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 should assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given 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 should give credit for any equivalent figure/figures drawn.
5) Credits to 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 (as long as the assumptions are not incorrect).
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 <u>THREE</u> of the following:** 12

1 a) (i) State the causes of faults in power system.

Ans:

Causes of faults in power systems:

1) Over voltages due to direct lightning strokes.
2) Over voltages due to switching surges.
3) Falling of external conducting objects, tree branches etc. on conducting lines.
4) Accumulation of dust, dirt etc. on exposed components such as lines, insulators etc.
5) Perching of birds on lines, insulators or other components.
6) Ill-maintained sections of the power systems.
7) Heavy unbalanced loading on three phase lines even for short times.
8) Prolonged unbalanced loading conditions leading to overheating (due to harmonics).
9) Failure of joints.
10) Open circuited or broken conductors.
11) Mechanical damage to components of the power systems.
12) Unusually severe atmospheric conditions as storm, rains, too high humidity.
13) Defective/improper selection of components used and faulty design of the power system sections.
14) Failure of insulation of components and equipment parts.
15) Accidents.
16) Over temperature.
17) Excessive internal and external stresses.

Each point ½ Mark (any eight points) = 4 Marks

1 a) (ii) Define Plug setting multiplier and Time setting multiplier.

Ans:

i) Plug setting multiplier: It is the ratio of fault current in relay coil to pick-up current.

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

ii) Time setting multiplier: The adjustment arrangement provided for setting the operation time of protective relay from '0' sec to maximum permissible for a specified current setting is known as Time setting multiplier.

2 Marks for each definition = 4 Marks

1 a) (iii) List out all the important faults which may occur in alternator.

Ans:

Important faults in an alternator:

1) Stator winding faults.
2) Thermal overheating.
3) Rotor winding faults.
4) Loss of field.
5) Under/Over frequency.
6) Vibration &Bearing overheating.
7) Motoring of generator.
8) Faults because of external causes.
9) Over voltages.

Each point ½ Mark (any eight points) = 4 Marks

10) Over speed.
11) Over current.

1a) (iv) State the abnormalities and faults in transformer protection.

Ans:

Abnormalities and faults in transformer protection:

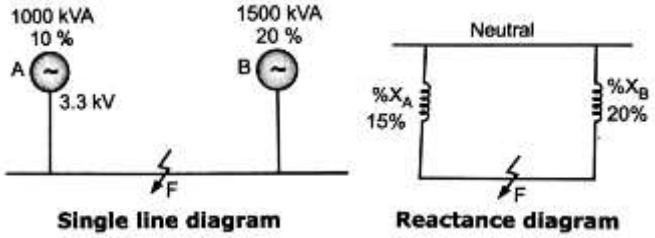
1) Earth fault
2) Through faults (beyond protected zone)
3) High Voltage surges due to lightning
4) Overloads/ Overheating
5) Incipient faults: Phase to Phase , Phase to ground, low oil level, decomposition of oil
6) Saturation of magnetic core
7) Faults in tap changer
8) Inter-turn fault

Each point 1 Mark (any four points) = 4 Marks

1b) **Attempt any ONE of the following:** **6**

1b) (i) Two three phase generators of rating 1000kVA and 1500kVA, 3.3kV having percentage reactance of 10 and 20 respectively with respect to their ratings, are connected to bus bars. A three phase short circuit occurs on the bus. Find the short circuit current.

Ans:



Assume base kVA = 1500 kVA

% Reactance related to base kVA

% X = (Base kVA / Rated kVA) x % Reactance on Rated kVA

X_A = (1500/1000) x 10%
= 15 %

1 Mark

X_B = (1500/1500) x 20%
= 20 %

1Mark

For Fault at Bus

Total reactance **,**

% X = X_A || X_B
= 15 || 20
% X = 8.571%

1 Mark

Rated current at base kVA = I = (1500 x 1000) / (√3 x 3.3 x 1000)
I = 262.431amp

1 Mark

I_{SC} = I x (100 /% X) = 262.431 x (100 /8.571)

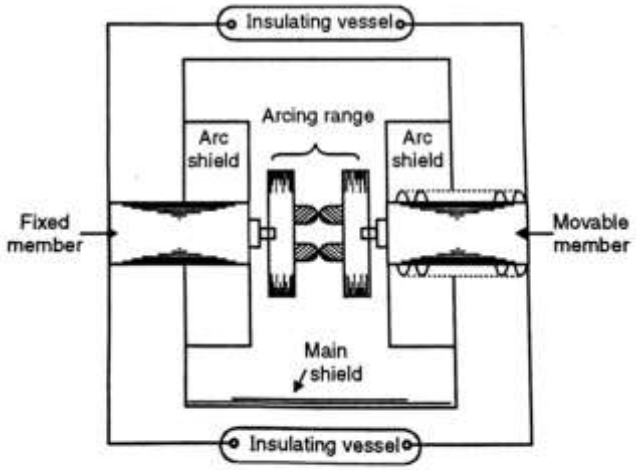
2 Marks

I_{SC} = 3061.848amp

1b) (ii) Describe with neat sketch the principle of operation of vacuum circuit breaker.

