WINTER – 2016 Examinations

Model Answer

Subject: 17508: Switchgear and Protection

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 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/figures 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 (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

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Model Answer
Subject: 17508: Switchgear and Protection

1 A) Attempt any <u>THREE</u> of the following: **12**

1 A) a) What are the causes of faults in power system? State any four harmful effects of faults.

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, ½ mark for each cause maximum 2 marks,
4) Accumulation of dust, dirt etc. on exposed components 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
14) Faulty design of the power system sections.

Effects of faults:

1) Heavy short circuits lead to damage to equipment mechanically and electrically.
2) Arcing during faults leads to fire hazards.
3) Heavy drop in the supply voltage to loads leading to their mal-operation. ½ mark for each effect maximum 2 marks
4) Overheated machines due to unbalanced supply voltages.
5) Loss of revenue to supply agency owing to stoppage of supply.
6) Loss of system stability due to generators losing synchronism.
7) Distress load shedding.

1 A) b) Explain the terms base kVA, base kV and percentage reactance. State the relationship between them.

Ans:

The analysis of the power system calls for calculations combining the different voltage levels and VA ratings of the components such as generators, transformers, motors etc. Transforming these calculations to individual voltage and current ratings of these components becomes cumbersome and time consuming. Hence the calculations are done on a common platform of these quantities. The values of these specified at the platform are called as base values. Then these quantities for individual components are expressed as fractions or percentages of the base values assumed/ specified. Hence base values of voltage and current assumed lead to base VA (base voltage x base current), base impedance [(base voltage)/(base current)]. Thus the calculations are simplified. 1 mark

base kVA:

The base kVA is a conveniently and arbitrarily chosen VA (kVA or MVA) value for ½ mark power system calculations. The VA ratings of all the components such as transformers, generators etc. involved in the calculations are expressed as a percentage or per unit quantity with respect to the base value. This is normally the VA rating of the largest rated component involved.

base kV:

The base kV is a conveniently and arbitrarily chosen Voltage (V or kV) value for power system calculations. The Voltage ratings of all the components such as transformers, generators etc. involved in the calculations are expressed as a percentage or per unit quantity with respect to the base value. This is normally the highest Voltage in the relevant systems involved. ½ mark

Percentage reactance:

The percentage reactance is the valued expression (of a power system component under consideration such as transformer, generator etc.) expressed as percentage of the base impedance or base reactance (when the resistance is neglected). 1 mark

Base impedance or reactance z_b or $x_b = \frac{\text{(base voltage)}}{\text{(base current)}}$ ohms

The reactance 'x' will be expressed in percentage reactance as $\%\, x = \frac{x}{x_b} x100$

Relationship between them:

Base impedance or reactance z_b or $x_b = \frac{(kV)^2}{(kVA)} X\ 1000$ ohms

1 mark

percentage reactance as $\%\, x = \{(x)/[\frac{1000(kV)^2}{(kVA)}]\}x100$.

1 A) c) Define the terms 'Plug setting multiplier' and 'Time setting multiplier' as used in the context of the IDMT relay.

Ans:

Plug setting multiplier(PSM):

It is related to the current setting of the overcurrent relays.

The plug setting multiplier is defined as the ratio of the 'transformed fault current on the relay side' to the 'relay pickup current'. 1 mark

$$PSM = \frac{transformed\ fault\ current\ on\ CT\ secondary\ side}{relay\ current\ setting}$$

1 mark

$$= \frac{fault\ current\ on\ CT\ primary\ side\ (i.e\ line\ fault\ current)}{relay\ current\ setting\ \ x\ CT\ ratio}$$

Time setting multiplier(TSM):

It is related to the operating time of the relay during faults. The angular distance through which the relay disc travels during faults before the trip contacts close is varied to get different times of operation of the relay. This is time setting. These times of motion of the disc are set in 10 steps starting with maximum time setting of 1 (when disc is set farthest) to minimum (when disc is nearest) of 0 (instantaneous). For 1 mark example if the angular travel from trip contacts is set to maximum then TSM =1, then for a particular PSM if the operating time of relay is 1 second then for the same PSM if the TSM is set to 0.4 then the time of operation will be (1 second x TSM) — 1 mark

= 1 x 0.4 = 0.4 seconds.

Thus TSM is used to define the steps for time setting of relay operation.

1 A) d) What is voltage surge? Draw a standard lightning voltage surge.

Ans:

Voltage surge: Voltages of magnitudes larger than the standards specified with waveform shapes different than the normal supply standards, are called as voltage surges. — 1 mark

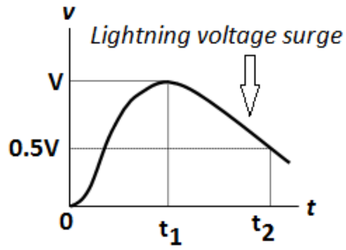


Figure 2 marks (labeled)

V = 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 (max value).

It is specified by ratio t_1/t_2 (both in μ seconds).

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

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

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

1 B) a) Two 3 phase, 6.6 kV, 5 MVA generators having sub-transient reactances of 12.5% operate in parallel. The generators supply power to a transmission line through a 10 MVA transformer of ration (6.6/33) kV and having leakage reactance of 4%. Calculate fault current and fault MVA for 3 phase fault on i) LT side and ii) HT side of transformer.

