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 try to 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) Credits 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 judgement 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) Comparison:

	Points	Fuse	MCCB
i)	Size	Requires more space.	Accommodated in smaller space with more no. of features.
ii)	Cost	Lower cost	Comparatively higher along with more features
iii)	Reliability	Reliable	More reliable
iv)	Safety	Safe	More safe with more features

1 mark each

1 b) Definitions:

i) **Recovery voltage** : It is the normal system frequency (India: 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.

ii) **Re-striking voltage** : - It is the transient voltage that appears across the contacts at or near current zero during arcing period.

2 Marks for each definition.

1 c) Over current relay: it is a relay which senses over current in circuits and initiates corrective measures. Used to sense overcurrents for protection purposes. Normally connected by means of CTs in power systems.
Types of overcurrent relaying/protection:
- high speed protection,
- definite time protection,
- inverse minimum time protection, and
- directional protection

2 marks

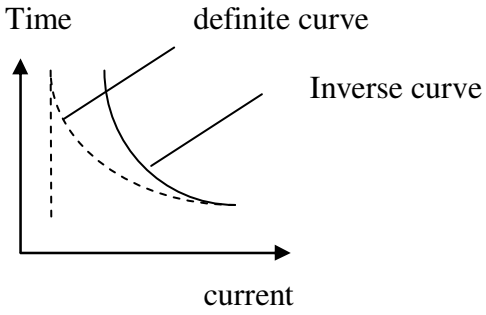


Diagram 2 marks

1 d) Microprocessor based over current relay :

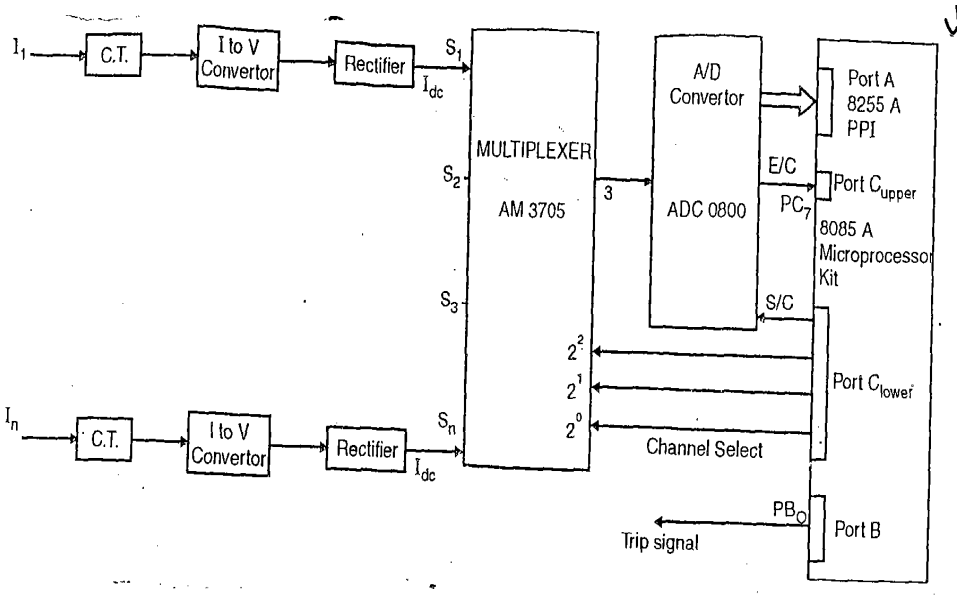


Diagram 2 marks;

The a.c. voltage proportional to the load current is converted in to d.c. using a precision rectifier. Thus, the microprocessor accepts d.c. voltage proportional to the load current. The schematic diagram is shown above. The out put of rectifier is fed to the multiplexer. The output of multiplexer is fed to the A/D converter to obtain the single in digital form. The A/D conveyor ADC 0800 has been used for this purpose. The microcomputer sends signal to the ADC for stating the conversion. The microcomputer reads the end of conversion signal to examine whether the conversion is over or not. As soon as conversion is over, the micro computer reads the current signal in digital form and then compares it with the pickup values . The microcomputer first determines the magnitude of the fault current and then selects the corresponding time of operation from the look up table. Then it goes in delay subroutine and sends a trip signal to the circuit breaker after the predetermined time delay.

operation 2 marks

1 e) **Faults / Abnormalities in Alternators :**

External causes/ faults/ abnormalities :

- Overload on alternators (of sustained type).
- Overload on alternators (of momentary nature)
- These overloads lead to over current conditions.
- Over current conditions load to executive temperatures if sustained for long periods.
- Unbalanced loading on alternators mainly occur when external faults occur on lines (unsymmetrical faults).
- Over- voltage conditions due to lighting strokes, switching surges.
- Improper prime mover working such as over speed, and under speeding (Improper governor settings of Prime mover).

