Model Answers

Winter – 2019 Examinations

Subject & Code: Switchgear and Protection (22524)

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance (Not applicable for subject English and Communication Skills).
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Model Answers

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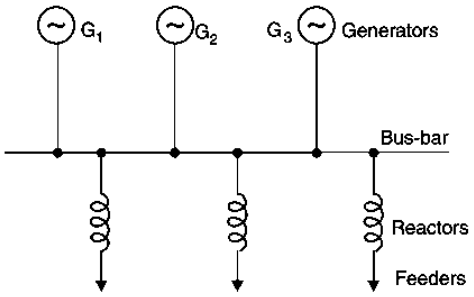
1 Attempt any FIVE of the following: 10

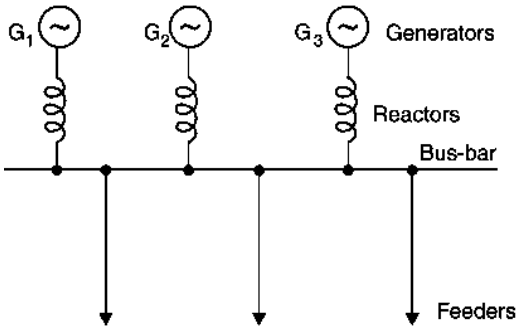
1 a) Draw neat circuit diagram of
i) Feeder reactor and
ii) Generator reactor

Ans:

1) Circuit Diagram of Feeder Reactor:



2) Circuit Diagram of Generator Reactor:



1 Mark for each diagram = 2 Marks

1 b) State four functions of protective system.

Ans:

Functions of Protective System:

1) To switch ON or OFF the electric power during normal conditions for operation and maintenance.
2) To protect the power system by isolating the faulty parts due to abnormal conditions within shortest possible time.
3) To provide the reliable and continuous supply to consumers.
4) To isolate faulty sections of system only without affecting the healthy sections of system.
5) Constantly monitor the electrical quantities of system so that occurrence of fault should be minimized.
6) To prevent the occurrence of major faults.
7) To ensure maximum safety conditions from generation stage to consumers premises.

½ Mark for each of any four functions = 2 Marks

OR Equivalent Answer

Model Answers

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1 c) Define the term "Insulation co-ordination".

Ans:

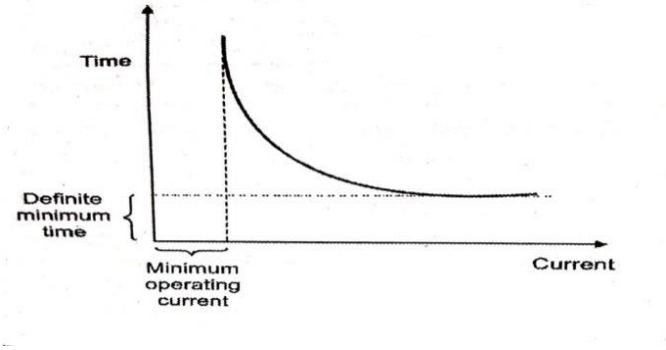
Insulation Co-ordination : It is the correlation of the insulation of electrical equipment and the lines with the characteristics of protective devices such that the insulation of the whole power system is protected from the excessive over voltages. — 2 Marks

OR Equivalent Answer

1 d) Draw a typical time-current characteristic for IDMT relay.

Ans:

Time-Current Characteristic for IDMT Relay:



2 Marks

1 e) List two limitations of Differential-Protection scheme for transformer.

Ans:

Limitations of Differential Protection Scheme of Transformer:

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

1 Mark for each of any two limitations = 2 Marks

1 f) State two requirements of transmission line protection.

Ans:

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 circuit breaker nearest to it must operate to open the line, while the other circuit breakers remain closed.
4) Adjacent circuit breakers should provide immediate backup protection in the event of failure of circuit breaker (nearest to fault) to operate.

1 Mark for each of any two requirements = 2 Marks

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1 g) State four abnormalities that taking place in case of motors.