Ans:

Vacuum circuit breaker:



Vacuum circuit breaker

3 Marks for diagram

Principle of operation :

During the operation of the breaker, the moving contact separates from the fixed contact resulting in arching between them. The production of arc is due to the ionization of metal ions and depends very much upon the material of contacts. The arc is quickly extinguished because the metallic vapour, electrons and ions produced during arc are diffused in a short time and seized by the surface of moving and fixed members and shields. The arc gets extinguished quickly as vacuum has very good recovery of dielectric strength. The arc extinction occurs at a small vacuum gap of about 0.6 to 0.7cm.

3 Marks for principle of operation

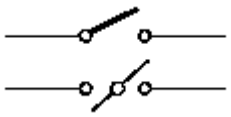
2 **Attempt any <u>FOUR</u> of the following:** **16**

2 a) Draw the symbol and state the function of
- (i) Isolator
- (ii) Circuit breaker
- (iii) Earthing switch
- (iv) Lightning arrester

Ans:

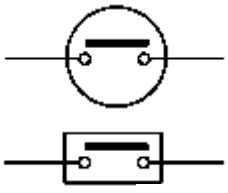
Isolator :-

To disconnect or isolate a part of the power system for maintenance from live circuit under no current condition.



Circuit breaker:

To make or break a circuit manually or remotely under normal condition and to break circuit automatically under fault condition.

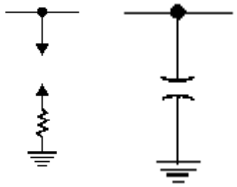


Earthing switch:

To discharge voltage on the line (due to charged of line capacitance) to earth after disconnecting line from live section.

½ Mark for each valid symbol + ½ Mark for each function = 4 Marks

Lightning arrester:
To divert the high voltage surges due to lightning to the earth and protect the system.



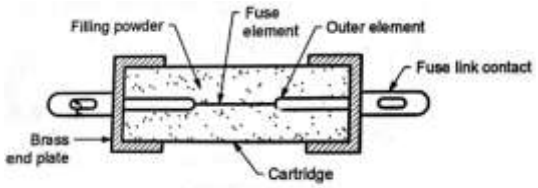
2b) Explain the construction and working of HRC fuse with diagram.

Ans:

Construction of HRC fuse:

HRC fuse mainly consists of heat resisting ceramic body. The current carrying element is compactly surrounded by the filling powder. Filling material acts as an arc quenching and cooling medium when the fuse element blows off due to excessive heat generated under abnormal conditions.

1 Mark for construction



H.R.C. fuse

2 Marks for diagram

Working:

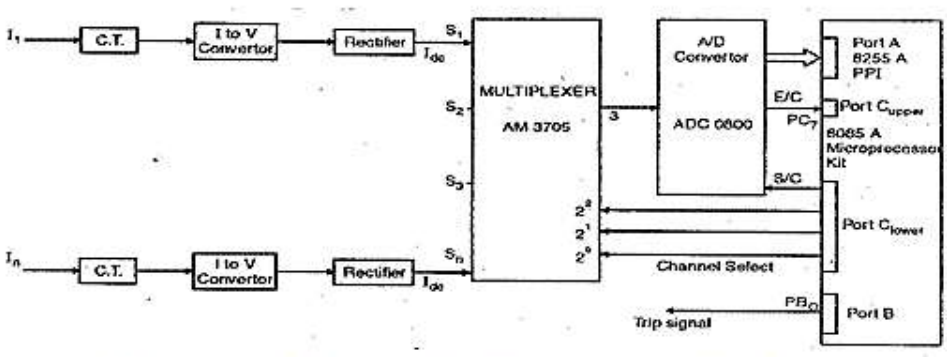
Under normal conditions, the fuse element is at a temperature below its melting point. Therefore, it carries the normal current without overheating.
When a fault occurs, the current increases and the heat produced is sufficient to melt these elements. Fuse element melts before the fault current reaches its first peak value. Vaporized metal /fuse element chemically reacts with filling powder and results in the formation of high resistance substance that helps in quenching the arc.

1 Mark for working

2c) Draw the block diagram of microprocessor based over current relay.

Ans:

Block diagram of microprocessor based over current relay:



Block diagram of Microprocessor based Over Current Relay.