1 - 2 points – 1 mark, three to five points – 2 marks

Internal causes/fault /abnormalities :

- Field winding open circuited
- Field winding short circuited.
- Weakening of insulation of field and armature windings.

1 to 2 pts. 1 mark, 3 to 5 point 2

- Intra phase faults such as coil – coil s.c, open circuited coils, turn – turn short circuit (inter turn S.C.) in the armature. marks
- Inter phase faults such as phase – phase winding s.c, phase – phase to body (earth) s.c in armature.
- Phase winding faults such as phase to body (earth) s.c, winding or coil open circuit of armature.

1 f) Bus bar differential protection:

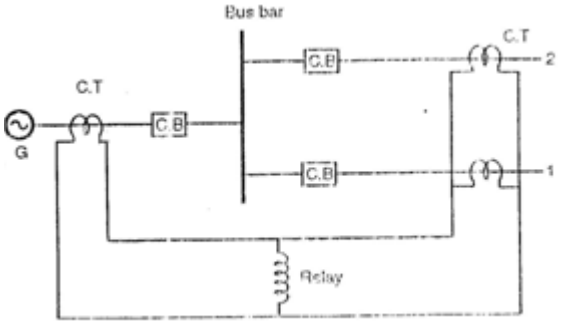


Diagram 2 marks

- Responds to vector difference of two or more similar electrical quantities.
- Here vector sum of currents entering and leaving the bus zone is used to activate the protection system for tripping or corrective action. 1 mark
- Under normal condition the sum of currents entering the bus zone is equal to the sum of currents leaving the bus zone.
- On fault in the bus zone the current leaving the zone from differs the one entering by the value of the fault current.
- This out of balance current operates the relay to initiate tripping. 1 mark

1 g) Lightning:

- Discharge of charges on a charged cloud to ground/earth or neighboring cloud whose potential is much different than it.
- Takes place when clouds get charged to highly positive or negative levels such that the insulation of surrounding medium (air) breaks down. 2 marks

Lightning surges cause heavy/severe over voltages of very high magnitudes on power systems that contain enormous amount of electric energy which has to be dissipated quickly and safely to earth. Hence protection against such surges due to such lightning strokes has to be provided at every stage in the power system. 2 marks

2 a) i)

	Faults	Causes
1	Single line to ground.	One line touches the grounded part (support etc)

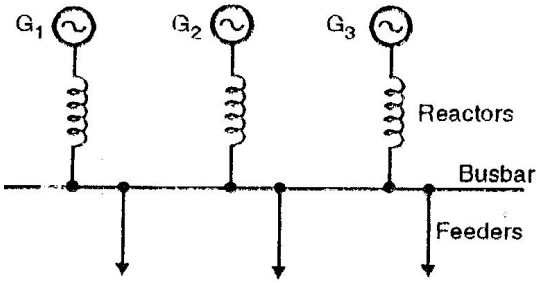
2	Line to line	Two lines get stuck to each other due to insufficient distance or swaying due to wind.	1 mark each, any four.
3	Double line to ground	Two line conductors together get connected to ground or grounded parts as pole/tower.	
4	Three phase short circuit	All three phase lines make contact in abnormal conditions as storms, falling/bending of trees, poles, towers etc	
5	Open circuit	Broken line conductor/s.	
6	Simultaneous fault	Of three phase lines two are shorted while the third is shorted to ground.	

2 a) ii) Use of current limiting reactors: 2 marks

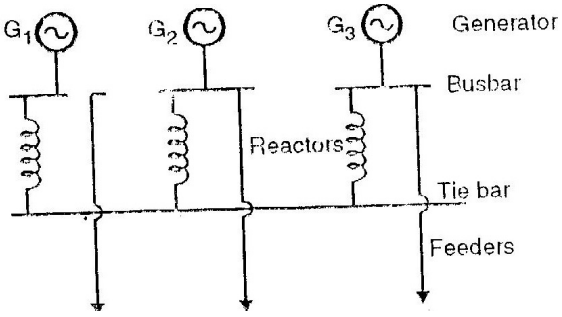
Limit fault currents to reasonable levels for the CBs to handle in short circuits occurring in power system at the generators, busbars, feeders etc.