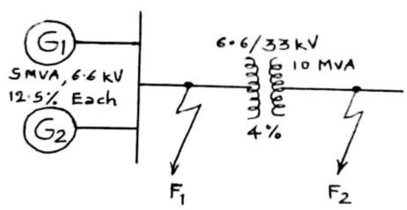
Ans:

Per unit reactances of each generator and transformer are j0.125 and j0.04 respectively.

Let base MVA = 10

Base kV = 6.6 (LT or generator side)

= 33 (HT or transmission line side).



1 mark

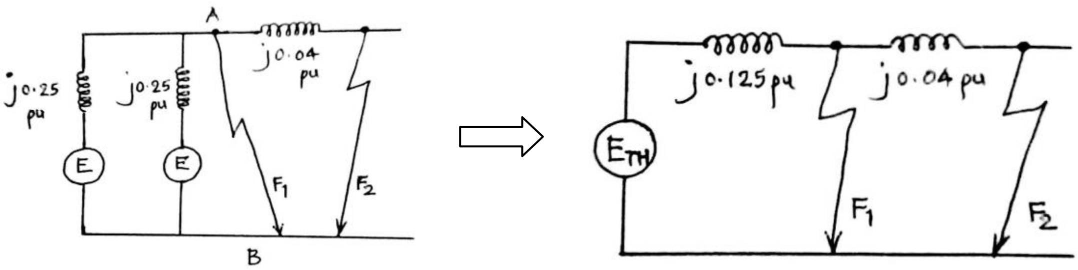
The per unit reactance of each of the identical generators with respect to new base MVA,

$= (pu\ generator\ reactance) \text{X} \frac{base\ MVA}{generator\ MVA}$

$= (j0.125)\frac{10}{5}$ = j0.25 pu — 1 mark

As the base MVA is same as MVA of transformer its per unit reactance remains unchanged at j0.04.

From the equivalent circuit the Thevenin's source reactance across the fault feeding terminals A and B consists of the generator reactances in parallel which gives an equivalent source reactance of j0.25/2 = j0.125 pu.



i) Fault on LT side of transformer:

For fault at F_1 the reactance up to the fault point from the Thevenin's equivalent generator is j0.125 pu.

Fault MVA = $\frac{base\ MVA}{pu\ reactance\ in\ fault\ path}$ = $\frac{10}{0.125}$ = 80MVA. 1 mark

Fault current = $\frac{fault\ MVA \times 1000}{\sqrt{3} \times (\text{base kV})} = \frac{80 \times 1000}{\sqrt{3} \times 6.6}$ = 6998 A around 7 kA 1 mark

ii) Fault on HT side of transformer:

For fault at F_2 the reactance up to the fault point from the Thevenin's equivalent generator is,

(j0.125 + j0.04) = 0.165 pu. 1 mark

Fault MVA = $\frac{base\ MVA}{pu\ reactance\ in\ fault\ path}$ = $\frac{10}{0.165}$ = 60.6 MVA.

Fault current = $\frac{fault\ MVA \times 1000}{\sqrt{3} \times (\text{base kV})} = \frac{60.6 \times 1000}{\sqrt{3} \times 33}$ = 1060 A around 1 kA. 1 mark

1 B) b) A three phase 66/11 kV, star-delta connected transformer is protected by Merz-Price protection scheme. The CTs on LT side have a ratio of 420/5. Find the ratios of the CTs on the HT side. Also draw a neat connection diagram of the complete scheme.

Ans:

The CTs on LT side are connected in star as transformer is in delta. Whereas those on HT side are in delta as the transformer is in star on that side. ½ mark

Assume CT line current on LT side to be 5 A and then that on HT side will also be 5 A. But HT side CTs are in delta. Hence the HT side CT current will be

(CT line current)/√3 = 5/√3 A. 1 mark

Assume line current (for convenience) of 420 A on LT side (delta side) of transformer. When transformed to HT side the line current will be I_{Lht} given by

$$\sqrt{3} \times 66 \times I_{Lht} = \sqrt{3} \times 11 \times 420$$ ½ mark

$$I_{Lht} = (11/66)\times(420) = 70\ \text{A}.$$

On HT side the CT primary current is 70 A and CT secondary current is 5/√3 A,

hence the CT ratio is 70/(5/√3) = (70√3/5). 1 mark

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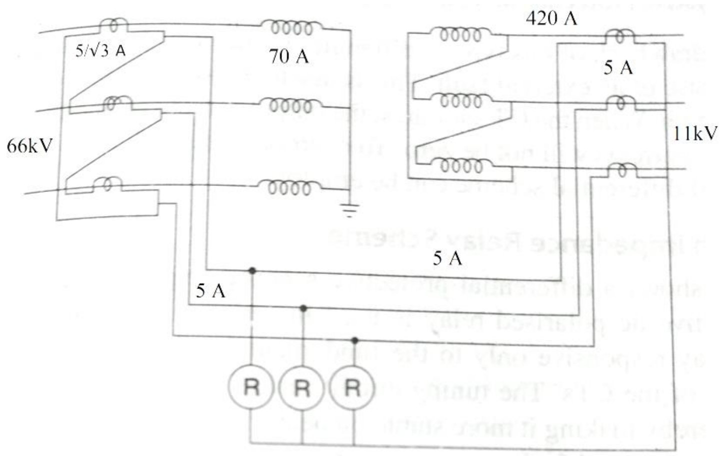


3 marks

2 Attempt any FOUR of the following: 16

2 a) Explain the terms:

i) Arc voltage,
ii) Recovery voltage,
iii) Restriking voltage,
iv) RRRV.

