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) 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 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 any four abnormal conditions which can develop in power systems and state its effect on power systems.

Soln.

Abnormal conditions:

1) LG fault
2) LL fault
3) LLG fault
4) Open circuited phases
5) Short circuited phases
6) 3 phase fault

½ mark each any four = 2 marks

Effects on power systems:

Damage to the equipment,
Overheating,
Arcing,
Fire hazards,
Reduction in supply voltage of healthy phases,
Unbalance of supply voltage and currents,
Loss of system stability,
Interruption of supply to the consumers,

½ mark each any four = 2 marks

1 A b) State the necessity of current limiting reactors in power systems and classify the reactors on basis of their location.

Soln.

Necessity of current limiting reactors:

Generally reactance of the system under fault condition is low and fault currents may rise to dangerously high values. In order to limit the fault current to reasonable magnitudes which the CB can handle, additional reactances (reactors) are connected in series with system at suitable points. — 2 marks

Classification of reactors:

1) Generator reactors,
2) Feeder reactors,
3) Busbar reactors
   i) Ring system,
   ii) Tie bar system.

2 marks

1 A c) State various causes of over voltages in electrical power systems.

Soln.

a) Internal causes:
   i) Switching surges
   ii) Arcing grounds,
   iii) Insulation failures,
   iv) Resonance,

3 marks

b) External causes:
   i) Lighting strokes,

1 mark

1 A d) What fundamental requirements of protective relaying? What qualities relay must possess for satisfactory functioning.

Soln:

Fundamental requirements:

1) Detect abnormal conditions. 2 marks
2) Disconnect abnormally operating part so as to prevent the subsequent fault.
3) Disconnect faulty part quickly so as to improve system stability, service continuity and system performance.
4) Improve Transient stability.

Qualities of relay: ½ mark each

1) Selectivity , any four = 2
2) Speed, marks
3) Sensitivity,
4) Reliability/trust worthiness,
5) Simplicity, and
6) Economical.

1 B Attempt any one: 6 marks

1 B a) Two 11 kV, 3 phase, 3000 kVA generators having reactance of 15 % operate in parallel. Generators supply power to a transmission line through a 6000 kVA transformer of ratio 11 kV/ 22kV having leakage reactance of 5 %. Calculate fault current and fault kVA on HT side of the transformer.

Soln:

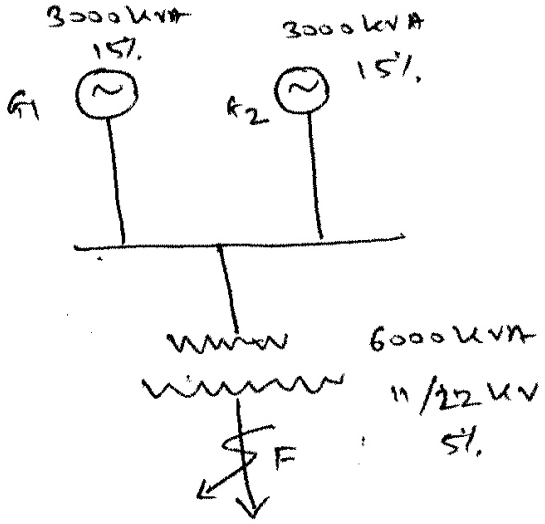
Assume base kVA = 6000 kVA

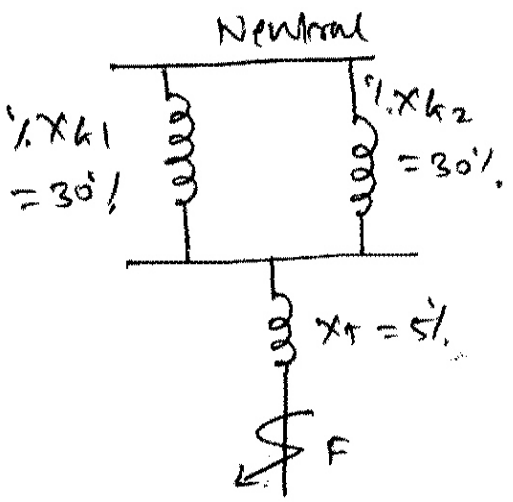
% reactance related to base kVA

% X = (base kVA/rated kVA) x percentage reactance of rated kVA

Hence X_{G1} and X_{G2} = (6000/3000) x 15% = 30 %.

X_T = (6000/6000) x 5% = 5 % 1 mark





2 marks

Total reactance up to fault at F =

% X = (X_{G1}|| X_{G2}) + X_T = [(30 x 30)/(30+30)] + 5 = 15 + 5= 20 %. 1 mark

Rated current at base kVA, I = (6000 x 1000)/(√3x22x1000) = 157.64 A.

I_{SC} = I x 100/%X = 157.64 x 100/20 = 788.23 A. 1 mark

Short Circuit kVA = base kVA x 100/%X = 6000 x100/20 = 30000 kVA = 30 MVA. 1 mark

1 B b) A three transformer of 220/11000 V connected in star/delta is protected by Merz Price circulating current scheme. The protective transformer on 220 V side have current ratio of 600/5. What should be ratio on 11000 V side? Draw a neat diagram and indicate given values at appropriate places.

