GUJARAT TECHNOLOGICAL UNIVERSITY
BE- SEMESTER–1 PAPER SOLUTION – WINTER 2024

Subject Name & Code:
Basic Electrical Engineering- 3110005

MARKS

Q.1 (a) State and explain Kirchhoff's current Law. **03**

Answer:

Kirchhoff's Current Law (KCL):
Statement:
"The algebraic sum of currents entering a junction in an electrical circuit is zero."
In other words, the total current entering a node (or junction) is equal to the total current leaving the node.

Mathematical Form:

$$\sum I_{in} = \sum I_{out} \text{ or } \sum I = 0$$

Explanation:
- A **junction** is a point where two or more electrical conductors meet.
- According to the law of conservation of electric charge, charge cannot accumulate at a junction.
- Therefore, all current entering the junction must leave it.

Example:
If three currents meet at a junction such that:
- $I1$ enters the junction
- $I2$ and $I3$ leave the junction

Then according to KCL:

$$I1=I2+I3$$

Or rearranged as:

$$I1-I2-I3=0$$

Conclusion:
Kirchhoff's Current Law is based on the conservation of charge and is used to analyze current flow in electrical networks, especially at junctions and nodes.

(b) Prepare a list of parts of a Single-phase AC Motor. **04**

Answer:

A **Single-phase AC motor** mainly consists of the following **important parts**:

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1. Stator:
- The **stationary part** of the motor.
- Contains **core and windings**.
- Provides the **rotating magnetic field** when AC supply is given.

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2. Rotor:
- The **rotating part** placed inside the stator.
- Usually a **squirrel cage type** rotor.
- Rotates due to interaction with the magnetic field from the stator.

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3. Shaft:
- Connected to the rotor.
- Transfers **mechanical power** to the load.

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4. Bearings:
- Support the shaft and allow **smooth rotation** with minimum friction.

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5. End Covers:
- Protect both ends of the motor.
- Hold the bearings in place.

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6. Cooling Fan:
- Fitted on the rotor shaft.
- Maintains **temperature** by removing heat during operation.

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7. Casing or Frame:
- Outer covering of the motor.
- Made of **metal or strong plastic** to provide **mechanical protection**.

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8. Auxiliary or Starting Winding (in some types):
- Additional winding used in **split-phase or capacitor-start motors** to help in starting torque.

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9. Terminal Box:
- Enclosure for **connecting electrical wires** to the motor windings.

Conclusion:
These parts work together to convert **electrical energy into mechanical energy** in single-phase AC motors, commonly used in household and small industrial applications.

(c) State & Explain the Thevenin's theorem with suitable example. **07**

Answer:

Thevenin's Theorem

Statement:
"Any two-terminal linear bilateral network, consisting of voltage sources, current sources, and resistors, can be replaced by an equivalent circuit consisting of a single voltage source (called Thevenin voltage, Vth) in series with a single resistance (called Thevenin resistance, Rth)."
This simplification is valid for the portion of the network **as seen from two terminals**, typically where a load is connected.

Steps to Apply Thevenin's Theorem:
1. **Remove the load resistance** RLR_LRL from the original circuit across which Thevenin equivalent is to be found.
2. **Find Thevenin voltage Vth:**
   Calculate the **open-circuit voltage** across the terminals where the load was connected.
3. **Find Thevenin resistance Rth:**
   Deactivate all **independent sources**:

- Replace voltage sources with short circuits.
- Replace current sources with open circuits.

  Then, calculate the **equivalent resistance** across the terminals.

4. **Draw the Thevenin equivalent circuit:**
   Connect Vth in series with Rth and reconnect the load resistance RL.
5. **Analyze the simplified circuit** to find current through or voltage across RL.

Example:
Consider a circuit:

- A 12 V battery is connected in series with a 4 Ω resistor.
- A 6 Ω resistor is connected across terminals A and B (as load resistor).

Step 1: Remove Load Resistor (6 Ω):
Now, only 12 V source and 4 Ω resistor are in the circuit.
Step 2: Find Vth:
The 6 Ω resistor is removed. So, the voltage across A-B (open terminals) is same as voltage across 4 Ω resistor, which is:
Vth=12 V(Since it's open circuit, no current flows)

Step 3: Find Rth:

- Deactivate the voltage source (12 V → short circuit).
- Now only the 4 Ω resistor remains across the terminals A and B.