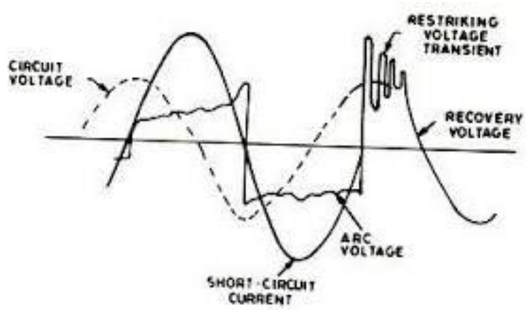
Ans:

i) Arc Voltage: The voltage existing between the circuit breaker contacts during arcing is called as the arc voltage. It is low value compared to the system rated voltage. Normally it is around 3% to 5% of the rated system voltage. 1 mark

ii) Recovery voltage: The normal power frequency voltage that appears across the contacts after the arc is finally extinguished and the transients have fully disappeared is the recovery voltage. 1 mark

iii) Restriking voltage: The transient voltage that appears across the contacts of the circuit breaker at the instant of the arc getting extinguished is called as the restriking voltage. 1 mark

iv) RRRV: The RRRV (rate of rise of the restriking voltage) is defined as the slope of the steepest tangent to the restriking voltage curve. It is expressed in volts per micro-second. 1 mark

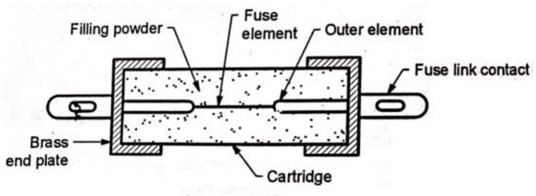


2 b) With a neat sketch explain the construction and working of HRC fuse.

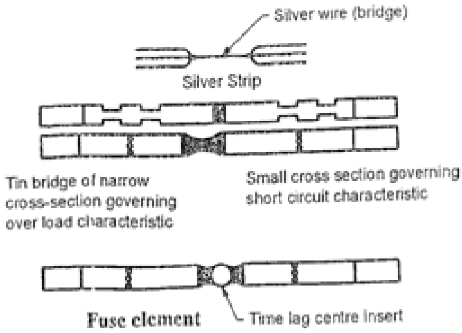
Ans:

Construction:

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 1 mark for construction generated under abnormal conditions.



H.R.C. fuse



Fuse element

Diagram 2 marks (1 mark each diagram)

Under normal conditions, the fuse element is at a temperature below its melting point. Therefore, it carries the normal current without overheating.

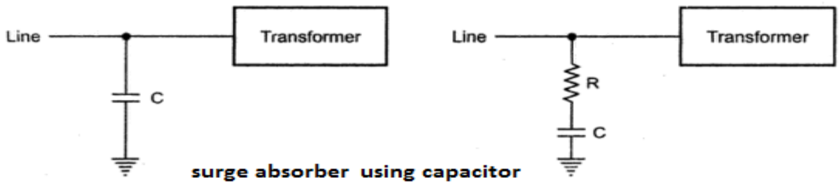
When a fault occurs, the current increases and the heat produced is sufficient to melt these elements. Fuse element melts before the fault current reaches its first peak value. Vaporized metal /fuse element chemically reacts with filling powder and results in the formation of high resistance substance that helps in quenching the arc. 1 mark for working

2 c) What are surge absorbers? How they differ from surge diverters?

Ans:

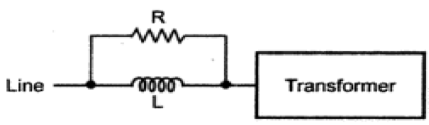
Surge absorbers:

A surge absorber is a device or an arrangement that absorbs the energy contained in a travelling wave and reduces the amplitude of the surge and the steepness of the wave front. It is also called as the surge modifier. It can be in the form of a capacitor connected across the line and earth of an air cored inductor in series with the line. 1 mark



surge absorber using capacitor

Or



surge absorber using inductor L

Any one Figure 2 marks

The surge absorbers differ from surge diverters in the following manner:

Surge absorbers reduce the energy level of the travelling wave by absorbing or dissipating a portion of it, whereas the surge diverters provide path of low resistance to over voltages or surges to go to the earth. When the surge is over the low resistance path becomes a high resistance path when normal system voltage exists (for the surge diverter) 1 mark

2 d) State any four advantages of grounding the neutral of a system.

Ans:

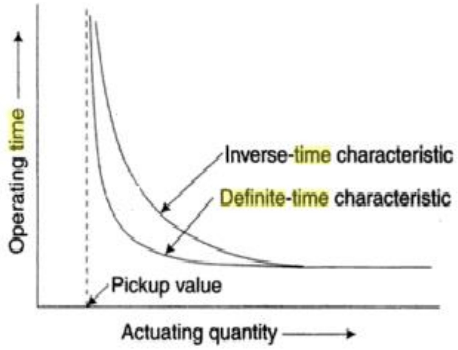
Advantages of grounding the neutral of a system: 1 mark each any four = 4 marks.

1. Reduces voltage stresses/ (transients effects) due to switching operations.
2. Reduces voltage stresses/ (transients effects) due to lightning surges.
3. Limits fault currents.