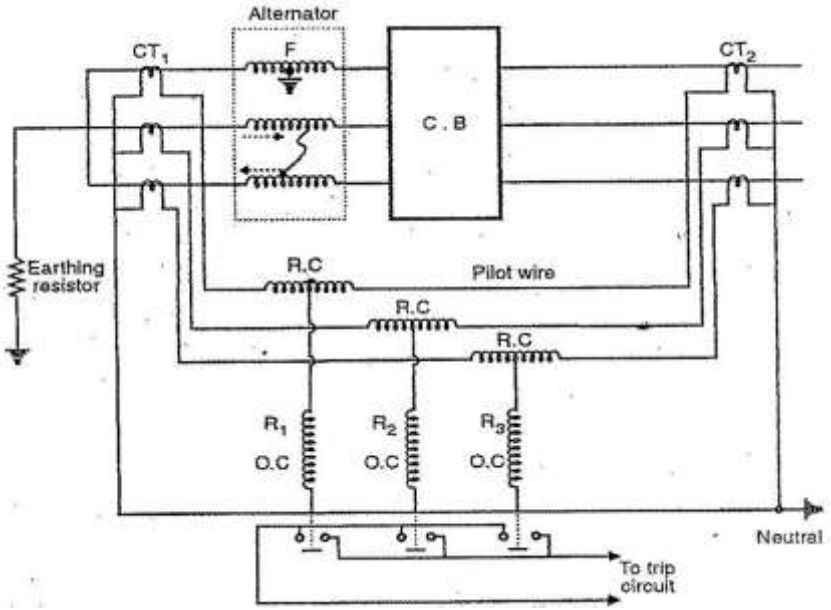
Labeled diagram 4 Marks

Partially labeled 2 Marks

2 d) Explain merz price protection of alternator.

Ans:

Merz price protection of alternator:



2 Marks for diagram

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.

2 Marks for explanation

2 e) Describe the behavior of three –phase induction motor under single phasing.

Ans:

Behavior of three-phase Induction motor under single phasing:

When one of the supply lines of the three phase supply connection gets disconnected then this situation is known as single phasing. Under this condition, motor continues to operate on two phase supply. If the motor is loaded to its rated full load it will draw excessive current, thus the current in these two healthy phases increases by√3times on single phasing. Single phasing may cause extreme magnetic unbalance, reduction in torque and over- heating due to negative phase sequence current. This condition may cause damage to the motor. Hence protection against single phasing is necessary.

4 Marks for description

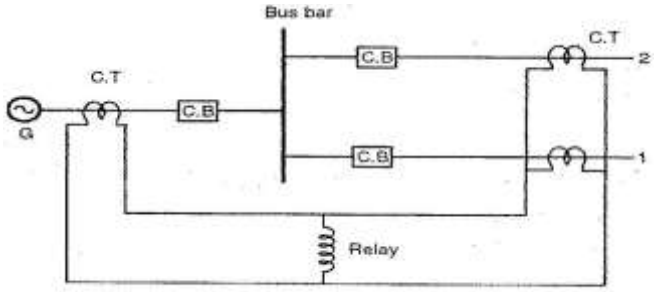
2 f) Describe differential protection of bus bar with neat labeled diagram.

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 relay coil causing opening of circuit breaker.

2 Marks for description



Differential protection of bus bar

2 Marks for diagram

3 **Attempt any <u>FOUR</u> of the following**: **16**

3a) Compare the fuse and MCCB on the basis of speed of operation, cost, construction and replacement strategy.

Ans:

Sr. No	Point	Fuse	MCCB
1	Speed	Operating time is very small (0.002 Sec or so)	Operating time is comparatively large (0.1 to 0.2 Sec)
2	Cost	Less	Comparatively more
3	Construction	Simple	Comparatively Complicated
4	Replacement Strategy	Requires replacement after every operation	No replacement after operation

Each point 1 Mark (four points = 4 Marks)

3b) State the specifications of CT and PT as a protective transformer.

Ans:

Specifications of CT as a protective transformer:

Typical specifications of CT as a protective transformer is as below:

1) Rated primary current.
2) Rated secondary current.
3) Current (ratio) error.
4) Accuracy limit factor.
5) Phase displacement.
6) Composite error.
7) Accuracy class.
8) Rated burden.
9) Short time rating etc

2 Marks for two CT specifications

Specifications of PT as a protective transformer:

Typical specifications of PT as a protective transformer is as below:

1) Rated primary voltage.
2) Rated secondary voltage.
3) Rated burden.
4) Accuracy class.
5) Rated voltage factor.
6) Rated temperature.
7) Class of insulation etc.

2 Marks for two PT specifications

3c) What is differetial relay? Explain the working of current differential relay.

Ans:

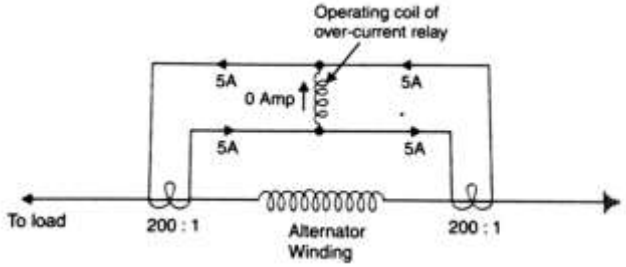
Differetial relay:

A differential relay is one that operates when the phasor difference of two or more similar electrical quantities exeeds a pre-determined value. 1Mark

Working of current differential relay:

Figure shows an arrangement of an overcurrent relay connected to operate as a differential relay for alternator protection under fault conditon.