So,

Rth=4 Ω

Step 4: Draw Thevenin Equivalent:
A 12 V source in series with 4 Ω resistor, connected to 6 Ω load resistor.
Step 5: Find Load Current:

$$I = \frac{V_{th}}{R_{th} + R_L} = \frac{12}{4+6} = \frac{12}{10} = 1.2 \text{ A}$$

Conclusion:
Thevenin's theorem simplifies complex linear circuits to a basic two-element series circuit. It is especially useful in analyzing power systems and electronic networks involving variable loads.

Q.2 **(a)** Write short note on autotransformer. **03**

Answer:

An **autotransformer** is a type of transformer with a **single winding** that acts as both the primary and the secondary winding. A part of the winding is common to both sides. It works on the same principle of electromagnetic induction as a two-winding transformer.

Construction:

- It has a **single continuous winding** wound on a laminated iron core.
- Taps are taken at different points to provide variable output voltages.
- The portion of the winding between the input terminals is called the **primary**, and the portion between one input and one tap is the **secondary**.

Working Principle:

- When AC voltage is applied to the input terminals, it produces a changing magnetic flux in the core.
- This changing flux induces voltage in the rest of the winding (as per Faraday's Law).
- The output is taken from the tapped section of the same winding.

Advantages:

- Requires **less copper and core material** (more economical).
- **Smaller in size** and **higher efficiency** than a two-winding transformer for the same rating.
- Commonly used in applications where the **voltage difference is small**, such as voltage regulators and motor starters.

Conclusion:

An autotransformer is a single-winding transformer that is efficient, compact, and cost-effective, especially suitable for small voltage transformations.

(b) Derive the EMF equation of single-phase transformer. **04**

Answer:

Assumptions:
Let:

- ϕm = Maximum flux in the core (in Weber)
- f = Supply frequency (in Hz)
- N1 = Number of turns in the **primary winding**
- N2 = Number of turns in the **secondary winding**

Flux Equation:
The magnetic flux ϕ\phiϕ varies **sinusoidally** with time:

$$\phi = \phi m \sin(\omega t)$$

where $\omega = 2\pi f$

Induced EMF Using Faraday's Law:
The RMS value of the EMF induced in a coil is given by:

$$E = 4.44 f N \phi m$$

Therefore:

- **Primary EMF, E1:**

$$E1 = 4.44\, f\, N1\, \phi m$$

- **Secondary EMF, E2:**

$$E2 = 4.44\, f\, N2\, \phi mE$$

EMF Equation of Transformer:

$$E = 4.44\, f\, N\, \phi m$$

Where:

- E = RMS value of induced EMF
- N = Number of turns
- f= Frequency in Hz
- ϕm = Maximum flux in Weber

Conclusion:
The EMF induced in any winding of a transformer is **directly proportional to frequency (f)**, **maximum flux (ϕm)**, and the **number of turns (N)**.
This equation is valid for both **primary and secondary windings** of a single-phase transformer.

(c) When three resistances of 10Ω, 20Ω, and 30Ω are connected in series across 230 V supply. Find (1) equivalent resistance (2) current flowing through each resistance, (3) voltage drop across each and (4) power loss in each Resistor **07**

Answer:

Given:

- R1=10 Ω
- R2=20 Ω
- R3=30 Ω
- Supply Voltage, V=230 V
- Series connection: Current is same through all resistors

(1) Equivalent Resistance:
In series, total resistance is the sum of individual resistances:

Req=R1+R2+R3=10+20+30=60 Ω

(2) Current Flowing Through Each Resistance:
In a series circuit, current is same through all elements:

$$I = \frac{V}{R_{eq}} = \frac{230}{60} = \boxed{3.83\ \text{A}}$$

(3) Voltage Drop Across Each Resistor:

Using Ohm's Law: $V = I \times R$

- For $R_1 = 10\,\Omega$:
  $V_1 = 3.83 \times 10 = \boxed{38.3\ \text{V}}$
- For $R_2 = 20\,\Omega$:
  $V_2 = 3.83 \times 20 = \boxed{76.6\ \text{V}}$
- For $R_3 = 30\,\Omega$:
  $V_3 = 3.83 \times 30 = \boxed{114.9\ \text{V}}$

Check: $V_1 + V_2 + V_3 = 38.3 + 76.6 + 114.9 = 229.8 \approx 230\ \text{V}$

(4) Power Loss in Each Resistor:

Use $P = I^2 \times R$

- For $R_1 = 10\,\Omega$:
  $P_1 = (3.83)^2 \times 10 = 14.66 \times 10 = \boxed{146.6\text{ W}}$
- For $R_2 = 20\,\Omega$:
  $P_2 = (3.83)^2 \times 20 = 14.66 \times 20 = \boxed{293.2\text{ W}}$
- For $R_3 = 30\,\Omega$:
  $P_3 = (3.83)^2 \times 30 = 14.66 \times 30 = \boxed{439.8\text{ W}}$

Final Answers (Boxed for Exam Presentation):

1. $R_{eq}=60\ \Omega$
2. $I=3.83\text{A}$
3. Voltage Drops:
   - $V1=38.3$ V
   - $V2=76.6$ V
   - $V3=114.9$ V
4. Power Losses:
   - $P1=146.6$ W
   - $P2=293.2$ W
   - $P3=439.8$ W

OR

(c) Derive the relationship between line and phase values of current in a three phase, balanced, delta connected system. **07**

Answer:

Delta Connection in a Three-Phase System:
In a **delta connection**, the ends of the three phase windings are connected end-to-end to form a closed loop, and the **line conductors are connected at the junctions of the phases**.

- **Phase voltage** = Voltage across each winding = V_{ph}
- **Line voltage** = Voltage between two lines = V_L

In delta connection:

$$V_L = V_{ph}$$

But **line current** differs from **phase current**.

Let's derive the relationship:
Let the three-phase currents be:

- I_{AB}: Current from phase A to B
- I_{BC}: Current from phase B to C
- I_{CA}: Current from phase C to A

Let each phase current be:

$$I_{ph} = I_m \angle \theta \text{ (equal magnitude, 120° apart)}$$

Let's find the **line current**, for example, **Line A current** I_A:
It is the **vector difference** of currents in two branches connected to point A.

$$I_A = I_{AB} - I_{CA}$$

Using phasor diagram (as in standard derivations):

If:

$$I_{AB} = I_{ph}\angle 0^\circ \quad \text{and} \quad I_{CA} = I_{ph}\angle 120^\circ$$

Then:

$$I_A = I_{ph}\angle 0^\circ - I_{ph}\angle 120^\circ$$

Apply vector (phasor) subtraction:

$$I_A = I_{ph}\left[1 - \cos(120^\circ) - j\sin(120^\circ)\right]$$

$$I_A = I_{ph}\left[1 - (-0.5) - j(0.866)\right]$$

$$I_A = I_{ph}\left[1.5 - j0.866\right]$$

Magnitude of IAI_AIA:

$$|I_A| = I_{ph} \times \sqrt{(1.5)^2 + (0.866)^2} = I_{ph} \times \sqrt{2.25 + 0.75} = I_{ph} \times \sqrt{3}$$

Final Result:

$$\boxed{I_L = \sqrt{3}\, I_{ph}}$$

Where:

- IL = Line current
- Iph = Phase current

Summary Table (Delta Connection):

Quantity	Relation in Delta Connection
Line Voltage	VL= Vph
Line Current	IL=/3 Iph

Q.3 (a) Define following terms in connection with A.C wave forms: (i) Frequency (ii) Time period (iii) Amplitude. **03**

Answer:

(i) Frequency:
Frequency is the **number of complete cycles** of an alternating quantity that occur **in one second**.
It is measured in **Hertz (Hz)**.

Frequency (f)=1/Time Period (T)

In India, the standard frequency of AC supply is **50 Hz**.

(ii) Time Period:
Time period is the **time taken to complete one full cycle** of an alternating waveform.
It is measured in **seconds (s)**.