Ans:

Abnormalities that Taking Place in Case of Motors:

A) Electrical / magnetic sections:
1) Electrical supply failure due to single phasing, under voltage, unbalanced voltages and reversal of phases.
2) Short circuit faults between turns of a stator / rotor winding due to failure of insulation.
3) Short circuit faults between stator / rotor winding due to failure of insulation.
4) Short circuit faults between stator coils and body of motor due to failure of insulation.
5) Open circuit in stator winding / rotor winding or their terminal connections.
6) Loose or broken rotor winding.
7) Damaged core stampings / teeth.
8) Prolonged loading, improper loading, stalling, loss of synchronism etc.

B) Mechanical section:
1) Unbalanced rotor.
2) Damaged bearings.
3) Grooved slip rings.
4) Worn out brushes leading to abnormal operation with sparking etc.
5) End play in shaft, bent shaft.
6) Cooling / ventilation system failures, damaged fan.
7) Failure / disturbances of alignment.
8) Foundation arrangement disturbed.

½ Mark for each of any four abnormalities = 2 Marks

2 Attempt any THREE of the following: 12

2 a) Explain in brief four causes of faults in the power system.

Ans:

Causes of Faults in the Power System:

1) **Breaking of Conductors:** It is one of major causes of faults. Breaking of conductors is due to excessive heat or because of mechanical stresses.
2) **Failure of Insulation:** It is also one of the major causes of faults. The failure of insulation results in short circuits which are very harmful.
3) **Overvoltage due to Lightning or Surges:** In rainy seasons sometimes faults on transmission & distribution lines are caused by overvoltage due to lightning or switching surges.
4) **Mechanical Failure:** Because of mechanical failure, faults on power system may occur.
5) **Accidents:** Because of accidents faults on the power system may occur.
6) **Unbalanced Currents:** Unbalanced currents flowing in the system set up harmonics, there by heating the system, which results in fault.
7) **Faulty System Design:** Certain faults occur due to poor quality of system components or because of faulty system design.
8) **Improper Maintenance:** Improper maintenance of machines / equipment /

1 Mark for each of any four causes = 4 Marks

lines / protective system leads to faults in the power system.

OR Equivalent Answer

2 b) Define the following terms related to circuit breaker.
1) Breaking Capacity
2) Making Capacity
3) Short time rating and
4) Normal current rating

Ans:

1) **Breaking Capacity:** It is current (r.m.s) that a circuit breaker is capable of breaking at given recovery voltage under specified conditions (e.g. power factor, rate of rise of restriking voltage).
2) **Making Capacity:** The peak value of current (including d.c. component) during the first cycle of current wave after the closure of circuit breaker is known as making capacity.
3) **Short Time Rating:** It is the period for which the circuit breaker is able to carry fault current while remaining closed.
4) **Normal Current Rating:** It is the r.m.s. value of current which the circuit breaker is capable of carrying continuously at its rated frequency under specified conditions. The only limitation in this case is the temperature rise of current-carrying parts.

1 Mark for each definition = 4 Marks

OR Equivalent Definitions

2 c) Define the following terms with respect to protective relays
i) Relay time
ii) Reset current
iii) Plug setting multiplier and
iv) Time setting multiplier

Ans:

1) **Relay Time:** The time interval between occurrence of fault and closure of relay contacts.
2) **Reset Current:** The value of current below which the relay resets and comes back to its original state is called as reset current.
3) **Plug Setting Multiplier:** It is the ratio of fault current in relay coil to pick-up current.

OR

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

4) **Time Setting Multiplier:** The adjustment arrangement provided for setting the operation time of relay is known as Time setting multiplier.

1 Mark for each definition = 4 Marks

OR Equivalent Definitions

2 d) A three phase, 66/11 kV, star-delta connected transformer is protected by Merz-Price system. The CT's on LV side have a ratio of 400/5. Find the ratio of CT's on the HV side.

Ans:

The CTs on LV side are connected in star as transformer windings are in delta. Whereas those on HV side are in delta as the transformer windings are in star on

1 Mark

that side.