Soln:

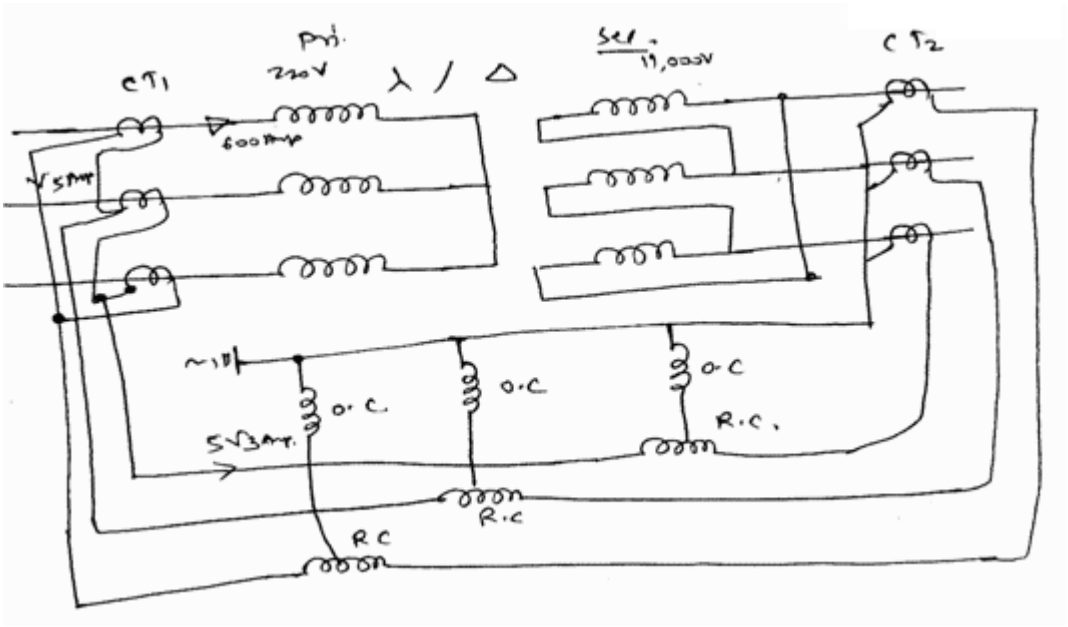


Diagram 2 marks

1) For star/delta transformers, CTs will be connected in delta on 220 V side and star on 11000 V side.
2) Suppose line on 220 V side is 600 A the phase current on delta connected CTs on 11000 V side is 5 A and CT line current = 5√3 A.
3) Line current of star connected CTs on 11000 V side is = 5√3 A. 1 mark
4) This current in pilot wires is in CTs secondaries on 11000 V side.
5) Hence phase current of star connected CTs on 11000 V side is 5√3 A. 1 mark
6) For transformer $\sqrt{3}V_1I_1 = \sqrt{3}V_2I_2$, 1 mark

$\sqrt{3}$ x 220 x 600 = $\sqrt{3}$ x 11000 x I_2. Hence I_2 = 12 A.

Therefore CT ratio on 11000 V side is 12 : 5√3 or 4√3 : 5. 1 mark

2 Attempt any four 16 marks

2 a) Compare HRC fuse and Circuit breakers as interrupting devices.
Soln:

Sr no	Point of comparison	HRC Fuse	Circuit Breaker
1	Function	Performs detection & interruption	Only interruption
2	Operation	Inherently automatic	Requires elaborate equipment
3	Breaking capacity	Low	Very large
4	Operating time	Low (0.002 seconds)	Higher (0.1sec to 0.2 sec)
5	Replacement	After every operation	No replacement needed
6	Size	Compact	Large
7	Cost	Low	High.
8	Reliability	Less	More
9	Safety	Safe	More safe

Any eight points ½ mark each = 4 marks

2 b) State the sequence of operation of isolator, CB, and earthing switches.
Soln:
While closing the Circuit:
1) Open earth switch
2) Close isolator
3) Close CB.

2 marks

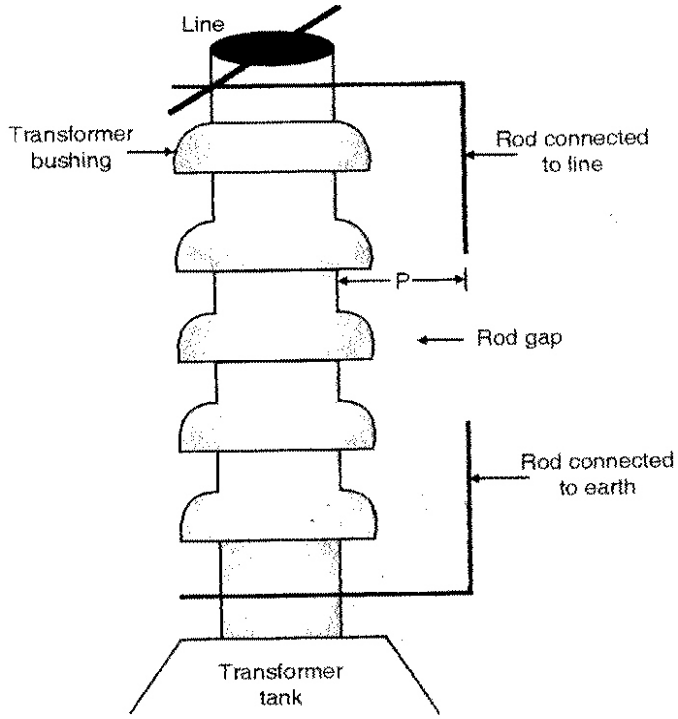
While opening the circuit:
1) Open CB
2) Open isolator
3) Close earth switch.

2 marks

2 c) Describe the construction and principle of operation of a typical lightening arrestor.
Soln:

Rod gap arrestor:

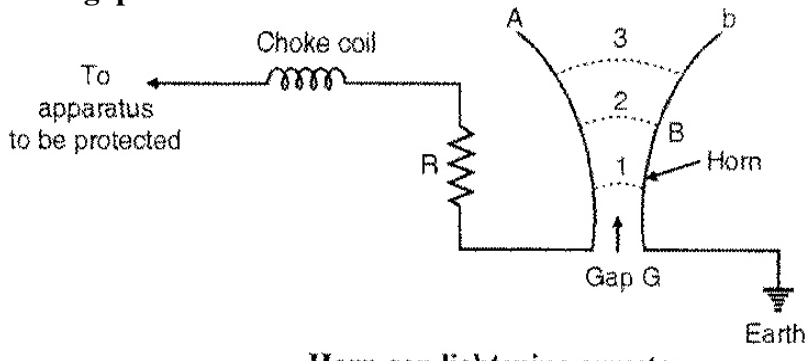
Diagram 2 marks and principle 2 marks any one arrestor



Rod gap lightening arrester

Simple surge diverter consisting of two 1.5 cm rod bent at right angles & an air gap is provided between them.
Under normal operating conditions the gap remains non-conducting. On occurrence of high voltage surge on line the gap sparks over the surge current is conducted to earth.