Time Period (T)=1/Frequency (f)

(iii) Amplitude:
Amplitude is the **maximum value** (positive or negative) of an alternating quantity from its zero or mean position.
In voltage or current waveforms, it is the peak value and is measured in **volts (V)** or **amperes (A)**.

Conclusion:
In AC waveforms, **frequency** indicates how often the waveform repeats, **time period** is the duration of one cycle, and **amplitude** is the peak value of the waveform.

(b) If the waveform of a voltage has a form factor of 1.11 and peak factor of 1.51 and if the maximum value of a voltage is 4500 volts. Calculate the average and r.m.s. values of the voltage. **04**

Answer:

Given Data:
- Peak value of voltage, Vmax=4500 V
- Form factor =1.11
- Peak factor =1.51

Definitions:

1. **Peak Factor** is defined as:

$$\text{Peak Factor} = \frac{V_{max}}{V_{rms}}$$

Rearranging to find RMS value:

$$V_{rms} = \frac{V_{max}}{\text{Peak Factor}} = \frac{4500}{1.51}$$

$$V_{rms} = 2{,}980.13\ \text{V}$$

2. **Form Factor** is defined as:

$$\text{Form Factor} = \frac{V_{rms}}{V_{avg}}$$

Rearranging to find average value:

$$V_{avg} = \frac{V_{rms}}{\text{Form Factor}} = \frac{2980.13}{1.11}$$

$$V_{avg} = 2{,}684.80\ \text{V}$$

Final Answers:
- **RMS Value of Voltage** = 2980.13 V
- **Average Value of Voltage** = 2684.80 V

(c) Describe the open circuit & short circuit test on single-phase transformer. **07**

Answer:

1. Open Circuit Test (No-load Test)
Purpose:
To determine:

- **Iron (core) losses**
- **No-load current**
- **No-load power factor**

Procedure:

- Rated voltage is applied to the LV winding.
- Since the secondary is open, only **no-load current (Io)** flows.
- The wattmeter reads the **core loss** (since copper loss is negligible at no load).

Readings:

- V_0 = No-load voltage (Voltmeter reading)
- I_0 = No-load current (Ammeter reading)
- W_0 = No-load power (Wattmeter reading)

Calculations:

- Power Factor ($\cos\Phi_0$) = $\frac{W_0}{V_0 \times I_0}$
- Core (Iron) loss = W_0

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2. Short Circuit Test
Purpose:
To determine:

- **Full-load copper loss**
- **Equivalent resistance and impedance**
- **Voltage regulation**

Procedure:

- A reduced voltage is applied to the HV winding until **full-load current** flows.
- The applied voltage is very small (usually 5–10% of rated), so **core loss is negligible**.
- The wattmeter measures the **full-load copper loss**.

Calculations:

- Copper Loss at full load = W_{SC}
- Equivalent Impedance (Zeq) = $\frac{V_{SC}}{I_{SC}}$
- Equivalent Resistance (Req) = $\frac{W_{SC}}{I_{SC}^2}$

Conclusion:

- The **Open Circuit Test** gives **core losses**.
- The **Short Circuit Test** gives **copper losses**.
- These tests are **performed without loading** the transformer and are **efficient, quick**, and **economical**

OR

Q.3 **(a)** List out the merits of two-watt meter method. **03**

Answer:

The **two-wattmeter method** is widely used for measuring power in **three-phase systems**, especially in both balanced and unbalanced loads.
The **merits** (advantages) of the two-wattmeter method are:

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1. **Applicable to Both Balanced and Unbalanced Loads:**
   - This method works reliably for both balanced and unbalanced three-phase loads.
2. **Only Two Wattmeters Required:**
   - It requires only **two wattmeters** instead of three, making it **economical and simple**.
3. **Used for Star or Delta Connection:**
   - The method can be used for **both star and delta connected loads**.
4. **Power Factor Determination:**
   - The power factor of the load can be **calculated directly** using the readings of the two wattmeters.
5. **No Need for Neutral Wire:**
   - The method works even **without access to the neutral point**, which is convenient in many practical cases.