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

(CT line current)/√3 = 5/√3 A. 1 Mark

Assume line current (for convenience) of 400 A on LV side (delta side) of transformer. When transformed to HV side the line current will be I_{Lht} given by

$$\sqrt{3} \times 66 \times I_{Lht} = \sqrt{3} \times 11 \times 400$$

I_{Lht} = (11/66)x(400) = 66.67 A. 1 Mark

On HV side CT primary current is 66.67A and CT secondary current is 5/√3 A,

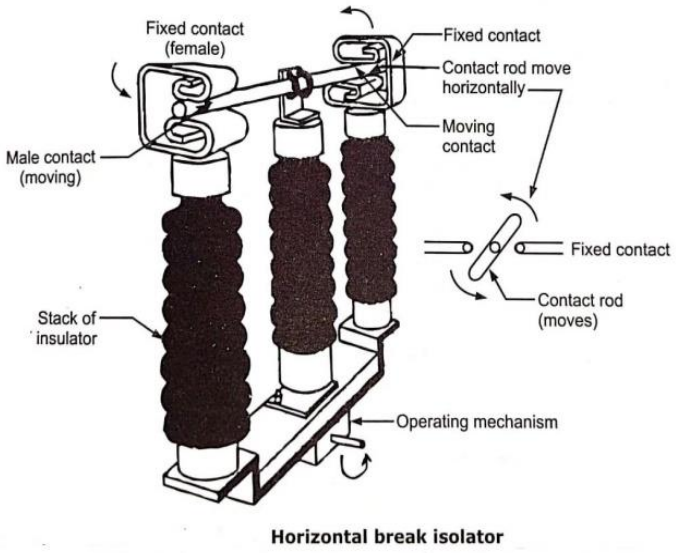
Hence the CT ratio is 66.67 / (5/√3) = (66.67√3/5) = 115.47 / 5. 1 Mark

3 Attempt any THREE of the following: 12

3 a) With neat diagram explain the operation of Horizontal break isolator.

Ans:

Operation of Horizontal Break Isolator:



Horizontal break isolator

2 Marks for diagram

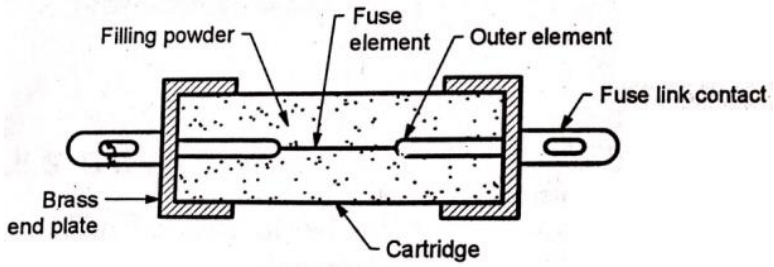
1) Fixed female contacts of metal are supported on stack of insulator.
2) Male contact rod is connected to central insulating support which can be moved to have horizontal movement of male contact for opening or closing into the female contacts.
3) The movement of the rod and its support may be done manually, electrically or pneumatically by operators.
4) The operating mechanism disengages or engages the rod into a female contact for closing and opening operation of isolator.
5) The male contact's movement is horizontal and hence this type of isolator is named as horizontal break isolator.
6) The assembly is supported on galvanized steel channel or steel frame. The moving male contact can be move through 90°.

2 Marks for operation

3 b) Describe the working of HRC fuse with neat diagram.

Ans:

Working of HRC Fuse:



H.R.C. fuse

2 Marks for labeled diagram

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

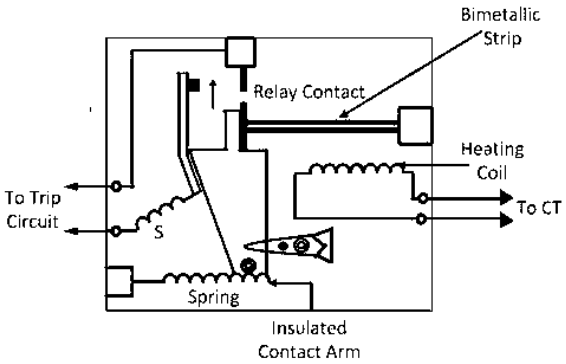
When a fault occurs, the current increases and the heat produced is sufficient to melt this element. Fuse element melts before the fault current reaches its first peak value. Vaporized metal or fuse element chemically reacts with filling powder and results in the formation of high resistance substance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

2 Marks for working

3 c) With a neat sketch, explain the working of Thermal relay.