Arrangement of reactors:

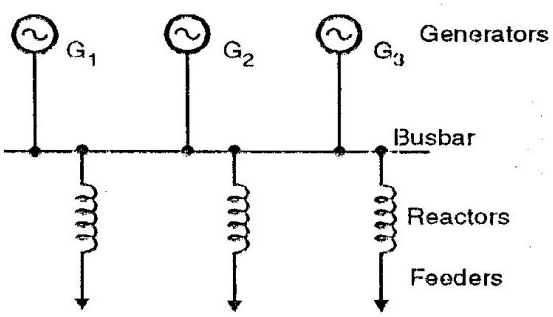
Generator reactors



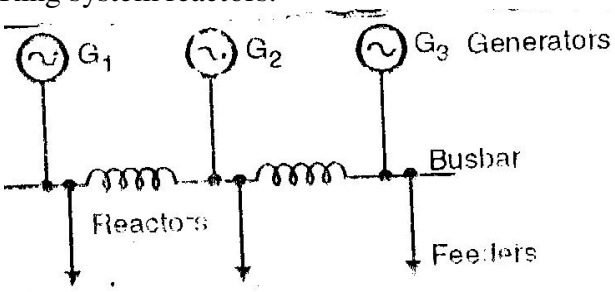
Busbar reactors: ½ mark each diagram



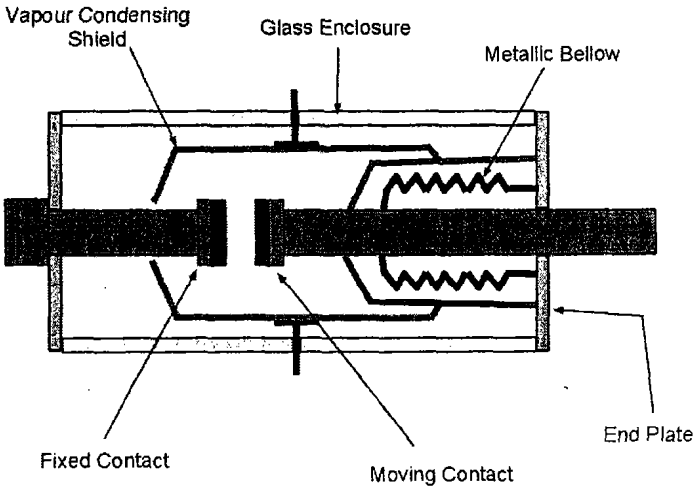
Feeder reactors:



Ring system reactors:



2 b) Vacuum circuit breaker:



Vacuum Interrupter

Diagram marks:

Unlabeled 2 marks; labeled 3 marks

Operation: (minimum points)

On operation of the breaker the moving contact separates from the fixed contact resulting in arching between them. The arc consists of metal ions of surface of the contacts. The arc get extinguished quickly and vacuum has good recovery of dielectric strength. The arc extinction occurs at a small vacuum gap of about 0.6 to 0.7 cm.

Operation 3 marks

Applications: used in conditions where maintenance free circuit breakers are required such as

1)remote areas,

2)employed for outdoor applications from 22 kV to 66kV

3) preferred for indoor switchgear upto 36 kV, 750 MVA.

Application s (any two or equivalent) 2 marks

2 c) Pick-up current: Pick up Current - It is the value of operating quantity which is on

i) border above which the relay operates and closes its contacts.

Plug setting multiplier: ratio of fault current in relay coil to pickup current i.e

ii) PSM = (Fault current in relay coil) / (Pickup current)

Time setting multiplier: A relay is generally provided to control and adjust the

iii) time of operation; this is known as time setting multiplier. Time setting dial is calibrated from zero to 1 in steps of 0.05 secs.

iv) 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.

2 marks each correct definition.

3 a) i) Necessity & functions of protective system:

- Protect various power system components such as generators, transformers, transmission lines, distributor line etc. against damage due to faults/abnormalities.
- Provide alarm signals about any incipient faults.
- Help to ensure quality power supply.
- Isolate faulty sections if they are harmful to the remaining healthy sections.
- Operate quickly to protect the power system by giving relevant signals to CBs etc.

1 mark each point any four

3 a) ii) Normal condition of power system:

- State of network where the voltages and frequency are in the tolerance limits and the current is at the rated value or below it.
- The current path is the intended one and not any that is not intended.
- The three phase voltages are equal in magnitude (variations are within tolerance) and their phase displacements are all equal from each other (120^o electrical) i.e balanced supply system.