Conclusion:
The two-wattmeter method is preferred for its simplicity, cost-effectiveness, and versatility in measuring power in three-phase systems.

(b) Compare series and parallel RLC circuit resonance. **04**

Answer:

The following table compares **series** and **parallel** RLC circuit resonance:

2. **Starting Torque**	Low to moderate	High, due to external resistance in circuit
3. **External Resistance in Rotor**	**Not possible** to insert	**Possible** through slip rings
4. **Maintenance**	Very low (no brushes or rings)	Requires regular maintenance (bru slip rings)
5. **Cost**	Comparatively **cheaper**	**More expensive** due to complex r construction
6. **Efficiency**	**High** due to less copper loss in rotor	Slightly **lower** due to external resis
7. **Applications**	Used in fans, pumps, compressors, etc.	Used in cranes, elevators, hoists (w high starting torque is needed)

(c) Derive an expression for the voltage across the capacitor during charging through the resistor at any instant $V_c = V(1\text{-}e^{-t/RC})$. Assume that RC series circuit is connected across a DC supply of voltage V. **07**

Answer:

Given:
An **RC series circuit** is connected across a **DC supply of voltage V**.
We are to derive the equation:

$$V_C(t) = V\left(1 - e^{\frac{-t}{RC}}\right)$$

Circuit Diagram:
A simple **DC voltage source (V)** is connected in series with a **resistor (R)** and a **capacitor (C)**. A switch is used to initiate the charging.

Let:

- V= Applied DC voltage (constant)
- VC(t) = Voltage across capacitor at time ttt
- i(t) = Current at time ttt
- q(t) = Charge on the capacitor at time ttt

We know that:

$$V_C(t) = \frac{q(t)}{C}$$

and the current:

$$i(t) = \frac{dq(t)}{dt}$$

Apply KVL (Kirchhoff's Voltage Law):

$$V = i(t)R + V_C(t)$$

Substitute $i(t) = \frac{dq}{dt}$ and $V_C(t) = \frac{q}{C}$:

$$V = R\frac{dq}{dt} + \frac{q}{C}$$

Rearrange the equation:

$$R\frac{dq}{dt} = V - \frac{q}{C}$$

Divide both sides by R:

$$\frac{dq}{dt} = \frac{V}{R} - \frac{q}{RC}$$

This is a first-order linear differential equation.
To solve it, we use the integrating factor method.
Let's write it in standard form:

$$\frac{dq}{dt} + \frac{1}{RC}q = \frac{V}{R}$$

The **Integrating Factor (IF)** is:

$$IF = e^{\int \frac{1}{RC}dt} = e^{t/RC}$$

Multiply both sides of the equation by IF:

$$e^{t/RC} \cdot \frac{dq}{dt} + \frac{1}{RC}e^{t/RC}q = \frac{V}{R}e^{t/RC}$$

Left-hand side becomes the derivative:

$$\frac{d}{dt}\left(q \cdot e^{t/RC}\right) = \frac{V}{R}e^{t/RC}$$

Now integrate both sides:

$$\int \frac{d}{dt}\left(q \cdot e^{t/RC}\right) dt = \int \frac{V}{R}e^{t/RC}dt$$

$$q \cdot e^{t/RC} = \frac{V}{R} \cdot RC \cdot e^{t/RC} + C_1$$

$$q \cdot e^{t/RC} = VC \cdot e^{t/RC} + C_1$$

Now divide both sides by $e^{t/RC}$:

$$q(t) = VC + C_1 \cdot e^{-t/RC}$$

At $t = 0$, the capacitor is uncharged, so $q(0) = 0$:

$$0 = VC + C_1 \cdot e^0 \Rightarrow C_1 = -VC$$

Thus:

$$q(t) = VC - VC \cdot e^{-t/RC}$$

Factor VC:

$$q(t) = VC\left(1 - e^{-t/RC}\right)$$

Now find voltage across the capacitor:

$$V_C(t) = \frac{q(t)}{C} = \frac{VC\left(1 - e^{-t/RC}\right)}{C}$$

$$\boxed{V_C(t) = V\left(1 - e^{-t/RC}\right)}$$

Conclusion:
This equation shows how the **voltage across the capacitor** increases **exponentially** from **0 to V** as time increases, with the rate of charging depending on the **time constant τ=RC**.