Ans:

Working of Thermal Relay:



Schematic Arrangement of Thermal Relay

2 Marks for labeled diagram

1) When the system is in normal operating condition, the heating element carries normal current from CT, this current produces heat = I^2Rt. This heat is not sufficient to bent bimetallic strip hence relay contact remain open.
2) The insulated liver arm is connected to the trip coil along with the spring and the bimetallic strips. The tension of the spring is varied by the help of the sector-shaped plate
3) When the fault occurs on the system, the heating element carries abnormal current supplied by the CT, hence developing more heat which bents bimetallic strip, the tension of the spring releases which operates relay contacts resulting into providing trip signal to trip circuit.

2 Marks for working

3 d) A star connected, 3-phase, 10 MVA, 6.6 kV alternator is protected by Merz-Price circulating current principle using 1000/5 amperes current transformers. The star point of the alternator is earthed through a resistance of 7.5Ω. If the minimum operating current for the relay is 0.5A, calculate the percentage of each phase of the stator winding which is unprotected against the earth faults, when the machine is operating at normal voltage.

Ans:

Let x% of winding be unprotected.

Earthing resistance r = 7.5 Ω

Voltage per phase = $\frac{6.6\times1000}{\sqrt{3}} = 3810\ V$ — 1 Mark

Minimum fault current which will operate the relay = $\frac{1000}{5} \times 0.5 = 100A$

E.m.f. induced in x % winding = $V_{ph} \times \frac{x}{100} = \frac{3810(x)}{100} = 38.1(x)\ volts$ — 1 Mark

Earth fault current which x% winding will cause

$$= \frac{38.1(x)}{r} = 5.08(x) ampere$$ — 1 Mark

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

$$\therefore 5.08(x) = 100$$

$$\therefore \mathbf{x = 19.68\ \%}$$ — 1 Mark

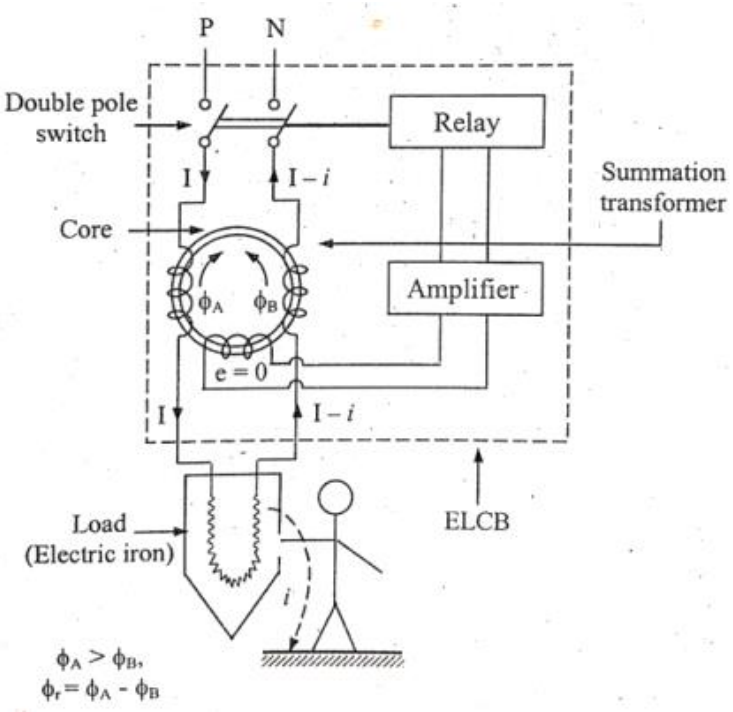
Hence 19.68% of alternator winding is left unprotected.