Under normal operating conditions, suppose the alternator winding carries a normal current then the current in the two secondaries of CTs are equal. These currents will only circulate between the two CTs and no current will flow through relay coil. If a fault occures on alternator winding, the two secondary currents will not be equal and resultant current flows through relay coil, causing the relay to operate. 2 Marks for explanation



1 Mark for diagram

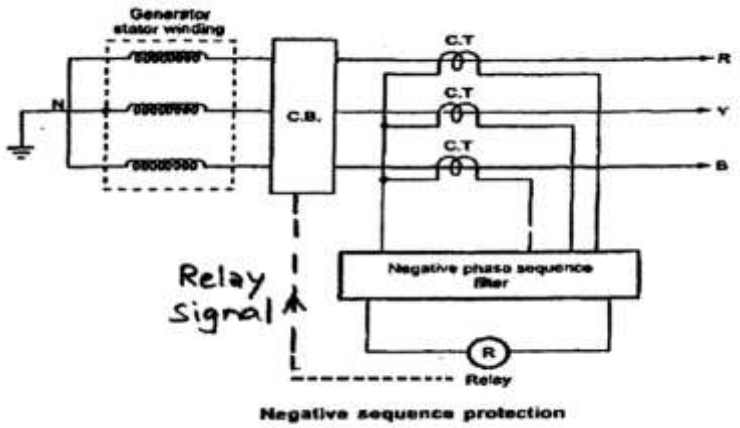
3d) Explain with neat diagram the negative phase sequence current protection for an alternator.

Ans:

Negative phase sequence current protection for alternators:

The CTs as shown in the diagram, feed the negative phase sequence filter that consists of resistors and inductors so arranged that under normal balanced load conditions the relay does not operate. 2 Marks for explanation

But when an appreciable unbalance occurs, the negative phase sequence currents are sensed by the CTs and fed to the negative phase sequence filter. This results in sufficient current to operate the relay R that trips the circuit breaker CB.



Negative sequence protection

2 Marks for diagram

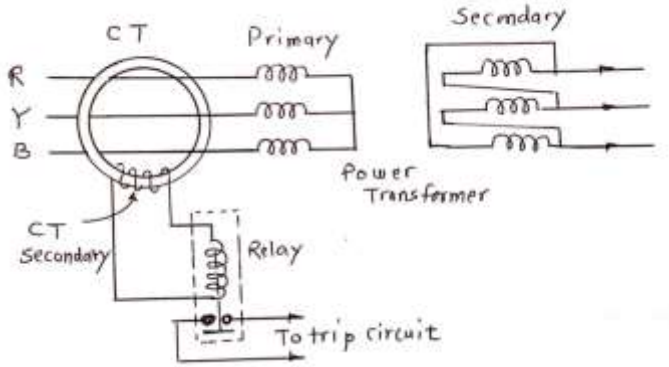
3e) Explain with neat sketch earth fault protection for star-delta transformer.

Ans:

Earth fault protection for star-delta transformer:

The three leads of the primary winding of star–delta transformer are taken through the core of a current transformer which carries a single secondary winding. The operating coil of a relay is connected to this secondary. Under normal conditions(i.e.no fault to earth), the vector sum of the three phase currents is zero and there is no resultant flux in the core of current transformer no matter how much the load is out of balance. Consequently, no current flows through the relay and it remains inoperative. However, on the occurrence of an earth fault, the vector sum of three phase currents is no longer zero. The resultant current sets up flux in the core of CT, ultimately induces an e.m.f. in the secondary winding which energizes the trip coil and protects the faulty transformer.

2 Marks for explanation



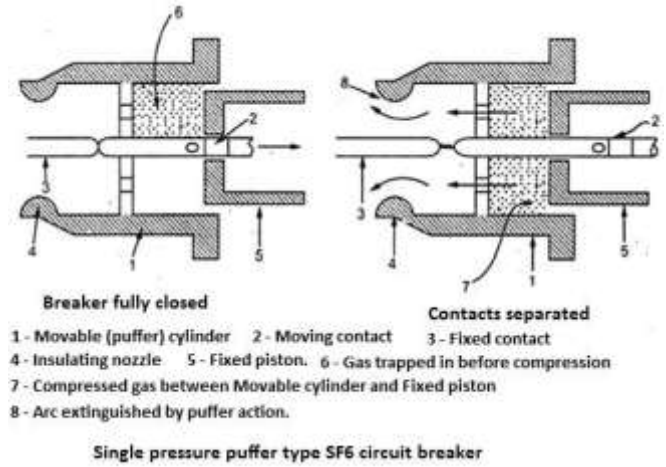
2 Marks for diagram

4 a) **Attempt any <u>THREE</u> of the following**: **12**

4 a) i) Describe with neat sketch arc extinction of SF_6 circuit breaker.

Ans:

Arc extinction of SF_6 circuit breaker:



Single pressure puffer type SF6 circuit breaker

2 Marks for diagram

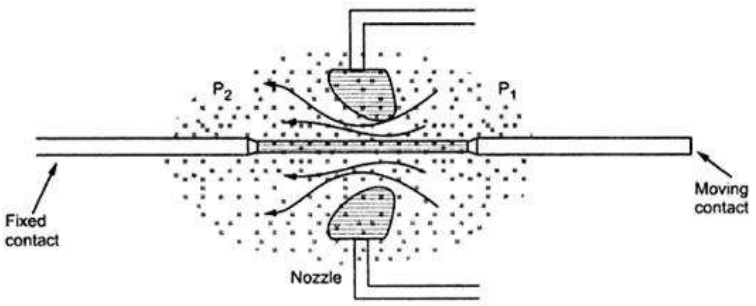
Gas is compressed by the moving cylinder and is released through the nozzle and rapidly absorbs the free electrons to extinguish the arc.