4. Sensing faults through appropriate relay systems possible and thus protects the system.
5. Safety of personnel, equipment.
6. Discharging paths for stored charges on system before maintenance provides protection.

2 e) Describe difference the between definite characteristics and inverse characteristics of relays.

Ans:



The difference between the definite and inverse characteristics in respect is relays is that the Definite time relays operate after a predetermined time when the current exceeds the pickup value irrespective of the current magnitude whereas the Inverse time relays operate in similar manner but the operating time depends on the current magnitude. Higher the magnitude lower will be the operating time.

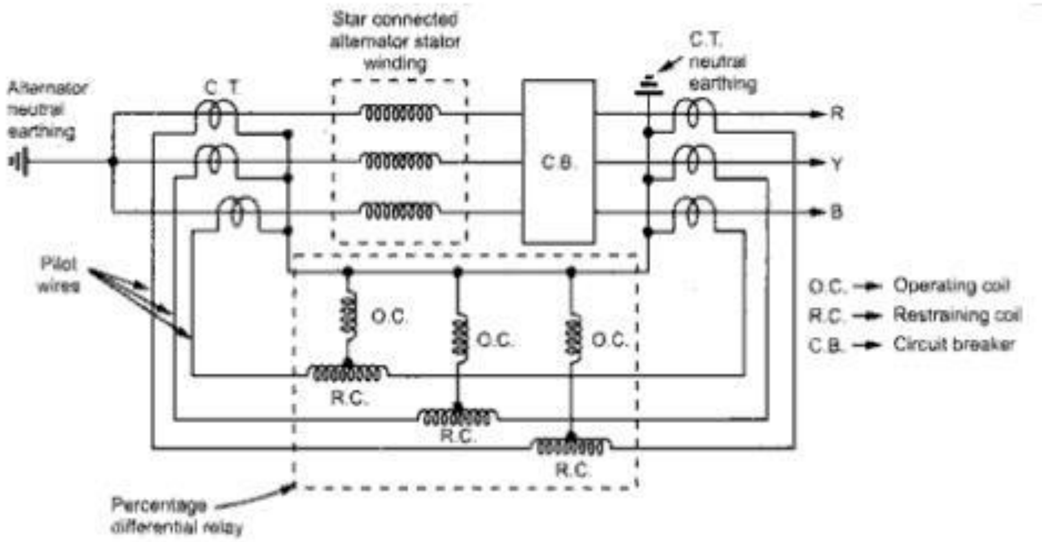
Labeled figure only allowed: 2 marks

Explanation 2 marks

2 f) With neat sketch explain the Merz Price protection applied to alternators.

Ans:

Merz Price protection of alternator:



Correct diagram: Labeled 3 marks,

Partially labeled 2 marks,

Unlabeled 1 mark.

The arrangement is as shown in the figure.

The scheme is used to sense phase to phase and earth faults in alternator windings. The scheme does not respond to through faults (external faults) or overloads as the CT currents on the two sides of generator winding are identical. The relay operating coils produce the required motion of the relay disc for trip signal to CB when the phasor difference of the CT secondary currents on the two sides of the alternator windings for any phase is more than the set value (relay pickup value). It is essential that due importance be given to the polarities of CT connections such that any OC will get the difference current for the two side CT secondaries of respective phase.

1 mark

3 Attempt any FOUR of the following:

3 a) State different types of circuit breakers (at least four) based on the medium used for arc quenching. Also mention the voltage range for which each circuit breaker is recommended.

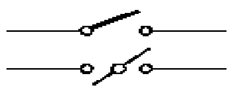
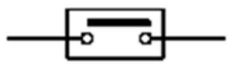
Ans:

Type	Arc quenching medium	Voltage range
MCCB / MCB	Natural air	Below 1000V
Air break CBs	Natural air	415V- 11kV
Air blast CBs	Compressed air	66kV – 110kV
Minimum oil CBs	Transformer oli	3.3kV – 220kV
Vacuum CBs	Vacuum	3.3kV – 33kV
SF6 Circuit Breakers	SF6 Gas	3.3kV- 765 kV

1 mark each (any 4 types along with voltage range)

3 b) Differentiate between isolator and circuit breaker (any four points).

Ans:

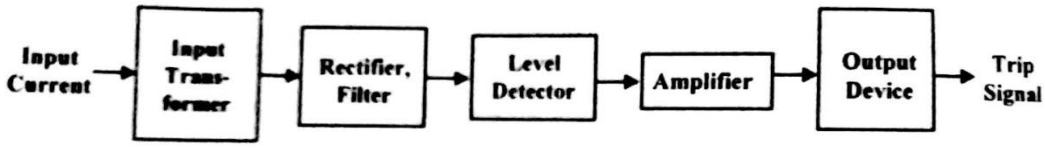
Particulars	Isolator	Circuit breaker
Symbol		
Function	To disconnect the part of the system for maintenance from live circuit under no current condition.	To make or break a circuit manually or remotely under normal condition and to break circuit automatically under fault condition.
Construction	Simple	Complicated
Operation	Manual	Relays are required for automatic operation
Ratings	Current, voltage etc.	Current, voltage, making capacity, breaking capacity etc.
Maintenance	Less	More, due to arcing at contacts
Cost	Low	High

Any 4 points 1 mark each

3 c) With a neat block diagram explain the operation of static overcurrent relay.