4 Attempt any THREE of the following: 12

4 a) "ELCB is must for a residential installation." Justify the statement

Ans:

ELCB is must for a Residential Installation:



2 Marks for diagram

When the insulation of equipment fails and person touches the metal casing, the leakage current (say i) flows through human body and he may receive severe shock. However, if ELCB is used with residential installation, it senses the fault current (leakage current) and operates in very short time under such conditions and the current flowing through the body of person / operator is interrupted. Thus the person is protected from getting electric shock.

Referring to the figure, under normal condition, the phase current I flow through circuit and same amount of current I return through circuit hence relay does not operate. But when fault occurs, a small part of I say i completes its path through fault, human being and earth. The return current through neutral gets reduced to (I - i).Therefore, flux ϕ_B reduces to a value less than the flux ϕ_A. Hence the resultant flux $\Phi_r = (\phi_A - \phi_B)$ induces an emf, which is further amplified and operates relay circuit within 50ms, resulting into opening of the mains and ultimately protects the person / operator because of ELCB. So it is must for a residential installation.

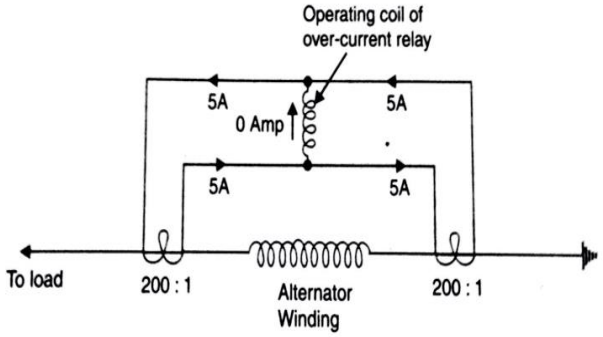
2 Marks for justification

OR Equivalent Answer

4 b) Describe the operation of current differential relay with neat sketch.

Ans:

Operation of Current Differential Relay:



2 Marks for diagram

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 seconderies of CTs are equal. These currents will only circulate between the two CTs and no current will flow through relay coil. If a fault occurs on alternator winding, the two secondary currents will not be equal and resultant current flows through relay coil, causing relay to operate for protection of alternator winding.

2 Marks for operation

4 c) Discuss in brief the principle of distance protection and state four advantages of distance protection scheme.

Ans:

Principle of Distance Protection:

Action of relay depends on impedance (distance) up to fault point. At fault point the ratio of V/I (= Z) falls below preset value due to which the relay operates to trip the circuit breaker.

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

2 Marks for principle

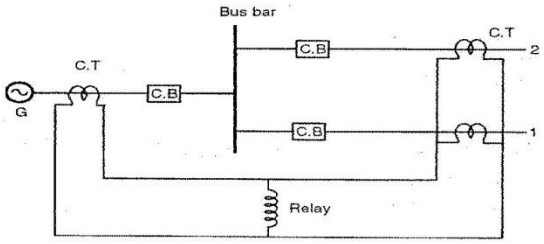
Advantages: ½Mark for each advantages = 2 Marks

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

4 d) Explain differential protection scheme for busbars with neat sketch.

Ans:

Differential Protection Scheme for Bus bar:



Differential protection of bus bar

2 Marks for diagram

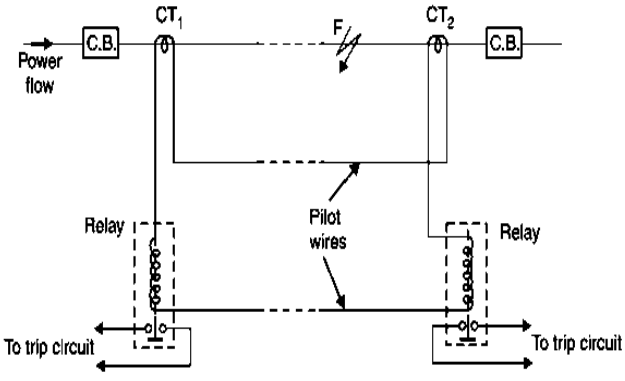
Under normal conditions, the sum of the currents entering the bus bar zone is equal to those leaving it and no current flows through the relay coil. If a fault occurs within the protected zone, the currents entering the bus will no longer be equal those leaving it. The difference of these currents will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

2 Marks for explanation

4 e) Explain with neat sketch, the Pilot wire protection scheme applied to transmission line.