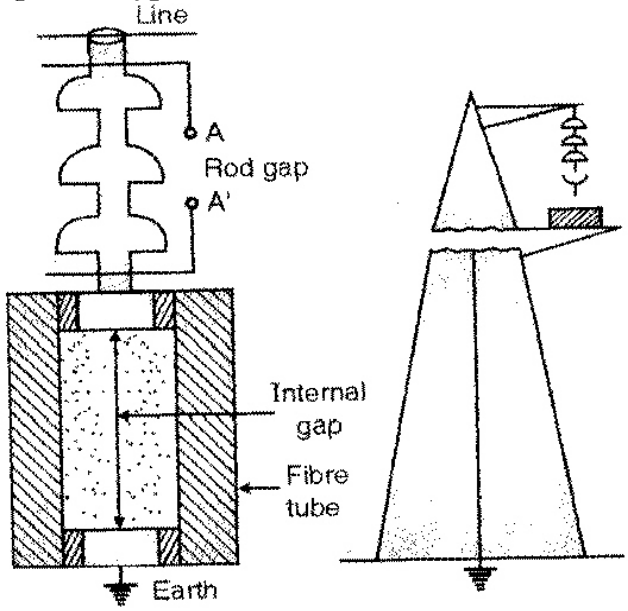
Horn gap arrestor:



Horn gap lightening arrester

Consists of two horn shaped metal rods A and B, separated by small air gap and series resistor R and inductor L which limit the fault (surge) current to a small value.
Under normal conditions supply voltage is insufficient to initiate the arc between the gap and remains non-conducting. On a voltage surge arcing takesplace across smaller section of the gap. Choke coil has low reactance to normal line frequency but high for over voltages due to their high frequency (transients) and hence the over voltage is discharged to earth through the horn gap. The resistance limits the fault current to small value. As the arc moves up the lengthening of the arc length takes place and it is extinguished.

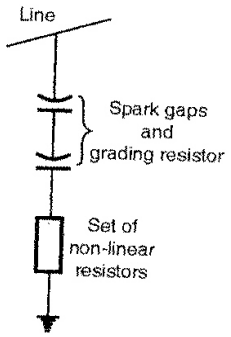
Expulsion type arrestor:



Expulsion type arrester

Consists of a rod gap A-A' in series with second gap enclose within the fibre tube. Under normal condition supply voltage is insufficient to initiate the arc between the gap. On voltage surge arcing takes place across series gap A-A' and thus an arc is also struck between the electrodes in the tube. Due to production of gas, which carries all the ionized air around the arc and de-ionosed effect takes place, thus the arc is quenched immediately.

Valve type arrestor:



Mainly consists of two parts: series spark gap and non-linear resistor discs.
Under normal operating conditions the normal power frequency voltage is not sufficient to break the air gap assembly but on lightning surge or travelling wave, the series spark gap breaks down and surge current is diverted to earth through the non-linear resistors which have low resistance for high current and high resistance for low currents.

2 d) State necessity of neutral earthing and list the different methods:
Soln:
Need:

Reduce/eliminate arcing grounds.
Provide easy means of protection against earth fault. 2 marks

Maintain rated voltage of healthy phases on fault on one of the phases.
Provide safety to personnel and equipment.

Methods of neutral earthing:

1) Solid or effective earthing.
2) Resistance earthing.
3) Reactance earthing/Peterson's coil earthing.
4) Resonant earthing.
5) Earthing transformer.

½ mark each any four = 2 marks.

2 e) Define following with respect to relay:

Soln:

1) **Relay time:** time interval between occurrence of fault and closure of relay contacts.
2) **Pickup:** the threshold value of operating quantity above which the relay operates.
3) **Reset:** value of actuating quantity (current, voltage etc.) below which the relay comes back to its original position (off position).
4) **Fault clearing time:** time elapsed between instant of occurrence of fault and instant of final arc extinction in CB.

1 mark each = 4 marks.

2 f) State abnormalities and faults in alternators with necessary protection:

Soln:

Fault	Protection
1. Stator winding SC fault (ph & earth)	Biased differential, sensitive earth fault, inter-turn fault protection.
2. Under frequency	Frequency relay
3. Rotor earth fault	Earth fault relay protection.
4. Over-voltages	Lightning arrestor
5. Thermal overloading	Thermo couples embedded in stator
6. External faults	Negative phase sequence relay
7. Over heating	Thermal relays

1 to 2pts 1mark,

3 to 4 pts 2 marks,

5 pts = 3marks,

6 or more = 4 marks.

3 Attempt any four: 16 marks

3 a) Describe current zero method of arc extinction in CB operation:

Soln:

Current zero or Low Resistance Method: This method is employed in a.c. circuit breakers since the alternating current passes through zero 100 times per second in 50 cycle current wave. When current wave passes through every zero the arc vanishes for a brief moment. However, the arc restrikes again with the rising current waves. 2 marks

In this method, at current zero instant, fresh unionized medium (such as oil or fresh air or SF_6 gas) is introduced between the space of contacts. Due to introduction of unionized medium deionization effect takes place. The dielectric strength of the contact space increases to such an extent that the arc does not continue after current zero. 2 marks

3 b) What is ELCB? Describe it's working.