Ans:

Static overcurrent relay:



Block diagram of static over current relay

2 marks for block diagram

The current derived from the main CT is feed to the input transformer which gives a proportional output voltage. The input transformer has an air gap in the iron core to give linearity in the current voltage relationship up to the highest value of current expected, and is provided with taping on its secondary to obtain different current settings. The output voltage is then rectified and then filtered at a single stage to avoid undesirable time delay in filtering so as to excurse high speed of operation. A zener diode is also incorporated in the circuit to limit the rectified voltage to safe values even when the input current is very high under fault conditions.

2 marks for explanation

A fixed portion of the rectified filtered voltage is compared against a preset pick-up value by a level detector and if exceeds the pick-up value, a singal through an amplifier is given to the output device which issues the trip signal.

3 d) List the special problems in applying biased differential protection to 3-phase transformer. How are they over come?

Ans:

Problems in applying biased differential protection:

i) Difference in length of pilot wires on either side of relay:
The difficulty is overcome by connecting adjustable resistors to pilot wires

ii) Difference in CT ratio:
This difficulty is overcome by using biased differential relay.

Any 4 points with remedy 1 mark each

iii) Magnetizing current in rush:
This difficulty is overcome by providing time lag of 0.2 Sec. in the relay, by this time the inrush current will vanish and relay does not trip unnecessarily. This problem can be overcome by using harmonic restraint relay.

iv) Phase difference between primary and secondary currents:
This difficulty is overcome by proper connections of CTs on both sides. e.g for delta-star connected transformer, CTs are connected in star-delta fashion.

v) Tap changing affects the ratio of transformer:
This problem is overcome by adjusting the turn's ratio of CT accordingly.

3 e) What is Buchholz relay? Which equipment is protected by it? State its any two advantages and limitations.

Ans:

Buchholz relay: It is gas actuated relay installed in the pipe connecting conservator to main tank of oil filled transformers for protection against all kinds of faults. 2 marks

Advantages of Buchholz relay: Two advantages & limitation ½ marks each = 2 marks

1. It detects the incipient faults at a stage much earlier than is possible with other form of relay.
2. It is simple form of transformer protection.

Limitations of Buchholz relay:

1. Only the faults below the oil level are detected.
2. Mercury switch setting should be very accurate otherwise even for vibration there can be a false operation.
3. The relay is slow operating type which is unsatisfactory.
4. They are not provided for transformers below 500 KVA because of economic reasons.

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

4 A) a) With a neat sketch describe protection scheme of an alternator against inter-turn fault.

Ans:

Inter-turn fault Protection:

Figure shows scheme for one phase only. It is identical for other phases. Description 2 marks

Under normal working condition, 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.

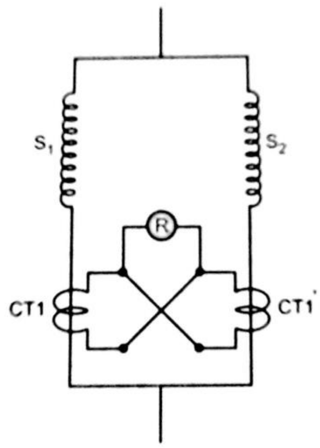


Diagram 2 marks

or Equivalent figure

4 A) b) What is meant by Basic Insulation Level (BIL)? Explain its significance in insulation co-ordination of power system.

Ans:

Basic Insulation Level (BIL):

Basic Impulse Insulation Level (BIL) is the reference level expressed in impulse crest voltage with a standard wave not longer than a 1.2/50µsec wave according to IS. 1 mark

Significance of BIL in 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. In order 3 marks

to protect the equipment of power system from over-voltages of very high magnitude, it is necessary to fix an insulation level for the system to see that any insulation in the system does not breakdown or flash over below BIL.
Curve A is volt time curve of protective device and curve B is that of equipment (apparatus) to be protected.

4 A) c) Explain the process of arc development and its extinction in vacuum circuit breaker.

Ans:

Process of arc development and its extinction in Vacuum CB :

During the operation of the breaker, the moving contact separates from the fixed contact resulting in arc 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 gets extinguished quickly because the metallic vapours, electrons and ions produced during arc are diffused in a short time and seized by surfaces of moving and fixed members and shields. Since vacuum has good recovery of dielectric strength the arc extinction occurs with a short contact separation. 4 marks

4 A) d) State the principle of distance protection. What are the advantages of distance protection over other types of protection of feeders?

Ans:

Distance protection:

Action of relay depends on impedance (distance) up to fault point. At fault point the ratio of V/I (=Z) at the relay falls below preset value due to which the relay operates to trip the circuit breaker. 2 marks
'V' is the restraining quantity while 'I' is the operating quantity.