2 marks

Abnormal condition of power system:

- Situations leading to disturbing of the normal working.
- Over currents
- Under voltages
- Unbalanced three phase system voltages
- Heavily unbalanced currents drawn

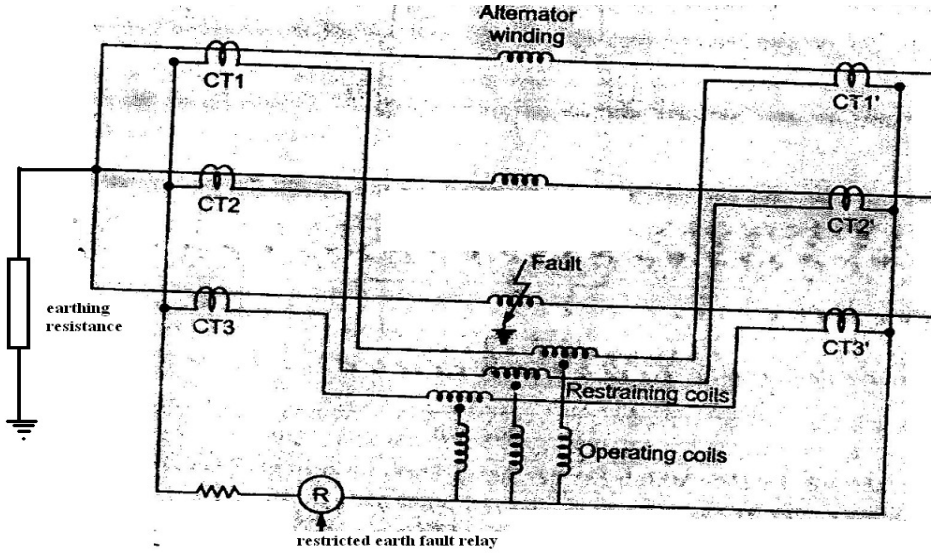
Any three points 1 mark

These occur due to

- Reverse power flow
- Power swinging
- Over voltages
- Over frequency / under frequency
- Heavy temperature rises
- Instability of power system

Any three points 1 mark

3 b) % differential protection of alternator:



Labeled diagram 4 marks

Partially labeled 2 marks
Unlabeled 1 mark

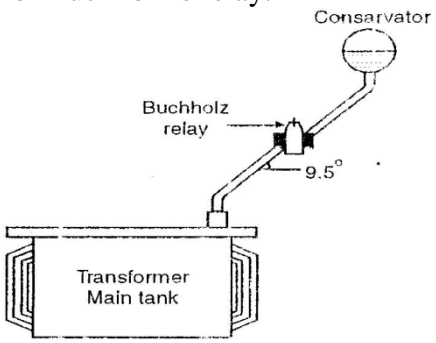
Explanation:

Percentage differential relay consists of two coils, operating coil and restraining coils. The restraining coils are connected at centre of pilot wires and operating coil is connected between midpoints of restraining coil and neutral pilot wire. The currents of the secondaries of CTs on either side of each phase winding balance under healthy conditions. Under fault condition (winding EF) the differential current on the secondaries operates the relay and alternator is protected by operating the CB to trip. Generally 80 to 85 percent of generator winding is protected against earth fault using differential protection.

2 marks

2 marks

3 c) Location of Buchholz's relay:



Labeled Diagram 3 marks
Unlabeled 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

Use 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. 2 marks
- Detect sudden heavy oil movements due to severely violent faults in the tanks and give the trip signals.

Limitations:

- Suitable for oil immersed machines only. 2 marks
- Only faults that are below oil level in the machine immersed tanks are detected.

4 a) i)

Abnormalities:

1. Over voltage
2. Over current
3. Under voltage
4. Magnetic core saturation (Over fluxing)
5. High oil temperature
6. Excessive Over load

½ mark each any eight, max 4 marks

Faults:

7. Insulator failure fault (Earth fault)
8. Phase to phase fault,
9. Phase to ground,
10. Low oil level
11. Tap changer fault
12. High voltage surges due to lightening and switching

4 a) ii) Restricted earth fault protection for transformers:

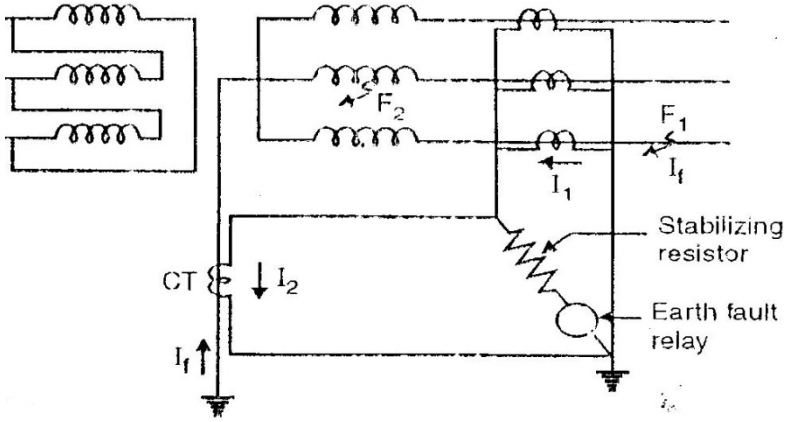
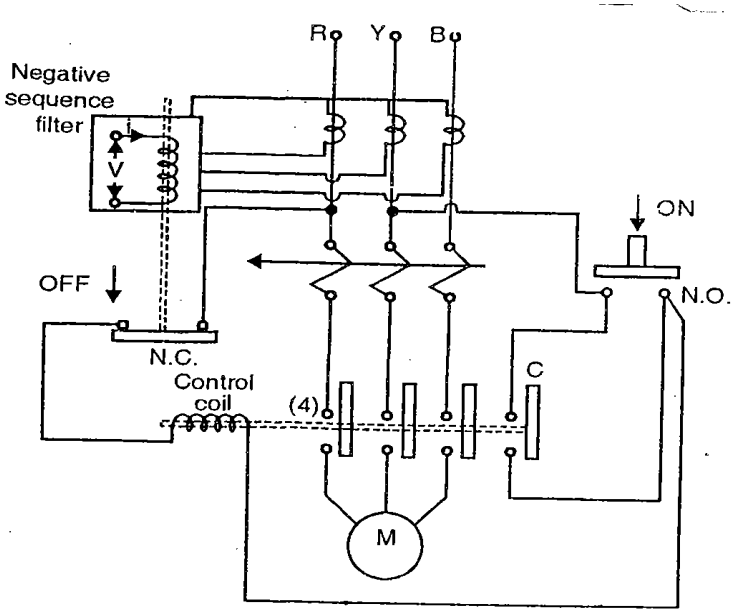


Diagram labeled 2 marks, partially labeled / unlabeled 1 mark.

- For Earth fault beyond transformer at point 'F_1 ' the current in the relay is negligible and hence relay does not operate.
- For Earth fault in transformer at point 'F_2 ' the current in the relay is the

difference of I_1 and I_2, which is sufficient to operate the relay.
- Very sensitive relays operate on external faults/switching surges also.
- To avoid such operations the relays are set to operate for earth fault current of the order of 15 % of rated winding current.
- Thus the setting protects a restricted portion of the winding and hence called restricted earth fault protection. 2 marks

4 b) i) Single phasing preventor:



Diag. 2 marks

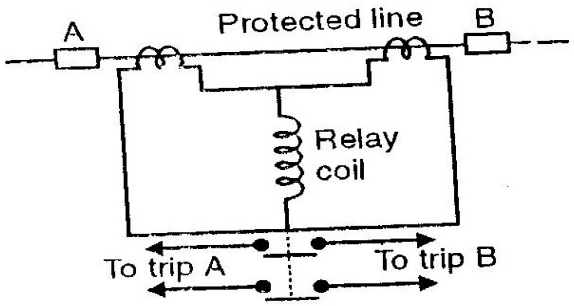
Working: these are connected in secondaries of line CTs. Mainly contain negative sequence filter whose output is fed to level detector which further send s tripping command to starter or CB. Thus it protects the motor from damage. 2 marks

4 b) ii) Abnormalities and faults in motor:

1. Prolonged overloading,
2. Stalling,
3. Unbalanced supply,
4. Single phasing,
5. Undervoltage,
6. Reversal of phase supply,
7. Stator fault: phase to phase or phase to earth fault, OC in windings.
8. Rotor fault, OC in winding, SC in wound coils.
9. Mechanical faults: bearing failure, cooling failure, loosing of bolts.

