DIPLOMA WALLAH

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Practice the sample paper covered both important questions and exam patterns

Subject: Switchgear and Protection (EEE303)   **Full Marks: 70**   **Time: 3 Hours**

Instructions:

- Question No. 1 is compulsory. (7 MCQs, 2 Marks each)
- Answer any FOUR questions from the remaining (Q.2 to Q.7).
- Q.2 to Q.6 carry 14 marks each (Divided into A and B, 7 Marks each).
- Q.7 consists of Short Notes (Answer any FOUR, 3.5 Marks each).

Q.1 Choose the correct option (Compulsory - 7 x 2 = 14 Marks)

i) In a circuit breaker, the active recovery voltage depends upon:

- a. Power factor
- b. Armature reaction
- c. Circuit conditions
- d. All of the above

ii) Which part of the circuit breaker is primarily helpful in extinguishing the arc?

- a. Contacts
- b. Arc chute
- c. Operating mechanism
- d. Bushing

iii) The relay operating coil is normally supplied through:

- a. Fuses
- b. Current Transformer and Potential Transformer
- c. Power Transformer
- d. Directly from the main line

iv) Under-voltage relays are primarily used for:

     a. Motor protection

     b. Transformer protection

     c. Transmission line protection

     d. Bus-bar protection

v) The burden of a protective relay is expressed in:

     a. Amperes

     b. Volts

     c. Volt-Amperes (VA)

     d. Watts

vi) The differential protection principle is inherently based on:

     a. Kirchhoff's Current Law (KCL)

     b. Kirchhoff's Voltage Law (KVL)

     c. Ohm's Law

     d. Faraday's Law

vii) Which of the following is NOT a routine test for a circuit breaker?

     a. Millivolt drop test

     b. Short circuit breaking capacity test

     c. Power frequency voltage withstand test

     d. Mechanical operation test

Answer any FOUR questions from Q.2 to Q.7

Q.2 A) Explain the working principle and construction of an Earth Leakage Circuit Breaker (ELCB) / RCCB. *(7 Marks)*

Q.2 B) What is an Automatic Mains Failure (AMF) panel? Draw its block diagram and explain its operation. *(7 Marks)*

Q.3 A) Describe the construction and working principle of a Vacuum Circuit Breaker (VCB). What are its main applications? *(7 Marks)*

Q.3 B) Discuss the various protection schemes usually employed for the protection of a large induction motor. *(7 Marks)*

Q.4 A) Explain the concept of Distance Protection. How is it implemented for the protection of long transmission lines? *(7 Marks)*

Q.4 B) What is the function of a Peterson coil in a power system? Explain the different methods of substation earthing. *(7 Marks)*

Q.5 A) Define the following terms related to circuit breakers: (i) Restriking Voltage (ii) Recovery Voltage (iii) Rate of Rise of Restriking Voltage (RRRV). *(7 Marks)*

Q.5 B) Draw the block diagram of a Microprocessor-based (Numerical) relay and explain its operation. List its advantages. *(7 Marks)*

Q.6 A) With the help of a neat diagram, explain the Circulating Current (Merz-Price) Protection scheme for a 3-phase transformer. *(7 Marks)*

Q.6 B) Explain the construction and working of an HRC fuse. List its merits and demerits. *(7 Marks)*

Q.7 Write short notes on any FOUR of the following (4 x 3.5 = 14 Marks)

    A. Bus-Bar differential protection

    B. Bimetal Relays

    C. RMU (Ring Main Unit) and LBS (Load Break Switch)

    D. ZCT (Zero Sequence Current Transformer)

    E. Pilot-Wire Protection

SOLUTIONS FOR SAMPLE PAPER 3

MCQ Answer Key

i) d, **ii)** b, **iii)** b, **iv)** a, **v)** c, **vi)** a, **vii)** b

Model Answers for Long Questions

Q.2 A) ELCB / RCCB:

Working Principle: It operates based on Kirchhoff's Current Law. It utilizes a Core Balance Current Transformer (CBCT) through which all phase wires and the neutral wire pass.
Under normal, healthy conditions, the vector sum of currents flowing out to the load and returning via the neutral is exactly zero ($I_P + I_N = 0$). Hence, no magnetic flux is induced in the CBCT core.
When an earth leakage fault occurs (e.g., a person touches a live wire), some current flows to the earth, bypassing the neutral. The vector sum is no longer zero, creating a residual magnetic flux. This flux induces a voltage in the secondary coil of the CBCT, which energizes the trip relay coil to open the circuit breaker contacts instantly, protecting against electrical shock.

Q.2 B) AMF Panel (Automatic Mains Failure):

Function: It is designed to automatically switch the electrical load to a standby generator when the main utility grid power fails or fluctuates severely.
Working: The panel's controller continuously monitors the incoming grid voltage. If a failure is detected, it waits for a preset delay (to ignore temporary dips) and then sends a starting pulse to the Diesel Generator (DG). Once the generator produces stable voltage and frequency, the AMF panel switches the load contactors from 'Mains' to 'Generator'. When grid power returns, it shifts the load back to mains, lets the generator cool down running idle for a few minutes, and then shuts it off automatically.

[Image of AMF panel block diagram]

Q.3 A) Vacuum Circuit Breaker (VCB):

Construction & Working: In a VCB, the fixed and moving contacts are enclosed within a highly evacuated vacuum chamber (interrupter). When a fault occurs, the mechanism pulls the moving contact away. The extreme heat vaporizes the contact material, forming an arc in the metal vapor. As the alternating current approaches its natural zero-crossing, the metal vapor rapidly condenses back onto the contacts and shields. The vacuum immediately regains its exceptionally high dielectric strength, extinguishing the arc permanently at the first current zero.

Applications: Ideally suited for medium voltage applications (11kV to 33kV) in industrial switchgears, rural distribution, and railway traction.

Q.3 B) Protection of a Large Induction Motor:

- **Short Circuit Protection:** Provided by HRC fuses or instantaneous magnetic overcurrent relays to quickly isolate severe phase-to-phase or phase-to-ground faults.
- **Overload Protection:** Achieved using Thermal Overload Relays (bimetallic strips). They mirror the heating characteristic of the motor and trip if a sustained overload occurs.
- **Single Phasing / Unbalance Protection:** Protected by negative sequence voltage/current relays. Single phasing causes severe heating due to negative sequence currents.
- **Earth Fault Protection:** Utilizes a Core Balance Current Transformer (CBCT) and an earth fault relay.
- **Under-voltage Protection:** To prevent the motor from drawing excessive current to maintain power during low voltage dips.

Q.4 A) Distance Protection:

Concept: Unlike overcurrent relays, distance relays operate on the ratio of voltage (V) to current (I), which is Impedance ($Z = V/I$). The relay continuously measures the impedance of the line from the relay location up to the fault point.

Implementation: The impedance of a transmission line is proportional to its length. The relay is set to operate for an impedance value corresponding to a specific "zone" or length of the line. If a fault occurs, the voltage drops and current increases, causing the measured Z to fall below the set value. The relay immediately trips, identifying that the fault is within its protected zone. This provides excellent high-speed primary and backup protection for long transmission lines.

Q.4 B) Peterson Coil & Substation Earthing:

Peterson Coil (Arc Suppression Coil): It is an iron-cored, adjustable reactor connected between the transformer neutral and earth. In an ungrounded system, a single-line-to-ground fault causes an "arcing ground" (repeated striking and extinguishing of the arc). The Peterson coil is tuned ($L = 1 / 3\omega^2C$) so its inductive fault current exactly cancels out the system's capacitive fault current. This makes the net fault current zero, extinguishing the arc naturally.

