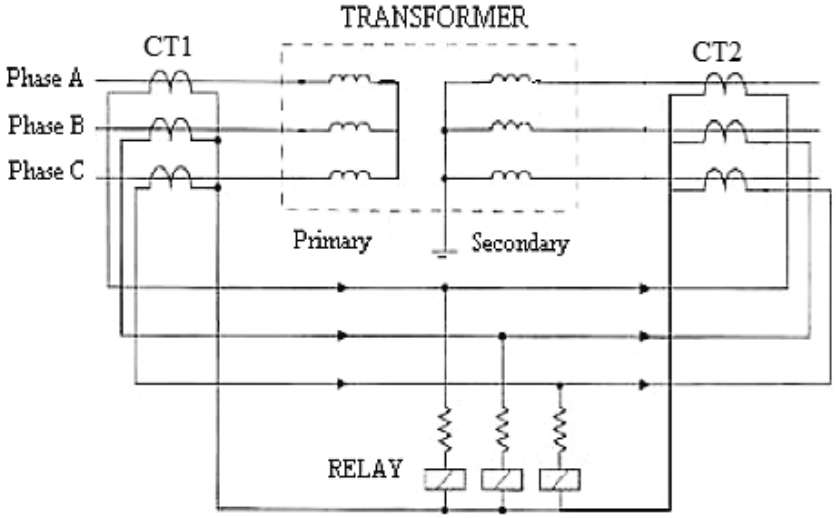


Diagram or equivalent 2 marks, partial proportional lesser marks.

Used for transformer winding faults detection. Works on the principle of balancing of currents of primary & secondary sides under healthy conditions.
Any path of fault current in between the placement location of the CTs on the two sides of the transformer to be protected creates a difference of currents in the CT secondaries current in the relays that operate to trip the CB.
The CT ratios are so adjusted such that under healthy conditions the secondary currents are equal and their resultant in the relay is zero.

Description 2 marks.

6 b) "Relays can be used to sense single phase open ckt. fault in an alternator". State whether true or false. Justify your answer.

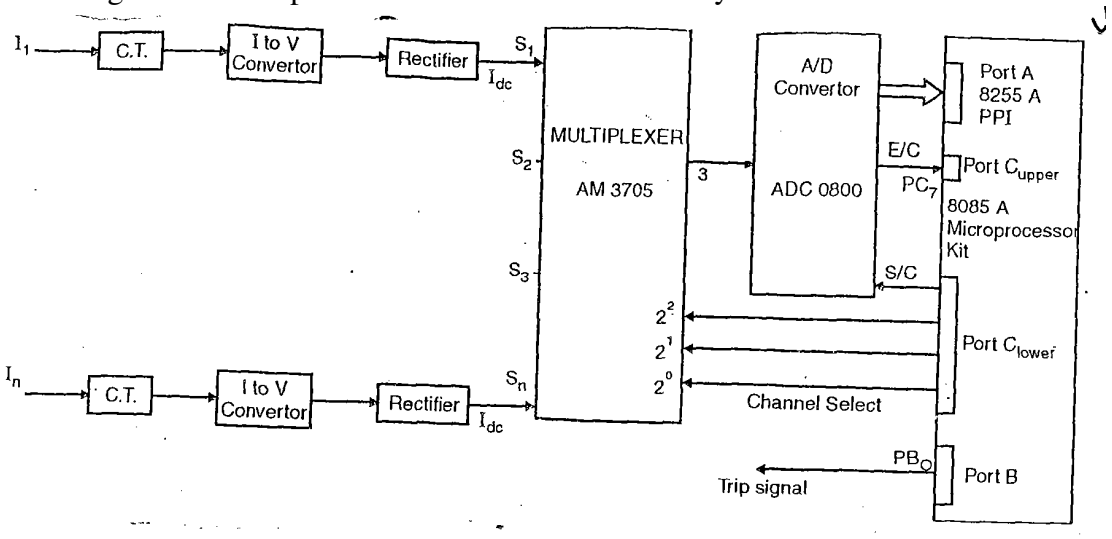
6 b) Ans:
The open circuit in the phase can be sensed by connecting separate PT (whose secondaries can be connected in star with star point earthed) for each phase (between each phase terminal & earth). These relays are connected on the secondary side of each PT in star. The CB is closed only when all the PT relays are actuated. In the case of open circuit of alternator winding the corresponding phase PT relay will drop out and the CB will open. 2 marks

Hence relays can be used to sense single phase open circuit in alternator. 1 mark

But the open circuit fault is not a condition that damages the alternator. As the protection schemes are to be implemented for protection of the alternator machines we may not require such a scheme. The open circuit may be easily sensed / seen from the measuring devices and the set may be switched off. The loads have their own single phasing sensing devices to care of themselves. 1 mark

6 c) Draw block diagram of micro-processor base over current relay.