Ans:

Pilot Wire Protection scheme of Transmission Line:



2 Marks for diagram

Figure shows the single line diagram of Merz price voltage balance system for pilot wire protection of three phase transmission line. The pair of CTs in each line is connected in series with a relay, in such a way that under normal conditions, their secondary voltages are equal and opposite. Because current entering is equal to current leaving, they cancel out and no current flows through relay coil. Suppose a fault occurs at point F, the current entering and leaving are different, hence causing current to flow through the relay, which gives trip signal

2 Marks for explanation

to the circuit breaker for protection of transmission line.

5 Attempt any TWO of the following: 12

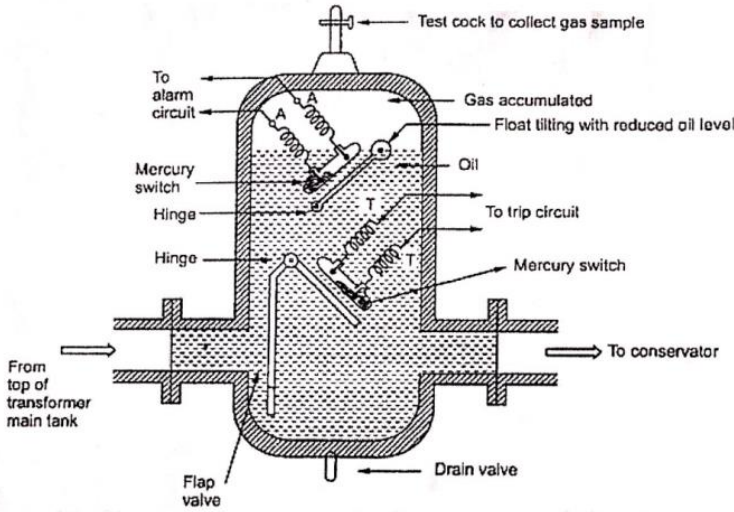
5 a) Describe the construction and Operation of Buchholz relay with neat labeled diagram.

Ans:

Construction of Buchholz Relay:

It takes the form of a domed vessel placed in the connecting pipe between the main tank and the conservator. The device has two elements. The upper element consists of a mercury switch attached to a float. The lower elements contain a mercury switch mounted on a hinged type flap located in the direct path of the flow of oil from the transformer to the conservator. The upper element closes an alarm circuit during incipient faults whereas the lower element is arranged to trip the circuit breaker in case of severe internal faults.

2 Marks for construction



Terminals 'A' : are for alarm and Terminals 'T': are for tripping.

Buchholz relay

2 Marks for labeled diagram

Operation:

As seen from diagram, the upper mercury switch operates the alarm circuit due to tilting of the float by accumulation of gas evolved slowly in the transformer tank due to minor faults which may develop into major ones if the alarm is not investigated.

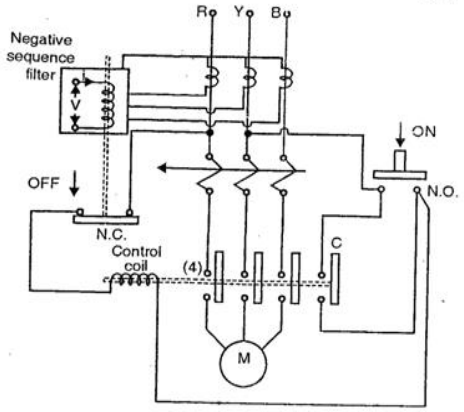
Further lower mercury switch operates the trip circuit to switch off the circuit breaker related to the transformer when there is a sudden flow of oil from the transformer tank to conservator. Such flow occurs when there is serious fault in the transformer tank. Here the float (lower) is placed in such a manner that it senses the sudden violent movement of oil/gas from transformer tank to conservator.