Advantages:

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

4 B) Attempt any ONE of the following: 6

4 B) a) Explain with the help of sketches the working of protection schemes for motor against
   i) Overload
   ii) Phase failure

Ans:

Protection schemes for motor:

The **overload** relay protects the motor against overloading by thermal relay principle and Single phasing preventers are generally used for small / medium capacity motors for **phase failure**.
Single phasing preventers are connected in secondaries 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 . Thus

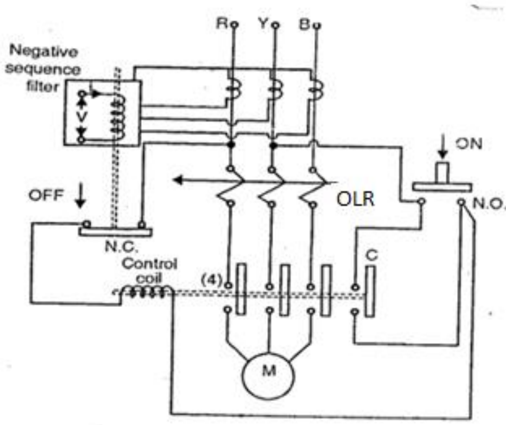


Diagram 3 marks

Explanation 3 marks

it protects motor from damage.

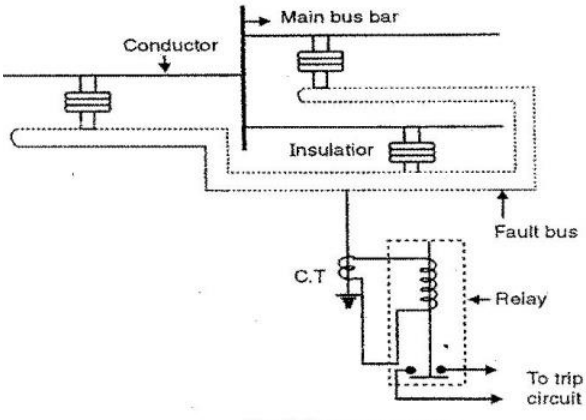
4 B) b) Why special attention is required for bus-bar protection? With a neat sketch explain the fault bus protection scheme.

Ans:

Importance of Bus-bar Protection:

The possibility of damage and service interruption from bus fault is very large because almost all incoming and outgoing lines are connected with Bus-bar so more attention is required for bus-bar protection. 2 marks

Fault bus protection of bus-bar:



Fault bus protection

Diagram 2 marks

Here 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 to ground and the relay remains inoperative. When any fault occurs on bus-bar involving a connection between conductor and earthed support structure, it 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.

Description 2 marks

5 Attempt any FOUR of the following: 16

5 a) Explain the following terms related to circuit breakers:

i) Rated current
ii) Breaking capacity
iii) Making capacity
iv) Short time current rating

Ans:

i) **Rated current:** The rated current of a circuit breaker is the r.m.s. value of current which the circuit breaker can carry continuously and with the temperature rise of various parts within specified limits. 1 mark each

ii) **Breaking capacity:** It is the highest value of short circuit current (r.m.s. current) which a circuit breaker is capable of breaking under specified conditions of recovery voltage and power frequency voltage.

Breaking MVA=√3 kA×kV

where, kA is rated breaking current and
kV is rated voltage.

iii) **Making capacity:** The peak value of current (including d.c. components) during the first cycle of current wave after the closure of circuit breaker is known as Making capacity.

Generally, Making capacity=2.55× Breaking capacity

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

The circuit breaker should be able to carry high current safely for some specified period while remaining closed i.e. they should have proven short time rating.

5 b) Describe the working of earth leakage circuit breaker with a neat diagram.

Ans:

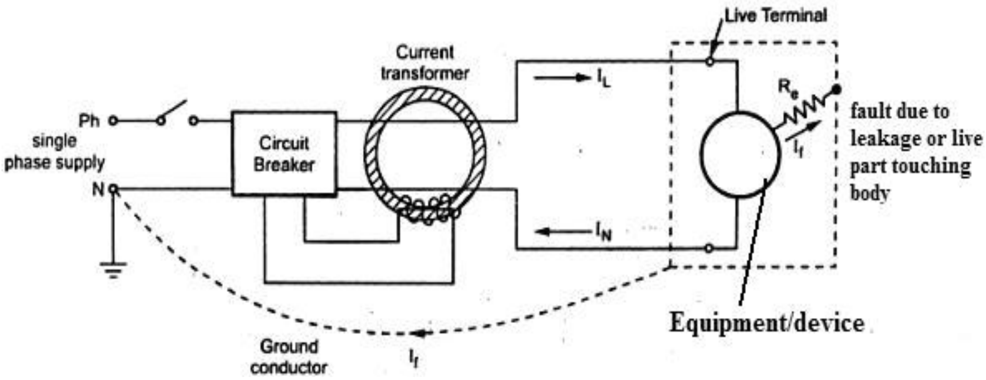
Earth Leakage Circuit Breaker (ELCB):

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. It works on principle of relaying when the current in the earth path exceeds a set value.

Description 2 marks

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: 440V. 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 personnel.

Diagram 2 marks



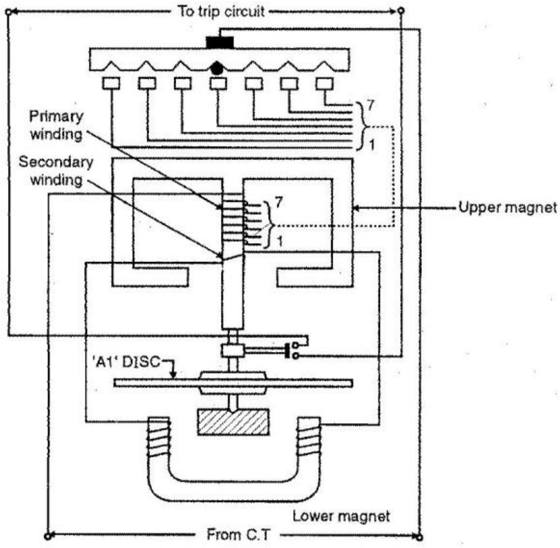
Under normal conditions $(I_L – I_N) = I_f$ is very low or nearly zero. The CT surrounding the phase and neutral senses the differential current under earth fault and actuates the CB to operate (open). The difference current I_f through fault path resistance R_e is the leakage to earth. If this value 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 25 msec.