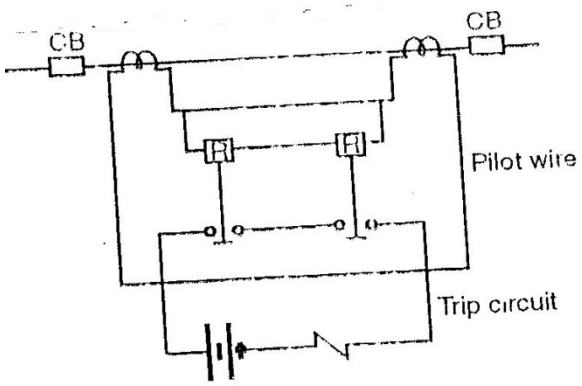
½ mark each any 8 points.

4 c) Pilot wire protection for transmission lines:



1 mark

(a) Pilot wire protection of line



1 mark

(b) Use of two relays, one at each end

- In fig a) differential circulating current protection principle is applied for feeder

  As in fig b):
- two CTs each one placed at the two ends of protected line.
- Under normal operation the sum of currents in CT secondary circuit is zero and the relay coil current is hence zero.
- Under abnormal conditions of faults between the portion covered by the CTs (internal faults) the differential current passes through the relay which operates the CB.

2 marks

Merits:

1. Very fast operation on ground faults.
2. Used for ring mains and parallel feeders.

1 mark each

Demerits:

1. Identical CTs needed.
2. Break in pilot wire – the circuit is useless.
3. Very expensive.
4. For long lines charging current due to pilot wire capacitance may cause relay operation.

Any two points
1 mark each point

5 a) Two main methods of arc extinction:

i) High resistance method. 1 mark each

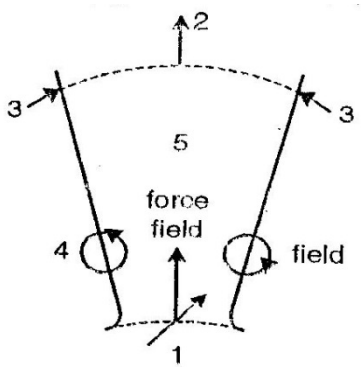
ii) Zero current extinction. method

High resistance method:

- Arc path resistance is increased to reduce the current to low values while interrupting the arc. Arc resistance = v_{arc}/i_{arc}.

The arc resistance mainly increased by three methods given below:

1) Lengthening of the arc over runners:

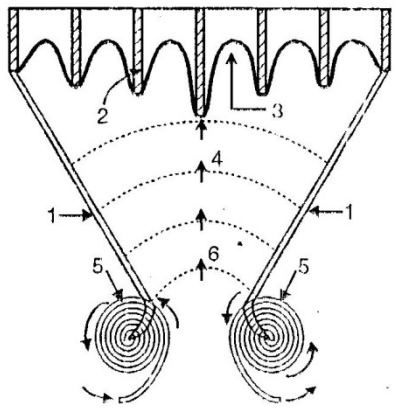


Diag. 1 mark

1 – initial position of arc, 2 – final position of arc, 3 – arc runner,
4 - electromagnetic force, 5 – force due to field.

Arc runners are horn like blades of conducting materials connected to arcing contacts of CB with their tips radiating upward in 'V' shape. The arc on getting struck is blown over the arc runners upwards by electromagnetic force which results in increase in arc resistance due to which the arc is extinguished. 1 mark

2) Splitting the arc:



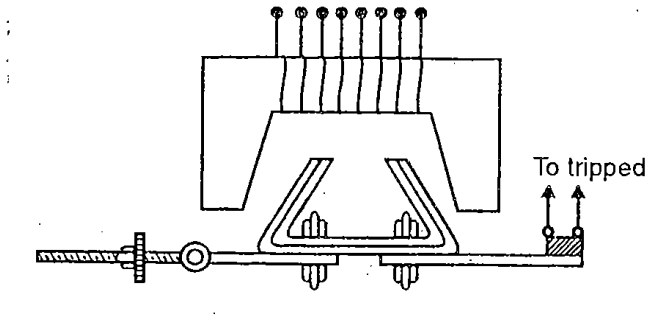
Diag. 1 mark

1 – arc runner, 2- arc splitters, 3 – elongated arc, 4 – travelling arc,
5 – blow out coil, 6 – arc origin.

Plates of resin bonded fibre glass (arc splitters) placed in path of arc (perpendicular to arc length). 1 mark
Arc is pulled over the plates by electromagnetic force leading to its elongation, splitting, cooling and finally extinction.