Soln:

ELCB:

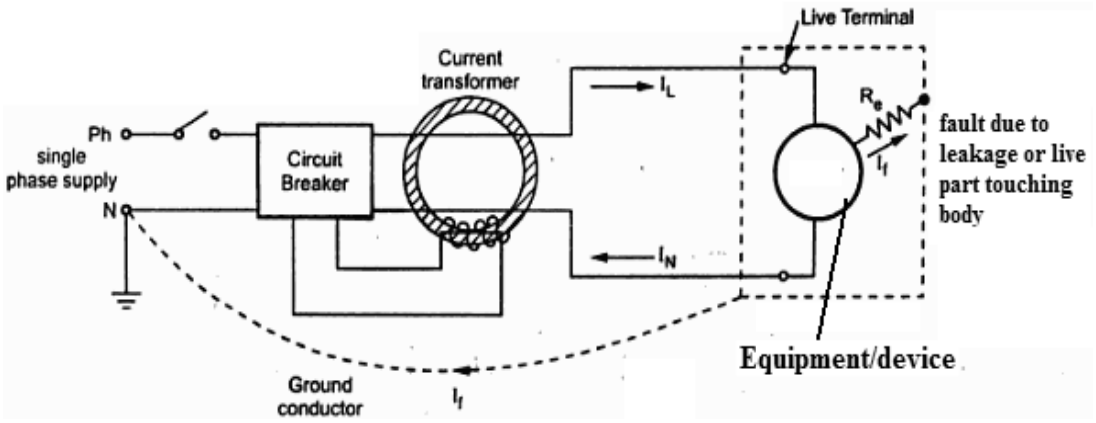


Diagram 2 marks

Earth leakage circuit breaker is a safety device used in electrical installations with high earth impedance to prevent shocks and disconnect power under earth fault conditions. Works on principle of relaying when the current in the earth path exceeds a set value. ELCB is used for protection against electric leakage in the circuit of 50 Hz or 60 Hz , rated voltage single phase 240 V, 3 ph. 4 kv. Rated current up to 60 Amp. When the earth fault occurs, the ELCB cuts off the power within the time of 0.1 sec. automatically to protect the personnel.

Description 2 marks

Under normal conditions $(I_L - I_N) = I_f$ is very low or nearly zero. The CT surrounding the phase and neutral senses the differential current under earth fault and actuates the CB to operate (open). The difference current I_f through fault path resistance R_e is the leakage to earth. If this value exceeds a preset value then the CB opens. Normally it is around 35 mA for tripping in domestic installations with tripping time being as low as 25msec.

3 c) Current rating of an overcurrent relay is 5 A, current setting is at 200%, TSM = 0.4, CT ratio = 400/5, fault current = 4000 A. determine the operating time of relay. Use following table operating at various PSM at TSM = 1.

PSM	2	4	8	20
Relay time in Seconds	10	5	3	2.4

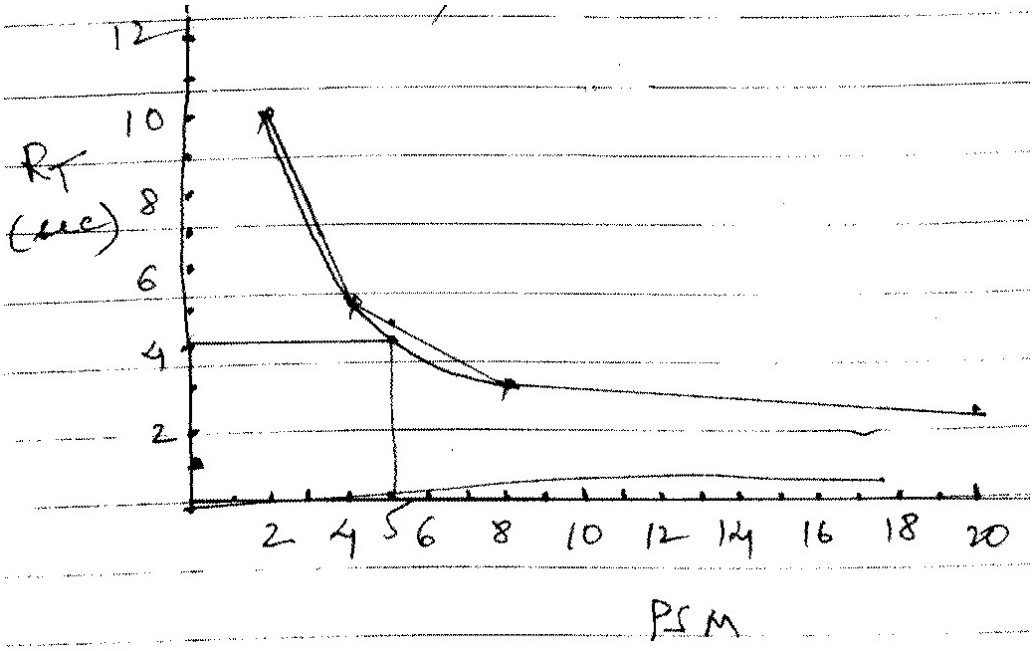
Soln:

Relay rated current = 5 A,

Relay pickup current = rated relay current x current setting = 5 x 2 = 10 A. 1 mark

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

PSM = (fault current in relay/relay pick up current) = 50/10 = 5. 1 mark



Now for PSM = 5 from above the students will get relay time roughly between 4 seconds to 4.5 seconds.
Hence actual relay operating time is = (relay time) x TSM — 1 mark
= (4 to 4.5) x 0.4
= 1.6 sec to 1.8 sec. — 1 mark
Students getting value around these will be awarded marks as given in last column.

3 d) State the common faults occurring power transformer. Suggest the protection for these faults.
Soln:

Sr no	Type of fault	Protection scheme suggested
1	Earth fault	1) Earth fault relay 2) Differential protection.
2	Through faults (beyond protected zone)	1) HRC fuses 2) Graded time lag overcurrent relay.
3	High voltage surges due to lightning.	1) Horn gaps. 2) Surge arrestor. 3) RC surge suppressor.
4	Overloads	1) Temperature relays 2) Thermal overload relays
5	Incipient faults: phase to phase, phase to ground, below oil level.	1) Buchholz's relay.
6	Saturation of magnetic core	1) Over fluxing protection 2) Overvoltage protection.

1 mark each any four = 4 marks

3 e) What are the difficulties in the differential protection scheme used for transformer?

Soln:

1) Difference in length of pilot wires on either side of relay may lead to mal-operation due to unequal resistance on the two sides. 1 mark each
2) Minor Difference in CT ratios of identically rated CTs may lead to improper operation in some cases.
3) Magnetizing current in rush may lead to unnecessary operation of relay.
4) Due tap changing unbalance conditions may be created.