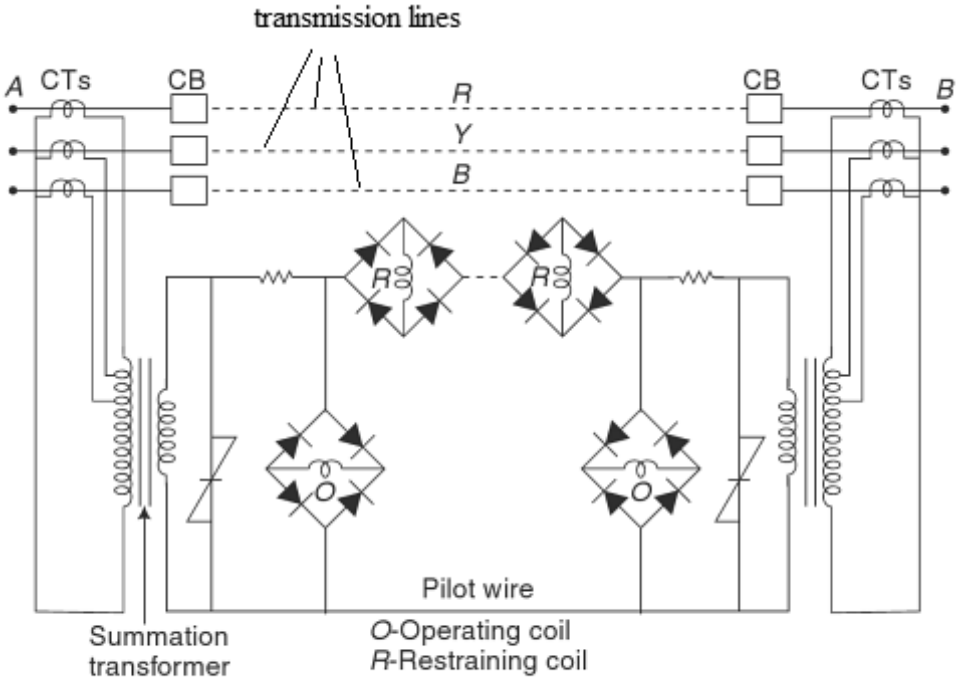
6 c) Ans:
Block diagram of microprocessor based over current relay:



Complete diagram labeled or equivalent 4 marks, partial proportional lesser.

6 d) Draw ckt. diagram for biased differential protection used for transmission line protection.

6 d) Ans:



Biased differential protection for transmission lines

Complete diagram labeled or equivalent 4 marks, partial proportional lesser.

6 e) Explain limitation of differential protection in a transformer.

6 e) Ans:

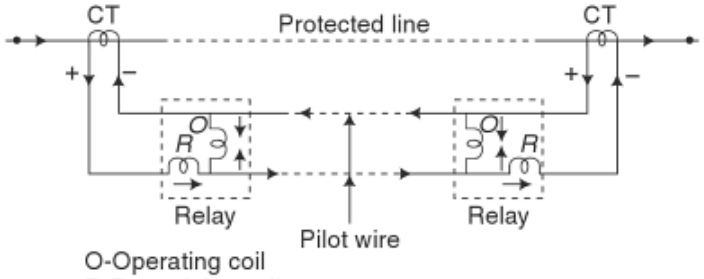
Limitations of differential protection of transformers:

1) Due to the magnetization characteristics of the CTs used the ratio errors change with respect to the currents circulating.
2) The pilot wires used may vary in length due to which the unbalance in the secondary circuit parameter (resistance) is created that results in improper scheme.
3) During heavy short circuit conditions the high currents create saturation of the flux in core of CTs that lead to abnormal relaying or unexpected behavior of the relaying circuit.
4) Tap changing may lead to change in settings & improper operation.
5) Inrush of magnetizing current may lead to inadvertent operation & hence the settings are done for higher values of fault current (higher imbalance) due to which accuracy of sensing & operation is decreased.

Any four points, 1 mark each = 4 marks

6 f) Explain how pilot wire protection is given to transmission line.

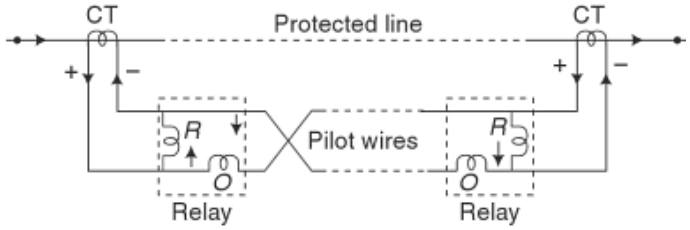
6 f) Ans:



Schematic diagram of circulating current principle

1 mark

And



Schematic diagram of balanced voltage principle

1 mark

Here two wires called as pilot wires are used to carry the information signals of relaying from one end of protected line to other end. These can be buried cables or auxiliary overhead lines other than the power lines. 1 mark

As pilot wires are expensive the three phase quantities are converted to equivalent single phase ones and relayed through one pair of pilot wires & not three wires. These are used for short lines with the break even distance being 15 km to 30 km in terms of cost. The pilot wire schemes can be implemented by two principles namely circulating current & balanced voltage as shown above. 1 mark