3) Arc cooling:
Arc in contact with cool air leads to recombination of ionized particles to recover the dielectric strength of the medium between the contacts and thus arc extinction. 2 marks

5 b) Electromagnetic attracted armature type relay:



Diag. 3 marks

It consist of laminated electromagnet carrying a coil and a pivoted laminated armature. The armature is balanced by a counter weight and carries a pair of spring contact fingers at its free and under normal operating conditions the current through the relay coil is such that counter weight holds the armature in the position shown. When a short circuit occurs, the current through the relay coil increases sufficiently and the relay armature is attracted upwards. This completes the trip circuit which results in the opening of the circuit breaker.

Working 3 marks

Applications:

1. Used for definite time lag over current and earth fault protection.
2. Over current protection. Time lag obtained by using instantaneous attracted armature relay in conjunction with a definite time lag relay or inverse time lag relay
3. Differential protection implemented by instantaneous attracted armature relay.

Applications 1 mark each any two.

5 c) i) X % winding unprotected, voltage 6.6 kV assumed. (if students assume any other value it must be assessed accordingly and full marks awarded for the correct steps)
Earthing resistance r_E = 7.5 ohms,

$V_{ph} = 6.6 \times 10^3/\sqrt{3} = 3810.62$ V.

Minimum fault current to operate relay $I_P = (1000/5) \times 0.7 = 140$ A.

EMF induced is X % of stator winding
$= V_{ph} \times (X/100) = 38.106.X$ (Volt).

2 marks

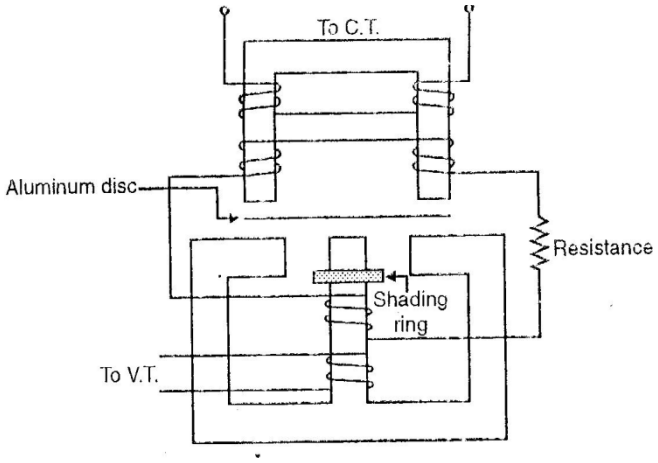
Earth fault current due to X % of stator winding

$= 38.106.X/r_E$ (A) $= 38.106.X/7.5$

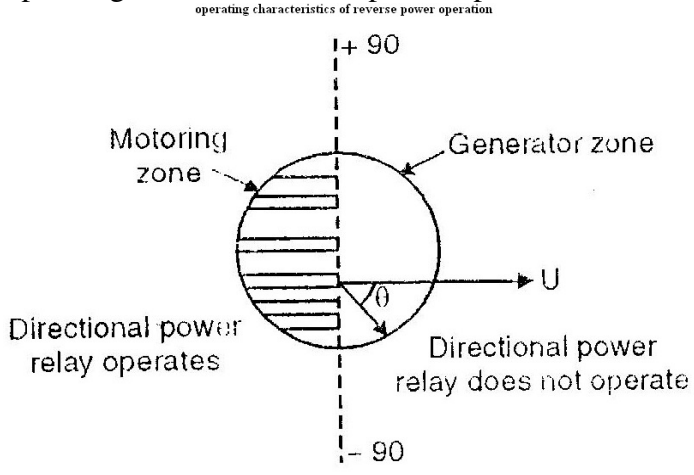
$I_P = 140 = 38.106.X/7.5$ from which

X = 27.55.
Hence 27.55 % of alternator winding is left unprotected. 2 marks

5 c) ii) Reverse power protection of alternator: relay arrangement:
Directional power relay:



Operating charac. of reverse power operation



Diag. 2 marks (Any one diag.)

On failure of input to the prime mover the alternator works as synchronous motor with low load (2 to 10 % of rated) and pf governed by the excitation. To protect the alternator from such reverse power flows a single element directional power relay that senses direction of power flow in alternator is employed. The CTs for this are placed either at neutral end or busbar end of alternator. An intentional time lag is used to avoid operation during temporary system disturbances when power may flow in the reverse. — 2 marks

6 a)i)

	Isolator	Circuit Breaker
1	Switching device operates on no load	Switching device operates on load or fault condition.
2	No arc quenching media.	Several methods of arc quenching .
3	Operated manually/remotely.	Operated manually/remotely under normal conditions and automatically under fault condition.
4	Specified by current carrying capacities as 800 A, 1000 A etc.	Specified by rated voltage, current, breaking current, making current, (breaking capacity, making capacity).
5	Types: vertical break, horizontal break, pantograph, single, double etc	Types: ACB, ABCB, MCB, MCCB, SF6, VCB, OCB, etc.