These can be overcome by using %differential protection.

4 A Attempt any three of following 3 x 4 = 12 marks

4 A a) Draw a diagram of differential protection scheme for a star connected alternator and explain its working.

Soln:

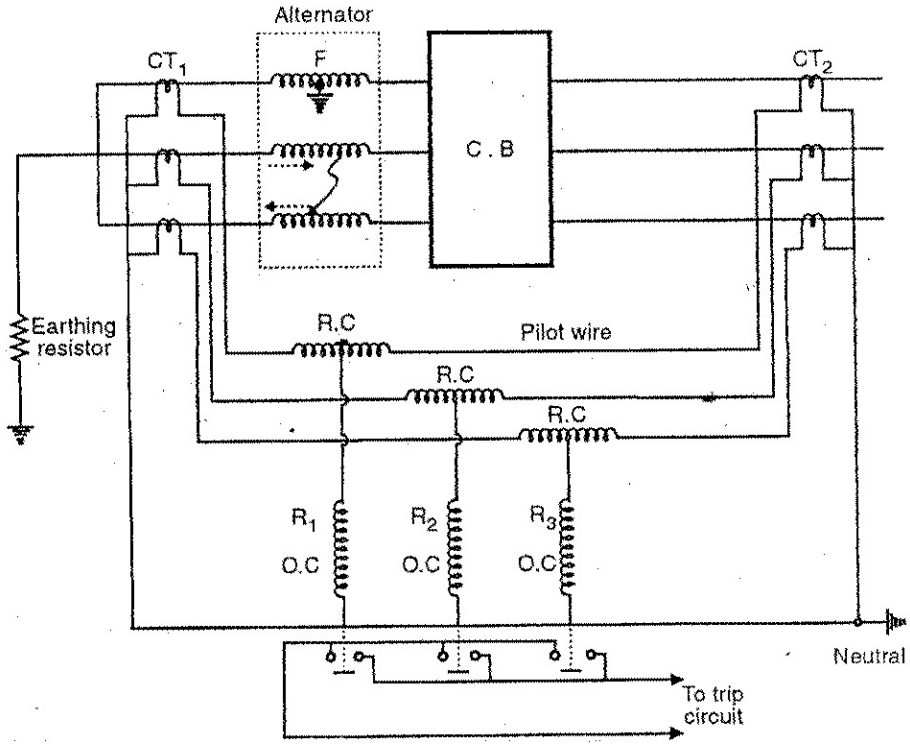


Diagram 2 marks

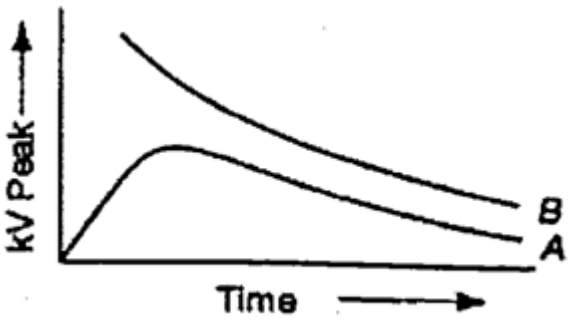
Under normal operating conditions, the currents in the pilot wires fed from CT connections are equal. The differential current flowing through operating coil of relay is zero ($I_1 - I_2 = 0$). When fault occurs in the protected zone balance is disturbed, the differential current flows through the operating coil of relay causing its operation. Relay sends signal to the CB thereby alternator circuit is tripped the field is disconnected and discharged through suitable impedance. 2 marks

4 A b) Define the term insulation coordination. Draw the volt-time curve of apparatus used in the power system.

Soln:

Insulation coordination:

Insulation coordination is the co-relation of the insulation of electric equipment and lines with the characteristics of protective devices such that the insulation of the whole power system is protected from excessive over voltages. 2 marks



2 marks

Curve A is volt time curve of protective device and curve B is that of equipment (apparatus) to be protected..

4 A c) Define following terms related to CB.

i) **Rated normal current:** it is the RMS value of current which the CB is capable of carrying continuously at its rated frequency under specified conditions. 1 mark

ii) **Rated breaking current:** it is the RMS current that the CB is capable of breaking at given recovery voltage and under specified conditions (eg. pf, RRRV). 1 mark

iii) **Short time rating:** it is the period for which the CB is able to carry the fault current while remaining closed. 1 mark

iv) **Symmetrical breaking current:** it is given by 1 mark
= (breaking capacity(MVA))/(√3 rated voltage)

4 A d) Which are the most commonly used schemes for bus bar protection? Explain any one scheme in detail.

Soln: Differential protection and Fault bus protection 1 mark

1) Differential protection:

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

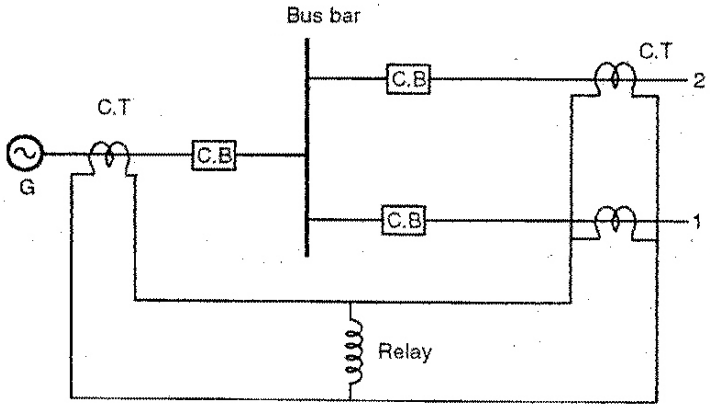


Fig 1 mark

Differential protection of bus bar

OR

2) Fault bus protection:

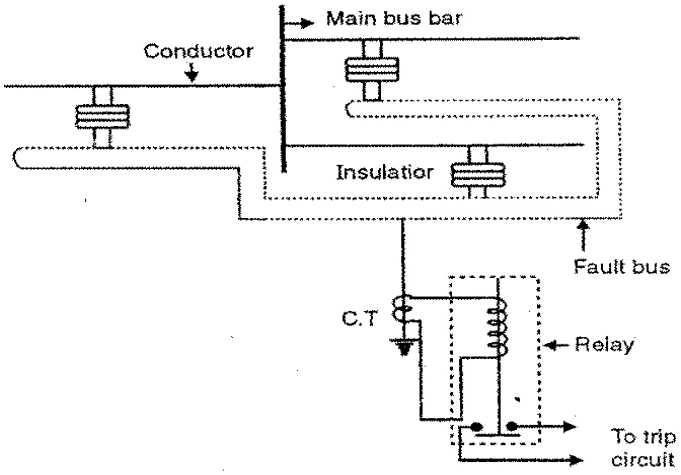


Fig 1mark

Fault bus protection

In this substation is so designed that every fault on the bus bar is converted to earth fault. Under normal operating conditions there is no current flowing through the fault bus flowing to ground and relay remains inoperative. When any fault occurs on bus bar involving a connection between conductor and earthed support structure will cause a flow of current to earth through the fault bus. This results in operation of relay to actuate trip coil of CB to trip the circuit. 2 marks

4 B Attempt any one of the following 6 marks

4 B a) What type of motor protection is used for high capacity induction motors? Describe the function of different relays used.
Soln:

Types Motor protection:
1) HRC fuses.
2) Thermal overload relays. 2 marks

3) Single phasing preventer.
4) Differential protection.
5) Instantaneous overcurrent relay.
6) Negative phase sequence relay.

Functions of different relays:

1) Thermal overload relay: protection against overloading, temperature rise.
2) Instantaneous overcurrent relay: protection against stalling, stator and rotor faults. — 1 mark each = 4 marks
3) Negative phase sequence relay: protection against unbalance supply voltage.
4) Under voltage relay: protection against under voltage.

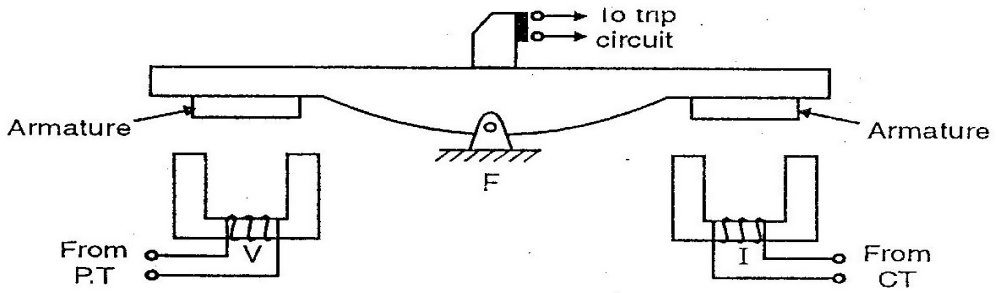
4 B b) What are the advantages of distance protection over other types of protection of feeders? Explain distance protection of transmission line.

Soln:

Advantages:

1) System is economical — ½ mark each = 2 marks
2) High speed of interruption
3) Suitable for very long and high voltage transmission lines.
4) No problem of pilot wires.

Distance protection of transmission lines:



Definite – distance type impedance relay — Fig 2 marks

Action of relay depends on impedance up to fault point i.e distance to it as impedance is directly proportional to length of line. — 1 mark

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. — 1 mark

'V' is the restraining quantity while 'I' is the operating quantity.

5 Attempt any four of following: — 4x4 =16 marks

5 a) State any eight properties of SF_6 gas which is suitable for arc quenching.

Soln:

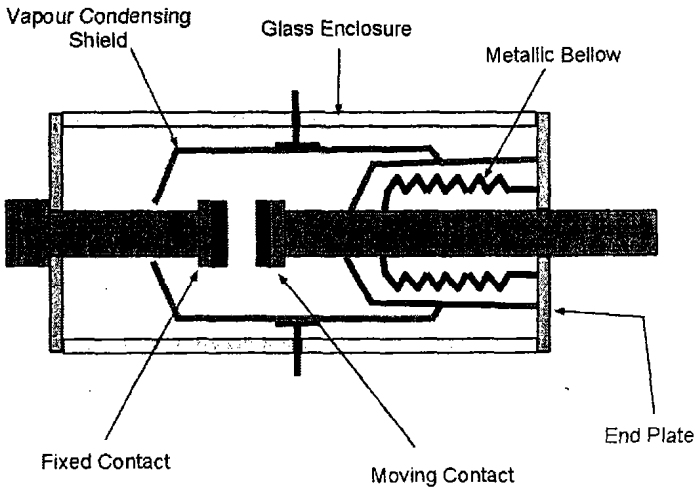
Properties of SF_6 gas suitable for arc quenching,

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.

½ mark each any eight = 4 marks

5 b) Describe the working principle, construction and advantages of vacuum CB with neat diagram.

Soln:



Vacuum Interrupter

Separate description of construction not needed, labeled diagram 2 marks

Working principle: (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 gets 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.

1 mark

Advantages:

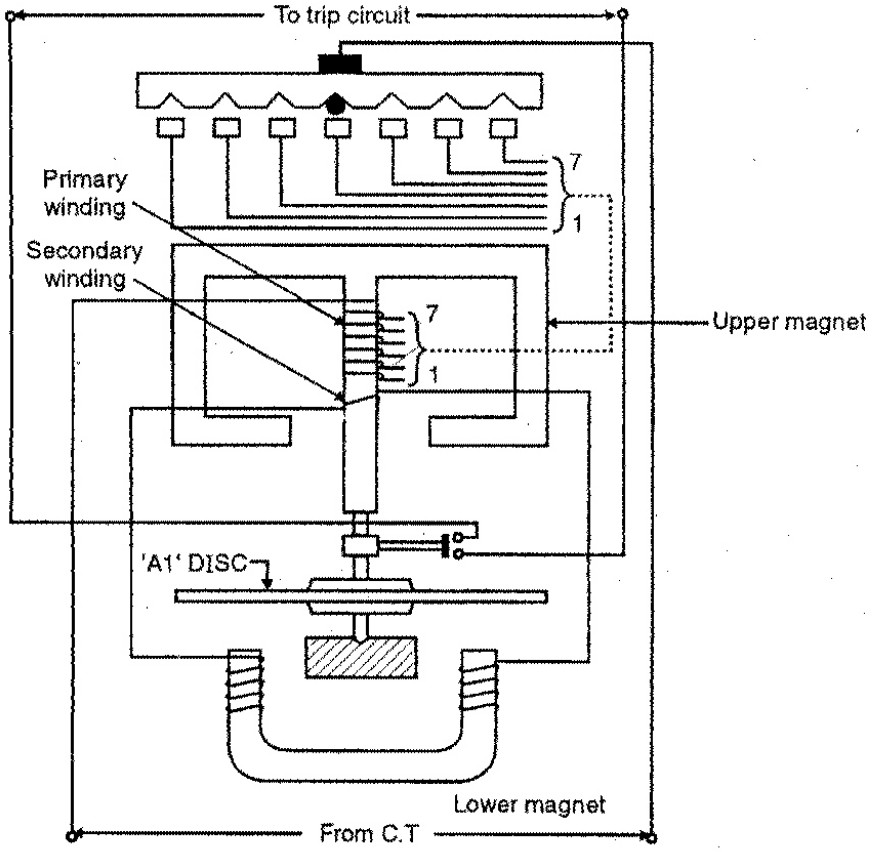
1) No fire hazards.
2) Compact in size.
3) Reliable and longer life.
4) Operation is quite.
5) Low maintenance.
6) No generation of any gas.

Any three to four pts 1 mark

5 c) Describe with help of neat diagram the construction and operation of induction type overcurrent relay.

Soln:

Separate description of construction not needed, labeled diagram 2 marks



Induction type over current relay (non – directional)

-

Operation:

Under normal operating conditions restraining torque is greater than driving torque, therefore the disc remains stationary. However if the current in the protected circuit exceeds the preset value the driving torque becomes greater than restraining torque. Due to this the disc rotates and moving contacts close over the fixed contacts. The trip circuit operates CB which isolates the faulty section. 2 marks

5 d) Explain how the plug setting and time setting can be done in induction relay.

Soln:

Plug setting:

The primary winding of the CT is connected in series with the line and secondary winding of CT is connected to primary winding of relay which is provided with number of tappings. These are connected to plug setting bridge by which the number of turns on relay coil can be varied which gives the desired current setting. 2 marks

Time setting:

The secondary winding is energized by induction from primary and is connected in

series with winding on lower magnet. The spindle of the disc carries a moving contact which bridges two fixed contacts when the disc rotates through a preset angle. This angle can be adjusted any value between 0 to 360 degrees. The relay time can be adjusted by adjusting this angle which is the travel of moving contact. — 2 marks

5 e) State advantages and disadvantages of static relays over electromagnetic relays.

Soln:

Advantages:

i) Low power required hence less burden.
ii) No motional parts hence bouncing, friction, erosion, arcing etc eliminated.
iii) Not affected by gravity, may be used in any position.
iv) Improved selectivity as resetting and overshoot times are reduced.
v) Lower operating times.
vi) One static relay can be used for multiple purposes.
vii) Higher torque/weight ratio.
viii) Compact.
ix) Good discriminating characteristics and reliability.
x) Suitable for reliable remote operation with PLCC.
xi) Can be programmed as required.

½ mark each any four = 2 marks

Dis-advantages:

i) Affected by voltage transients.
ii) Affected by electrostatic discharges which can occur.
iii) Sensitive to temperature.
iv) Costly.
v) Higher skilled manpower required to handle/program/install.
vi) Operating characteristics may be affected by operation of output device

½ mark each any four = 2 marks

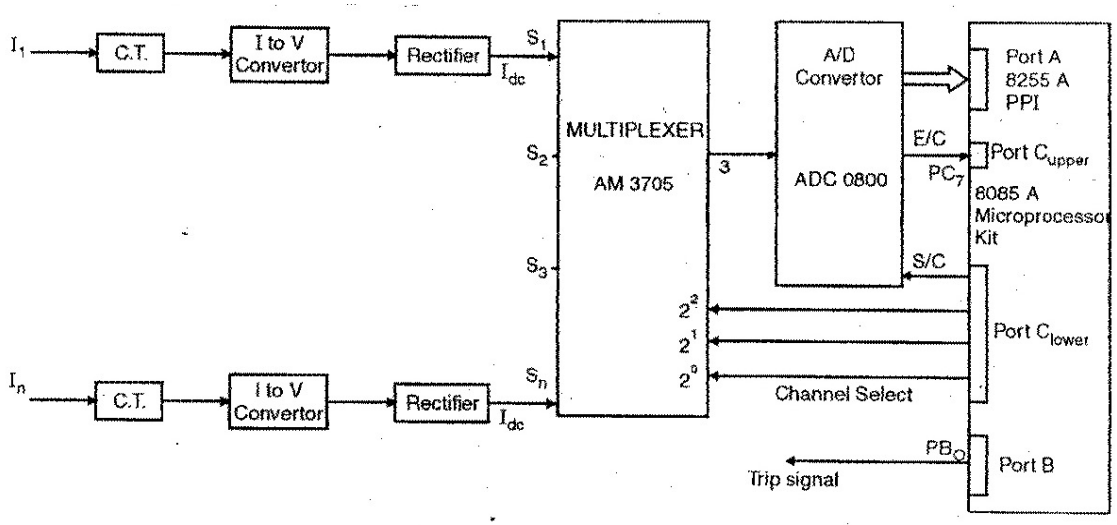
5 f) State salient features of micro processor based protection relay. Draw block diagram of micro processor based over current relay.

Soln:

Salient features:

1) Single relay for multiple functions.
2) High flexibility
3) Digital display of quantities.
4) Intelligent Self monitoring feature.
5) Increased reliability.
6) Data interface access.
7) User friendly.
8) High speed.