2 Marks for operation

5 b) Explain the working of single phasing preventer with neat diagram.

Ans:

Working of single phasing preventer:



3 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. When one of the three input lines get disconnected because of any reason, ultimately the NC contact gets opened which stops the motor to avoid further damage when single phasing occurs.

3 Marks for working

5 c) Two 11kV, 3 phase, 3000kVA generators having reactances of 15% operate in parallel. The generator supply power to transmission line through 6000kVA transformer of ratio 11kV/22kV having leakage reactance of 5%. Calculate Fault current and fault kVA on H.T. side of transformer.

Ans:

Assume base KVA = 6000kVA

% Reactance related to base kVA

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

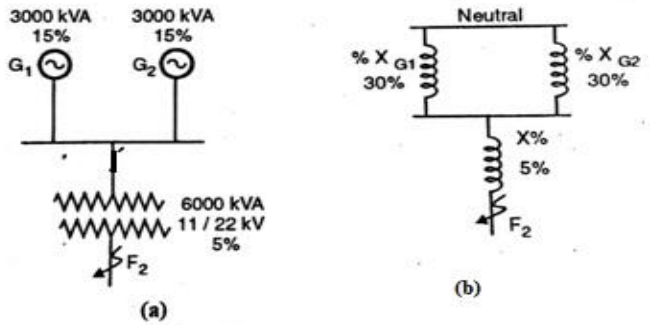
X_{G1} = (6000/3000) x 15%

= 30 %

X_{G2} = 30 % 1 Mark

X_T = (6000/6000) x 5

= 5 % 1 Mark



1 Mark

For Fault at F2 (HT side)

Total reactance is $\%X = (X_{G1} \parallel X_{G2}) + X_T = (30 \parallel 30) + 5$ — 1 Mark

$= 15 + 5 = 20\%$

Rated current at base kVA

$I = (6000 \times 1000) / (\sqrt{3} \times 22 \times 1000)$

$I = 157.45$ Amp.

$I_{SC} = I \times (100 / \% X)$

$= 157.45 \times (100 / 20)$

$I_{SC} = 787.29$ Amp — 1 Mark

S.C. kVA = Base kVA x (100/ % X)

$= 6000 \times (100 / 20)$

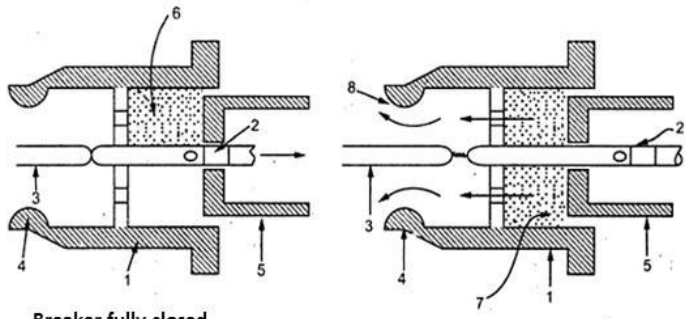
$= 30000$ kVA — 1 Mark

6 Attempt any TWO of the following. 12

6 a) Describe the construction of SF_6 circuit breaker with neat diagram.

Ans:

Construction of SF_6 Circuit Breaker :



1 - Movable (puffer) cylinder 2 - Moving contact 3 - Fixed contact
4 - Insulating nozzle 5 - Fixed piston. 6 - Gas trapped in before compression
7 - Compressed gas between Movable cylinder and Fixed piston
8 - Arc extinguished by puffer action.