The moving cylinder (1) is connected to moving contact (2) against the fixed piston (5). Due to relative motion between (1) and (5) the gas gets compressed

2 Marks for description

in enclosure (6) and is released through nozzle for arc extinction. This happens by puffing action. At current zero the diameter becomes too small and arc gets extinguished.

OR



Double pressure type breaker:

Here the gas is made to flow from area P_1 to P_2 through a convergent-divergent nozzle. The flowing gas covers the arc. In the divergent section the speed of the gas is very high and carries away most of the heat and absorbs free electrons from the periphery of arc that results in the reduction of diameter of arc, which becomes nearly zero at current zero, leading to arc being extinguished. Finally the gas enters the contact space increasing the dielectric strength.

4 a) ii) Write any two advantages and disadvantages of static over current relay.

Ans:

Advantages of static over current relay:

1) Low power required hence less burden.
2) No motional parts hence bouncing, friction, erosion, arcing etc. eliminated.
3) Not affected by gravity, may be used in any position.
4) Improved selectivity as resetting and overshoot times is reduced.
5) Lower operating times.
6) One static relay can be used for multiple purposes.
7) Higher torque /weight ratio.
8) Compact.
9) Good discriminating characteristics and reliability.
10) Suitable for reliable remote operation with PLCC.
11) Can be programmed as per requirement.

Any two advantages 2 Marks

Disadvantages of static over current relay:

1) Affected by voltage transients.
2) Affected by electrostatic discharges.
3) Sensitive to temperature.
4) Auxiliary power supply is needed.
5) Higher skilled manpower required to handle/program/install.
6) Operating characteristics may be affected by operation of output device.
7) Delicate construction.

Any two disadvantages 2 Marks

4 a) iii) Explain reverse power protection of alternator.

Ans:

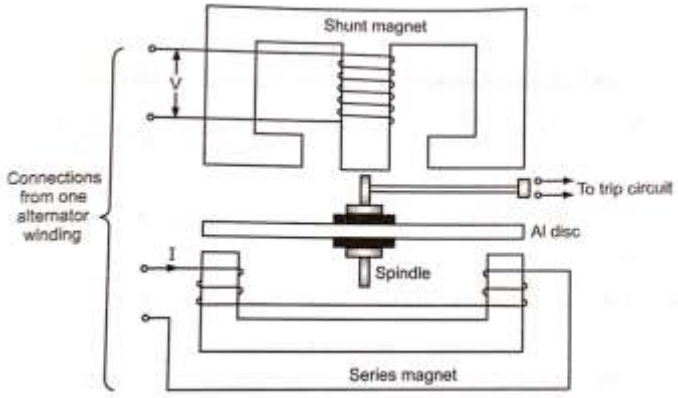
Reverse power protection of alternator:

The turbine drives alternator. Alternator is connected to supply system through transformers, busbars etc. and similarly so many alternators are connected to

supply system. If input to any one turbine is disturbed or stopped, then that alternator behaves as a synchronous motor by drawing power from the lines. This is the reverse power flow condition that is undesirable and detected by using directional relay in any one phase.

2 Marks for explanation

Figure shows the induction type directional relay used for the reverse power protection of alternator. Here the shunt magnet coil and series magnet coil are exited from alternator to whom protection is to be provided. When power flow direction is correct, the disc rotates in the normal direction and does not close trip contacts. But when the power flow reverses, the disc rotates in opposite direction causing closure of trip contacts.

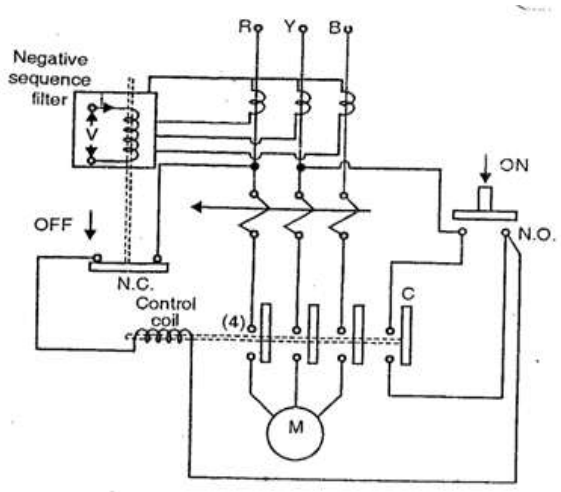


2 Marks for diagram

4 a) iv) Describe with circuit diagram of single phase preventer.

Ans:

Single phasing preventer:



2 Marks for diagram

Single phasing preventers are generally used for small / medium capacity motors. Single phasing preventers are connected in secondary of line CTs. These mainly contain a negative sequence filter. The output of negative sequence filter is fed to the level detector, which further sends tripping command to starter or CB and the NC contact gets opened which stops the motor to avoid further damage when single phasing occurs.