½ mark any four = 2 marks



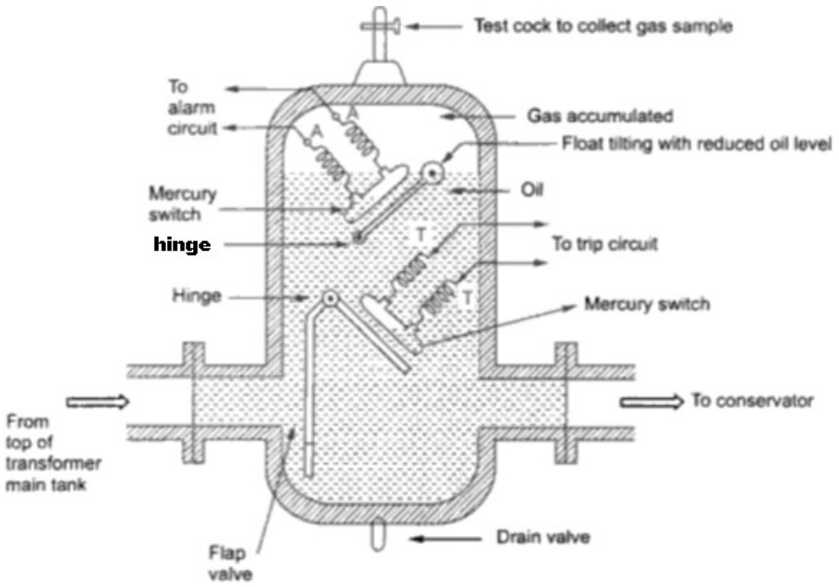
Schematic diagram of microprocessor based over current relay

Fig 2 marks

6 Attempt any four: 4x4 = 16 marks

6 a) Draw neat labeled diagram of Buchholz relay.

Soln:



Fully labeled = 4 marks, partially labeled 2 to 3 marks, unlabeled 1 mark.

6 b) State the specifications of CT and PT as protective transformer.

Soln:

SPECIFICATIONS applicable to both:

1) Normal system voltage (kV_{RMS})
2) Highest system voltage (kV_{RMS})
3) Frequency
4) Impulse withstand voltage
5) CT, PT Ratios as applicable
6) Rated output (VA burden)
7) Accuracy class

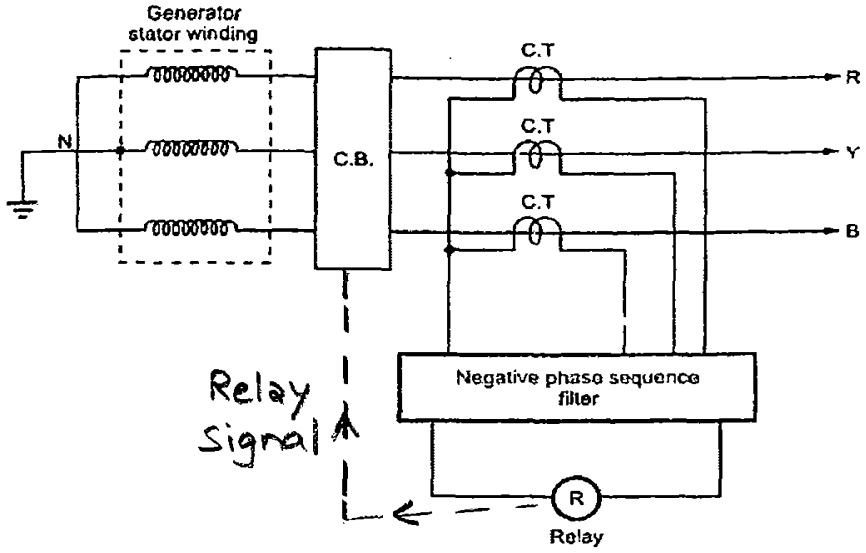
1 mark each any four = 4 marks

8) Maximum ratio error.
9) Maximum phase angle error.

6 c) How negative phase sequence currents are set up in an alternator? Draw the protective scheme for the same.

Soln:

Unbalanced loading on alternator mainly causes the rise to negative sequence currents which generate the negative sequence components of magnetic fields. These fields rotate in opposite direction of the main field and induce emfs of double frequency in rotor winding causing over heating. 2 marks



2 marks

Negative sequence protection

6 d) Describe restricted earth fault protection for three phase delta/star transformer with neat diagram.

Soln:

Restricted earth fault protection for transformers:

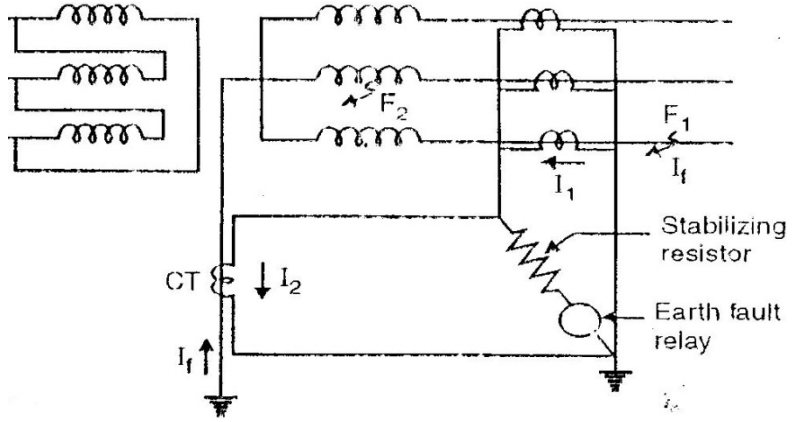


Diagram 2 marks

- 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. 2 marks

- 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.

6 e) What are the requirements of transmission line protection?

Soln:

Requirements of transmission line protection:

1) Faults on lines should be quickly detected to initiate actions to maintain system stability.
2) For very long lines the protection system must be capable of identifying the fault location.
3) In the event of short circuit fault on the line the CB nearest to it must operate to open the line while the other CBs remain closed.
4) Adjacent CB's should provide immediate backup protection in event of failure of CB (nearest to fault) to operate.

1 mark each = 4 marks