5 c) Draw a neat labeled sketch of induction type over-current relay and explain how pick-up current is changed by plug setting.

Ans:

Induction type over-current relay:

Here the upper electromagnet has a primary and a secondary winding. The primary is connected to the secondary of a CT in the line to be protected and is tapped at intervals. The tapings are connected to plug setting bridge by which the number of active turns on the relay operating coil can be varied there by giving the desired current setting. 1 mark



Induction type over current relay (non – directional)

Labeled diagram 3 Marks

Partially Labeled diagram 2 Marks

5 d) Why biasing is needed in differential relays? What is mean by percentage bias?

Ans:

When the differential relaying is used for protection, the CTs must be identical in design, otherwise if the error is excessive, it will cause a wrong operation of relay. To safe guard against such operations, biased current protection is used. Such a protection provides a biasing feature which automatically increases the relay setting in proportion to the load or through fault current i.e. the relay is set to operate not at definite current, but at a certain percentage of through current. 3 marks

By suitably proportionating the ratio of restraining coil turns to operating coil turns, any amount of biasing can be achieved and compensation for unwanted operations due to momentary high currents can be provided.

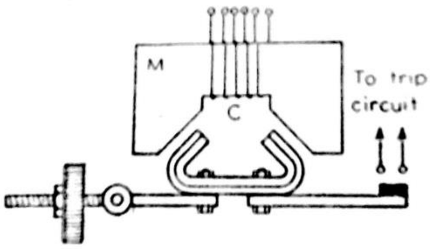
Percentage bias:

The ratio of differential operating current to average restraining current, expressed in percentage, is called percentage bias. 1 mark

5 e) Explain with a neat sketch the operation of attracted armature type relay. Also give its two merits and demerits.

Ans:

Attracted armature type relay:



1 mark for diagram

It consists of a laminated electromagnet M carrying a coil C and a pivoted laminated armature. The armature is balanced by a counterweight and carries a pair of contacts at its end. Under normal operating conditions, the current through the relay coil C, is such that counterweight holds the armature in the position shown. However when a short circuit occurs, the current through relay coil increases sufficiently and armature is attracted upwards which shorts the pair of contacts and completes the trip circuit. 1 mark for operation

Merits:

1. Simple construction.

2. Reliable operation.
3. Unaffected by temperature changes.
4. Long life.
5. Robust construction.

1 mark for any two merits

Demerits-

1. Somewhat less accurate than static/ microprocessor based relay.
2. Require maintenance.
3. Wrongly operated sometimes because of vibrations.
4. Counter weight has to be adjusted for every setting.

1 mark for any two demerits

5 f) Determine the time of operation of a 1A, 3 seconds over current relay having plug setting of 125% and a time multiplier of 0.6. The supplying CT is rated 400:1 A and fault current is 4000 A. The relay characteristics is as given below

PSM	1.3	2	4	8	10	20
Time of operation in Seconds	30	10	5	3.3	3	2.2

Ans:

Rated secondary current of C.T. = 1A

Pick up current $= 1 \times 1.25 = 1.25A$

Fault current in relay coil = $4000 \times \frac{1}{400} = 10A$ 1 mark

$\therefore$ Plug setting multiplier (PSM) = $\frac{fault\ current\ in\ relay\ coil}{pick-up\ current}$

$$= \frac{10}{1.25} = 8$$ 1 mark

Corresponding to PSM of 8 (consider given table), the time of operation is 3.3 seconds. 1 mark

Actual relay operating time = $3.3 \times time\ setting = 3.3 \times 0.6 = 1.98\ seconds$ 1 mark

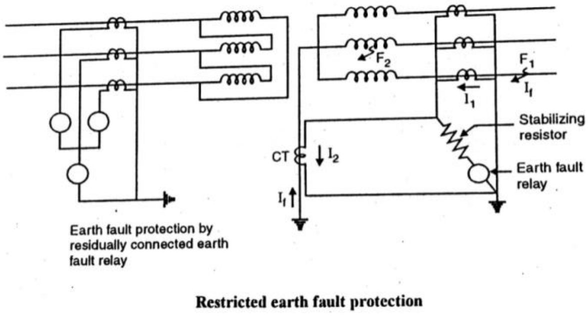
6 Attempt any FOUR of the following: 16

6 a) Describe 'Restricted Earth fault Protection' of a star connected, neutral earthed side of power transformer.

Ans:

Restricted Earth fault Protection:

Referring to Figure, the star connected neutral earthed side is protected by restricted earth fault protection. An earth fault F_1 beyond the transformer causes the currents I_2 and I_1 to flow in CT secondaries. Therefore, the resultant current in earth fault relay is negligible and relay does not operate.



Restricted earth fault protection

Diagram 2 marks

For earth fault within the transformer star connected winding F_2 only I_2 flows and I_1 is negligible. So earth fault relay operates.