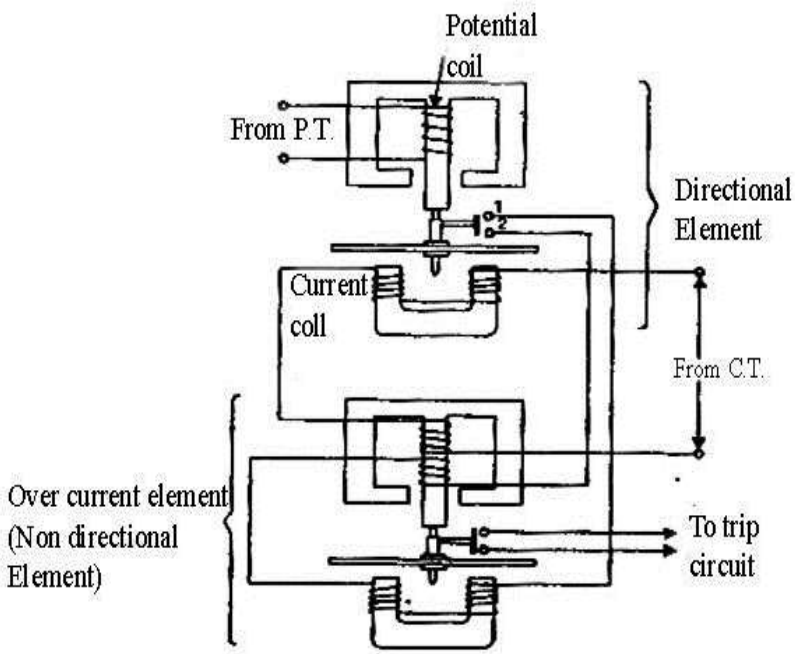
2 Marks for description

4 b) **Attempt any <u>ONE</u> of the following.** **6**

4 b) i) Draw neat circuit diagram of induction type directional over current relay.

Ans:

Induction type directional over current relay:



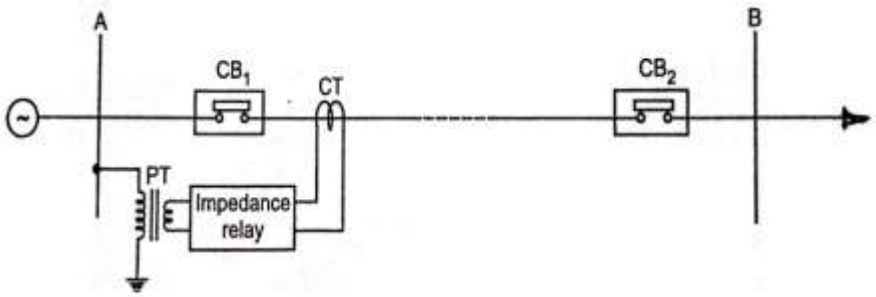
Labeled diagram 6 Marks

Partially labeled 3 Marks

4 b) ii) How impedance relay used for transmission line protection?

Ans:

Transmission Line protection using Impedance Relay:



Distance protection scheme for typical transmission line

2 Marks for diagram

Impedance or distance protection scheme uses impedance relay. The relay operation is based on the impedance (or distance) between the relay and point of fault. Figure shows arrangement for distance protection for typical transmission line.

The voltage element of impedance relay receives supply from PT secondary and current element receives supply from CT secondary. It measures Impedance at relay location(Z = V / I)

The protection zone of line is between A and B. Under normal working conditions, the impedance of line is Z_L. The impedance relay is so designed that,

4 Marks for description

it operates only when line impedance becomes less than Z_L.
When fault occurs between points A & B, the impedance of line becomes less than Z_L and impedance relay operates which trips the CB and line is protected.

5 Attempt any FOUR of the following 16

5a) Define the following terms: Rated normal current; Short time rating; Rated Breaking current; Rated Symmetrical breaking current.

Ans:

Rated normal current: It is r.m.s. value of current which the circuit breaker is capable of carrying continuously at its rated frequency under specified conditions.

Short time rating: It is the period for which the circuit breaker is able to carry fault current while remaining closed.

Rated Breaking current: It is the current (r.m.s.) that a circuit breaker is capable of breaking at given recovery voltage and under specified conditions (e.g. power factor, rate of rise of restricting voltage).

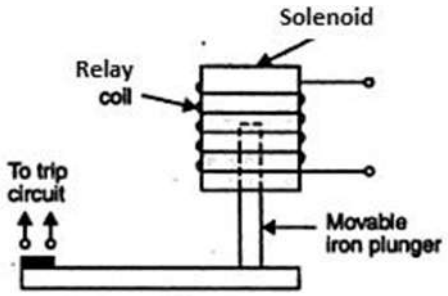
Rated Symmetrical breaking current: It is given by,
Rated Symmetrical breaking current = (Breaking capacity/(√3 rated voltage).

1 Mark for each definition = 4 Marks

5b) Explain with neat diagram solenoid type over current relay.

Ans:

Solenoid type over current relay:



Solenoid relay

2 Marks for diagram

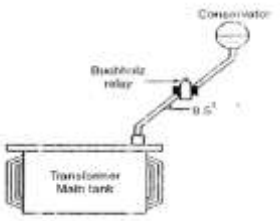
During the normal operation the current in solenoid coil is not sufficient to pull the plunger up by magnetic force. Whereas on overcurrent condition (Current exceeds pickup value) the magnetic pull of the solenoid coil overcomes the restraining force on the plunger (Spring or gravity) and pulls the plunger up to close the trip contacts. This operates the relay circuit causing the opening of the CB.