Single pressure puffer type SF6 circuit breaker

3 Mark for diagram

A sulphur hexafluoride (SF6) circuit breaker consists of fixed and moving contacts enclosed in a chamber. The chamber is called arc interruption chamber, which contains the sulphur hexafluoride (SF6) gas. This chamber is connected to sulphur hexafluoride (SF6) gas reservoir. A valve mechanism is provided to permit the gas to the arc interruption chamber. When the contacts of breaker are opened, the valve mechanism permits a high-pressure sulphur hexafluoride (SF6) gas from the reservoir to flow towards the arc interruption chamber.

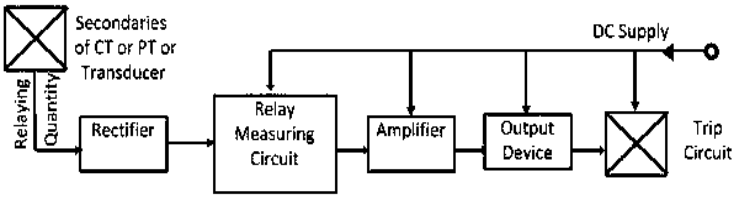
The fixed contact is a hollow cylindrical current carrying contact fitted with an arcing horn. The moving contact is also a hollow cylinder with rectangular holes in the sides. The holes permit the sulphur hexafluoride gas (SF6) gas to let out through them after flowing along and across the arc. The tips of fixed contact, moving contact and arcing horn are coated with a copper-tungsten arc-resistant material.

3 Marks for description

6 b) With the help of neat diagram, explain operation of static relay.

Ans:

Operation of Static Relay:



Block Diagram of Static Relay

3 Mark for diagram

Operation:

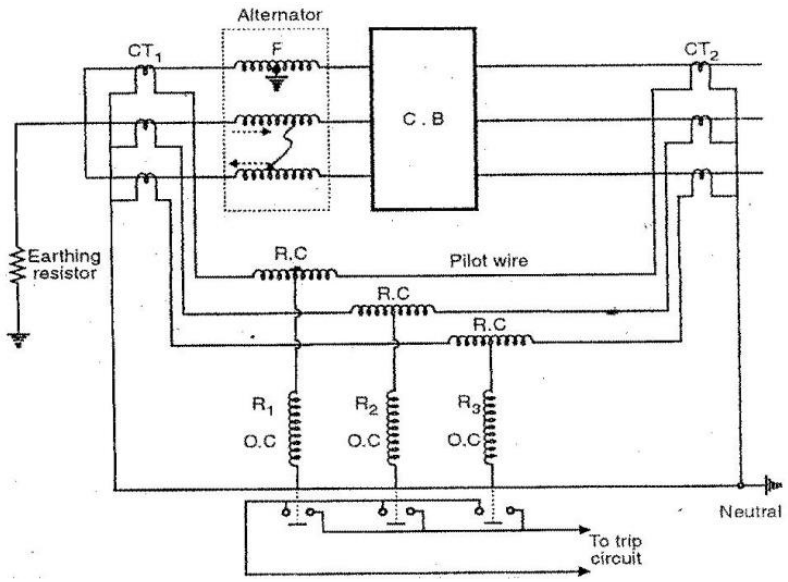
1) The solid-state component used are transistors, diodes, resistors, IC's, capacitor etc. The function of comparison and measurement are accomplished by static circuits.
2) Here the relaying quantity i.e. output of CT or PT or a transducer is rectified by rectifier.
3) The rectified output is supplied to a relay measuring unit comprising of comparators, level detectors, filters and logic circuits.
4) The output of relay measuring unit is amplified by the amplifier and fed to the output device which actuates the trip circuit as per requirement.
5) An auxiliary dc supply is provided for operation of static relay elements as shown in figure.

3 Marks for operation

6 c) Explain the "Differential Protection Scheme" used for alternators with neat labeled diagram.

Ans:

Differential Protection Scheme for Alternator:



3 Marks for labeled diagram

Figure shows the differential protection provided to 3 phase alternator. Here identical CTs are placed on both sides of 3 phase alternator and their secondary's are connected in star formation. Protective relays are connected as shown.

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 trip signal to the CB, thereby alternator circuit is tripped.

3 Marks for explanation