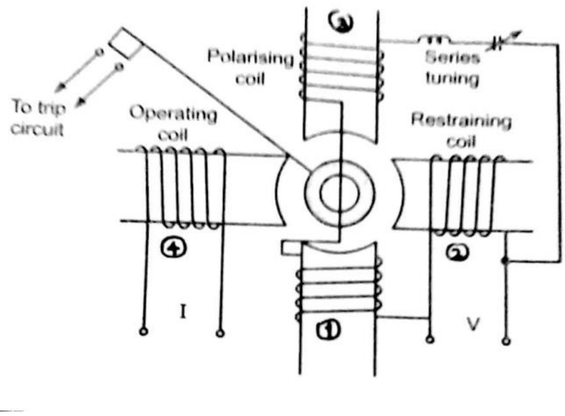
Description 2 marks

When fault occurs very near to neutral point, the voltage available for driving earth fault relay is very small. Hence the practice is to set the relay such that it operates for earth fault current of the order of 15% of rated current. Such setting protects restricted portion of winding, hence the name is restricted earth fault protection.

6 b) Describe the working principle of MHO relay with the help of a neat diagram

Ans:

MHO Relay:



In this relay, poles 1, 2, 3 are energized by a voltage V through polarizing coil to produce flux, the capacitor connected provides phase shift. The left pole 4 is energized by a current which is the operating quantity. Diagram 2 marks

Here the rotor is hollow cylindrical type which turns around its axis. Inside the rotor stationary core is there. The rotating field is produced by operating coil flux and polarized flux. This rotating field induces currents in the cup to provide necessary driving torque, which closes the trip contacts of CB. Description 2 marks

The relay operation depends upon polarized flux because of voltage and operating flux because of current hence on the ratio (I/V) = Y i.e. admittance, hence called as MHO relay.

OR Equivalent figure

6 c) The neutral point of a three phase 20 MVA, 11kV alternator is earthed through a resistance of 5Ω. The relay is set to operate when there is an out of balance current of 1.5A. The CTs have a ratio of 1000/5. What is the percentage of winding protected?

Ans:

Let x% of winding be unprotected.

Earthing resistance r = 5 Ω

Voltage per phase = $\frac{11\times1000}{\sqrt{3}} = 6350.8529\ volts$

Minimum fault current which will operate the relay = $\frac{1000}{5} \times 1.5 = 300A$ 1 mark

E.m.f. induced in x % winding = $V_{ph} \times \frac{x}{100} = \frac{6350.82(x)}{100} = 63.508(x)\ vlots$ 1 mark

Earth fault current which x% winding will cause = $\frac{63.508(x)}{r} = 12.70(x)$

This current must be equal to minimum fault current which will operate the relay.

$\therefore 12.70(x) = 300$ 1 mark

$\therefore x = 23.6188\ \%$

So percentage of winding protected = 100 – 23.6188 = **76.3811 %** 1 mark

6 d) What are the faults likely to occur in a power transformer? What do mean by incipient faults and through faults?

Ans:

Faults likely to occur in a power transformer:

1. Earth fault
2. Overloads and overheating
3. Incipient faults below oil level resulting into decomposition of oil — 2 marks
4. Through faults — (any 4)
5. High voltage surges due to lightning or switching
6. Tap changer faults
7. Phase-to-phase, Phase-to-ground faults
8. Saturation of magnetic core
9. Inter-turn and winding faults

Incipient faults: - It means slow developing faults. — 1 mark

Through faults: - It means faults beyond protection zone but fed through the protected zone. — 1 mark

6 e) Explain the principle of time graded protection of feeders using IDMT over-current relays.

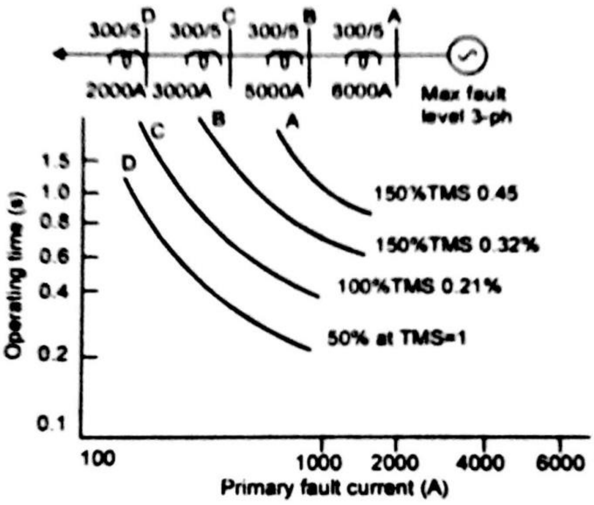
Ans:

Time graded protection of feeders using IDMT over-current relays:

Figure shows time-graded over current protection of radial feeder using IDMT over-current relays. Here the operating time is inversely proportional to the fault current and finally becomes definite for particular current. With this arrangement, the farther the circuit-breaker from the generating station, the shorter is its relay operating time. The line or feeder is divided into number of sections. Over-current relays are provided for each section. On occurrence of fault in any section, all the relays towards generating station are initiated to operate but the nearest relay operates first and trips the respective CB. If this relay fails, the next relay towards generating station operates and so on. The relays towards generating station are set for higher currents and they operate with time delays according to their inverse definite minimum time characteristics.

3 marks for explanation

1 marks for diagram



Radial feeder protection by IDMT relays