Substation Earthing Methods:
- **Solid Earthing:** Neutral directly connected to earth (zero impedance). Used for < 33kV.
- **Resistance Earthing:** A resistor is placed between neutral and earth to limit fault current, preventing equipment damage.
- **Reactance Earthing:** Uses a reactor to limit fault current, typically used where charging currents are high.

Q.5 A) Circuit Breaker Terminologies:

- **Restriking Voltage:** The high-frequency transient voltage that appears across the breaker contacts immediately after the arc is extinguished at current zero. If this voltage exceeds the gap's dielectric strength, the arc restrikes.
- **Recovery Voltage:** The normal, 50 Hz RMS power-frequency voltage that appears across the contacts after the transient restriking voltage oscillations have died out and the fault has been completely cleared.
- **RRRV (Rate of Rise of Restriking Voltage):** It is the slope of the steepest tangent to the restriking voltage waveform, expressed in kV/μs. A higher RRRV makes arc extinction more difficult.

Q.5 B) Microprocessor / Numerical Relay:

Working: Analog signals from CTs and PTs are filtered and converted to digital signals via an Analog-to-Digital (A/D) converter. The microprocessor analyzes these digital samples using specialized protective algorithms (software). If the calculated parameters indicate a fault, the processor issues a digital trip command to the output module to open the breaker.
Advantages: High accuracy, multi-functionality (one relay can act as overcurrent, earth fault, and overvoltage), self-diagnostic capabilities, event recording, and easy integration into SCADA systems via communication ports.

Q.6 A) Merz-Price Protection for 3-Phase Transformer:

This is a differential protection scheme. CTs are placed on both the primary and secondary sides of the transformer. To compensate for the phase shift in Star-Delta transformers, the CT secondaries are connected in Delta on the transformer's Star side, and in Star on the transformer's Delta side.
Under normal conditions, the secondary currents of the CTs circulate in the pilot wires, and no current flows through the operating coils of the relay. During an internal fault, the balance is upset, the differential current flows through the relay coil, and it trips the transformer breakers.

Q.6 B) HRC Fuse:

Construction & Working: Consists of a heat-resistant ceramic body with a silver fuse element inside. The space around the element is filled with quartz sand powder. When a heavy fault current flows, the silver melts and vaporizes. The vapor reacts with the sand to form a high-resistance glass-like substance, effectively extinguishing the arc and cutting off the current.

Merits: Capable of clearing very high fault currents (high breaking capacity), very reliable, requires no maintenance, inverse time-current characteristic.

Demerits: It is a one-time use device; it must be completely replaced after operating. Fault finding takes longer compared to resetting an MCB.

Short Answer Solutions (Q.7)

A) Bus-Bar differential protection: Busbars are critical nodes. Differential protection compares the sum of currents entering the busbar with the sum of currents leaving it. According to KCL, it should be zero. If a fault occurs on the busbar, the sum is not zero, and the relay trips all connected breakers instantly.

B) Bimetal Relays: Used mainly for motor overload protection. It contains a bimetallic strip made of two metals with different expansion coefficients. Excess current heats the strip, causing it to bend and mechanically trigger a trip switch.

C) RMU & LBS: A Ring Main Unit (RMU) is a compact, enclosed switchgear unit used in ring-type distribution networks. It incorporates a Load Break Switch (LBS) which can safely make or break normal load currents, but cannot interrupt short circuit fault currents (for which a breaker or HRC fuse is needed).

D) ZCT (Zero Sequence Current Transformer): Also known as a Core Balance CT (CBCT). Unlike normal CTs, all 3-phase wires (and neutral if applicable) pass through its hollow core. It only detects zero-sequence unbalance currents (earth leakage) to operate sensitive earth fault relays.

E) Pilot-Wire Protection: A unit protection scheme for short transmission cables. It uses auxiliary cables (pilot wires) to communicate and compare the current magnitude/phase at both ends of the line. It is highly selective but too expensive for long distances due to the cost of the pilot wires.