2 Marks for description

5c) Give location of buchholz relay. State application of it for transformer protection.

Ans:

Location of buchholz relay: Buchholz relay is a gas actuated relay used with oil immersed transformer usually installed in the pipe connecting the conservator to the main tank.



1 Mark for location

Applications of buchholz relay: Normally for the transformers of capacities 500 kVA or more in various substations, generating stations etc.

3 Mark for applications

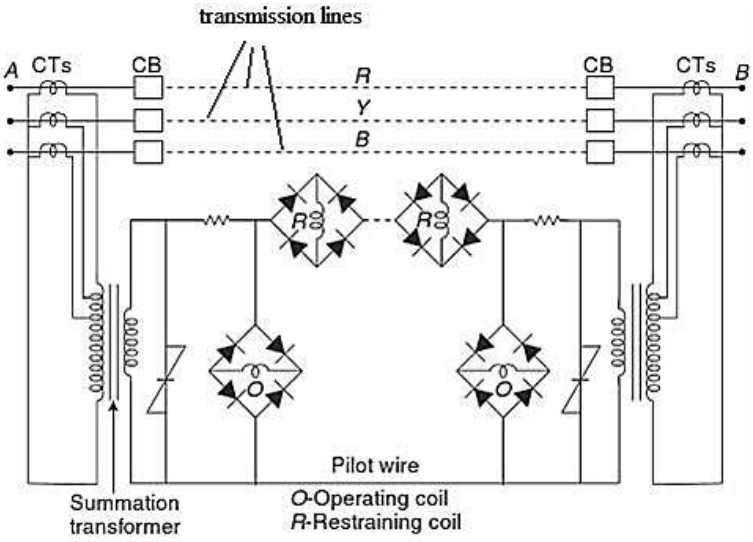
Detects incipient faults (minor faults leading to decomposition of oil with gas formation) occurring below oil level in oil immersed transformers such as phase-phase, phase-core and gives the alarm signals so that preventive action is taken before the condition leads to a major fault.

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

5d) Draw circuit diagram for biased differential protection used for transmission line protection.

Ans:

Circuit diagram for biased differential protection used for transmission line protection:



Biased differential protection for transmission lines

Labeled diagram 4 Marks

Partially labeled 2 Marks

5e) State the functions of substation earthing system.

Ans:

Functions of substation earthing system:

1) To ensure safety to personnel in substation against electrical shocks.
2) To provide the ground connection for connecting the neutrals of star connected transformer winding to earth.
3) To discharge the over voltages due to lightning to earth.
4) To discharge the over voltages from overhead ground wires to earth.
5) To provide ground path for surge arresters.
6) To provide a path for discharging the charge between phase and ground by means of earthing switches.
7) To provide earth connections to structures and other non-current carrying metallic objects in the substations.

Each point 1 Mark (any four points) = 4 Marks

5f) State different causes of over voltages in power system network.

Ans:

Causes of over voltages in powe system networks:

Causes external to system: 1 Mark

Lightning strokes during strong or rainy weather. These can be so high that the

magnitudes of voltage waves created can be in the range of 800 kV to 1500kV.

Causes internal to system:

- Switching surges occur when switching operations of circuit breakers are carried out especially under abnormal conditions.
- Switching an unloaded line sets up travelling waves that on reflection create a doubling effect to produce an instantaneous maximum voltage of ($2\sqrt{2}$ E) where 'E' is the rms (line voltage) value. Similar effect is obtained when an unloaded line is switched off.
- Resonance in power systems: line capacitance and system inductance resonate.
- Interrupting currents before their natural zero leads to charges on lines and components.
- Arcing grounds.
- Insulation failures.

1 Mark for each of any three points

6 Attempt any <u>FOUR</u> of the following **16**

6a) A 3-phase transformer of 220V/11 kV line volts is connected in star/delta. The protective transformers on 220V side have current ratio of 600/5. What should be the CT ratio on 11 kV side?

Ans:

1) Line current on 220 V side is 600 amp
Phase current on delta connected CT's on 220 V side = 5 amp

2) Line current of delta connected CT's on 220 V side = 5 √3 amp
= 8.66 amp. 1 Mark
This current i.e. 8.66 amp will flow through the pilot wires, obviously this will be the current which flows through the secondary of CTs on the 11kV side.

3) Phase current of star connected CT on 11 kV side = 5 √3 amp
= 8.66 amp 1 Mark

4) If I_2 is the line current on 11kV side, then
For transformer ,
$\sqrt{3}\ V_1\ I_1 = \sqrt{3}\ V_2\ I_2$
$\sqrt{3} \times 220 \times 600 = \sqrt{3} \times 11000 \times I_2$ 1 Mark
$I_2 = (\sqrt{3} \times 220 \times 600) / (\sqrt{3} \times 11000)$
$I_2 = 12$ amp

Therefore CT's Ratio on 11000 V side = 12 : 8.66 1 Mark

6b) Describe with a neat diagram of differential protection provided for transformer.