1 mark each point max 4 marks

6 a) ii) Fundamental requirements 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. — 2 points 1 mark,

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 points 2 marks,

iii) Sensitivity: - It is the ability of the relay system to operate with low value of actuating quantity. — 5 points 3 marks,

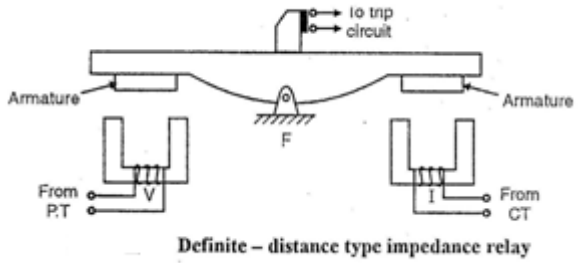
iv) Reliability: - It is the ability of the relay system to operate under predetermined conditions. — 6 points 4 marks.

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.

6 b) i) Distance protection of transmission line:



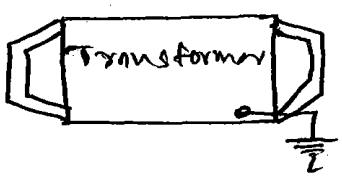
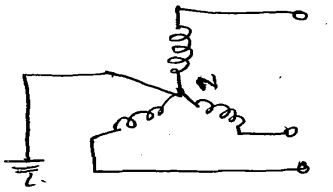
Definite – distance type impedance relay

Labeled Diagram 2 marks, unlabeled 1 mark.

Action of relay depends on impedance upto fault point i.e distance to it as impedance is directly proportional to length of line.
At fault the ratio of V/I at the relay falls to low value due to which the the relay operates to trip the circuit breaker.
'V' is the restraining quantity while 'I' is the operating quantity.

These points covered 2 marks

6 b) ii)

	Equipment earthing	Neutral earthing
1		
2	When the non current carrying metallic part of the electrical equipments are connected to earth is called as equipment earthing.	When neutral of transformer, generators, motors is connected to earth is called as neutral earthing
3	It is provided for protection of human being from electric shocks	It is provided for eliminating arching ground and over voltage surge.
4	It has nothing to do with stability	Stability of the system is increased.
5	Equipment earthing is provided through Pipe earthing, Plate earthing.	Neutral earthing is provided through solid earthing, Resistance earthing, reactance earthing.

1 mark each point
Any four points
4 marks

6	It does not provide any means for protection system against earth fault	It provides suitable means for earth fault protection system.

6 c) i) Causes of over voltages and their remedies:

Causes of over voltages
External causes: lightning strokes — 1 mark

Internal causes: switching surges, arcing grounds, insulation failure, resonance. — 1 mark any two causes.

Remedies:
External causes: providing lightning arrestor / surge arrestor/diverter in parallel to line to pass the disturbance / lightning to earth. — 1 mark

Internal causes: use proper insulation level equipment and proper grading of insulation of protective devices. — 1 mark

6 c) ii) Expulsion type lightning arrestor:

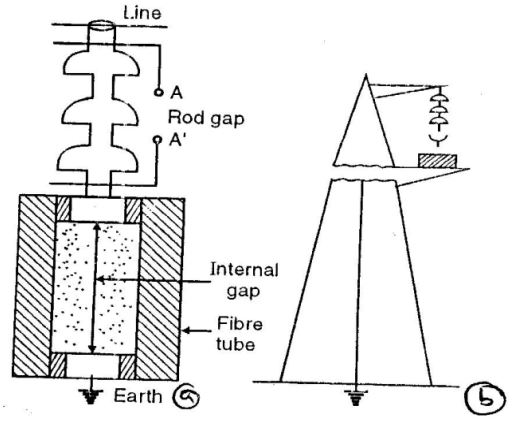


Diagram 2 marks

Figure shows functional details.

Principle: — 1 mark

On a voltage surge sparking occurs across gap AA' and arc is also struck across electrodes in tube.

Heat of arc vaporises some fibre of tube walls to produce neutral gas that builds up pressure to get expelled through hollow lower electrode. The gas also carries ionised air around the arc thus deionising the arc and quenching it and not allowing it to restrike. — 1 mark