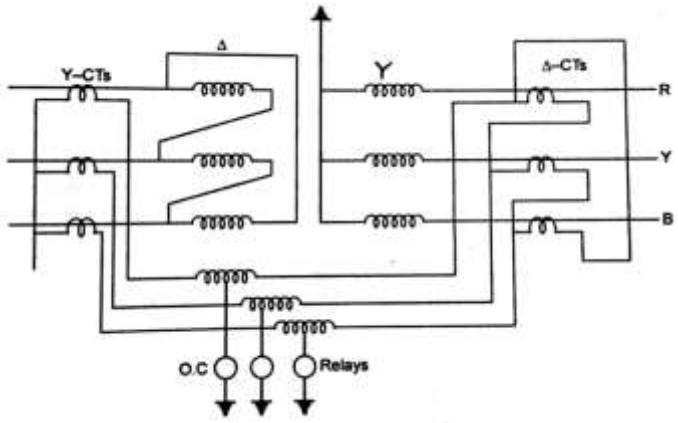
Ans:

Differential protection provided for transformer:

Figure shows a typical Merz-price or Differential protection scheme used for three phase transformer. The CTs on the two sides of transformer are connected by pilot wires and one relay is used for each pair of CTs. 2 Marks for description

During normal operating conditions, the secondaries of CTs carry identical

currents. Therefore the currents entering and leaving the pilot wires at both ends are the same and no current flows through the relays. If a ground or phase to phase fault occurs, the currents in the secondaries of CTs will no longer be the same and differential current flows through the relay coil which trips the circuit breaker on both sides of the transformer.



2 Marks for diagram

6 c) State necessity of neutral earthing and list the different methods.

Ans:

Necessity of neutral earthing:

The majority of three phase systems today operate with an earthed neutral, earthing being achieved either directly or through an impedance as the earthed neutrals have the advantages of:

1 Mark for each of any two points = 2 Marks

(i) Elimination of persistent arcing grounds by employing suitable protective gear
(ii) Utilization of earth faults for operation of protective relays for isolating the fault
(iii) Nearly constant voltage of healthy phases
(iv) Conducting induced static charges to earth without disturbance
(v) Possibility of installing discriminative protective gear on such system
(vi) Reliable service and greater safety to personnel and equipment and
(vii) Reduced maintenance and operating cost.

Different methods of neutral earthing:

1) Solid or effective grounding
2) Resistance grounding
3) Reactance grounding
4) Peterson coil grounding

2 Marks

6 d) Explain the voltage surge? Draw a typical lightning voltage surge.

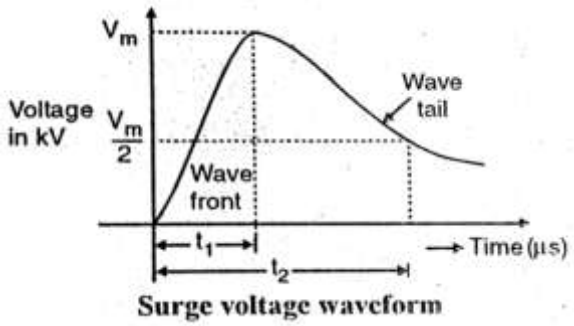
Ans:

Voltage Surge:

Basically voltage surge is defined as a sudden rise in voltage for very short duration on the power system. It is also called as transient voltage.Transients or surges are of temporary nature and exists for a very short duration (few hundred microseconds) but they are very harmful for the insulation of the various equipment connected in power system.

2 Marks

Typical lightning voltage surge is shown below.



Surge voltage waveform

1 Mark for diagram

where,

V_m = maximum value of surge voltage,

t_1 = time for lightning surge voltage to reach crest.

t_2 = time at which lightning voltage to falls to 50% of crest value

It is specified by ratio t_1/t_2 (both in μ seconds). 1 Mark for terminology

The typical values being t_1= 1 μsec. and t_2 = 50 μsec.

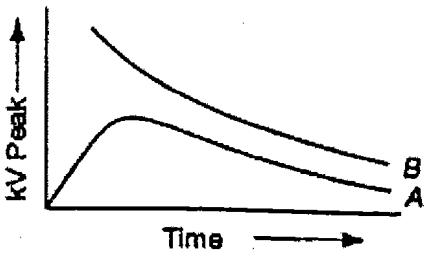
Hence it is called as an impulse wave of (1/50).

6e) Explain insulation co-ordination? What is its necessity?

Ans:

Insulation Co-ordination:

It is the correlation of the insulation of electrical equipment and the lines with the characteristics of protective devices such that the insulation of the whole power system is protected from the excessive over voltages. A and B are insulation characteristics of respective devices. 1 Mark for explanation



1 Mark for graph

Necessity of Insulation Co-ordination:

The insulation strength of various equipment like transformers , circuit breakers etc. should be higher than that of lightning arresters and other surge protective devices. The insulation Co-ordination is thus the matching of the volt time flash over and break down characteristcs of equipment and protective devices in order to obtain maximum protective margin at a reasonable cost. For example in figure above A can be the insulation level (BIL) of the lightning arrester while B will be the insulaton level (BIL) of the transformer. Similarly other devices BILs should be above A. 2 Marks for necessity