Q.4 (a) Mention Merits and Demerits of Single-Phase Induction Motor. **03**

Answer:

A **single-phase induction motor** is commonly used in domestic and small industrial applications due to its simple construction and operation using single-phase AC supply.

Merits (Advantages):

1. **Simple Construction:**
   - Fewer components make it easy to build, operate, and maintain.
2. **Low Cost:**
   - Economical compared to three-phase motors, suitable for small appliances.
3. **Operates on Single-Phase Supply:**

- Can be used in homes and places where only single-phase supply is available.

4. **Reliable and Rugged:**
   - Long operating life with less maintenance required.

Demerits (Disadvantages):

1. **Not Self-Starting:**
   - Requires auxiliary means (e.g., capacitor or shaded pole) to start.
2. **Low Efficiency and Power Factor:**
   - Operates at lower efficiency and poorer power factor compared to three-phase motors.
3. **Lower Torque Output:**
   - Not suitable for high-load industrial applications.
4. **Heating Problem:**
   - More prone to overheating under heavy load conditions.

Conclusion:

Single-phase induction motors are simple and cost-effective for light-duty applications, but they lack the performance and efficiency of three-phase motors.

(b) Compare Squirrel cage induction motor and Slip ring Induction Motor. **04**

Answer:

The comparison between **Squirrel Cage Induction Motor** and **Slip Ring Induction Motor** is given below:

Point of Comparison	Squirrel Cage Induction Motor	Slip Ring Induction Mo
1. **Rotor Construction**	Rotor bars short-circuited by end rings (squirrel cage type)	Rotor has **wound coils** connected to external resistors via slip rings
2. **Starting Torque**	Low to moderate	High, due to external resistance in rotor circuit
3. **External Resistance in Rotor**	**Not possible** to insert	**Possible** through slip rings
4. **Maintenance**	Very low (no brushes or rings)	Requires regular maintenance (brushes and slip rings)
5. **Cost**	Comparatively **cheaper**	**More expensive** due to complex rotor construction
6. **Efficiency**	**High** due to less copper loss in rotor	Slightly **lower** due to external resistance
7. **Applications**	Used in fans, pumps, compressors, etc.	Used in cranes, elevators, hoists (where high starting torque is needed)

(c) Describe construction of a DC machine. **07**

Answer:

Introduction:
A **DC machine** (whether used as a motor or generator) consists of **two main parts**:
1. **Stator (stationary part)** – provides the main magnetic field
2. **Rotor (rotating part)** – carries the armature winding

Main Parts of a DC Machine:
1. Yoke (Magnetic Frame):
- The outer frame of the DC machine.
- Made of **cast iron or steel**.
- Provides mechanical support and acts as a **protective cover**.
- Also serves as a **magnetic path** for the flux.

2. Poles:
- Bolted to the yoke.
- Each pole consists of a **pole core** and a **pole shoe**.
- Made of laminated steel to reduce **eddy current losses**.
- Pole shoes spread the flux over the armature surface uniformly.

3. Field Windings:
- Copper coils wound around each pole core.
- When current flows through them, they produce the **magnetic field** necessary for machine operation.
- Connected in such a way to form either **shunt, series, or compound** configuration.

4. Armature Core:
- Mounted on the **shaft**, made of laminated soft iron.
- Cylindrical in shape and has slots on its outer periphery to hold armature conductors.
- Laminations reduce **eddy current losses**.

5. Armature Winding:
- Conductors placed in the armature slots and connected properly to form **closed winding** (lap or wave).
- **EMF is induced** in these windings when the machine operates as a generator, or current flows when operating as a motor.

6. Commutator:
- A **cylindrical structure** made of copper segments insulated by mica.
- Converts the AC induced in the armature into **DC output** (for generators) or allows DC supply to produce a **rotating magnetic field** (in motors).
- Mounted on the shaft and rotates with the armature.

7. Brushes:
- Made of **carbon or graphite**.
- Rest on the commutator segments and conduct current between the rotating commutator and external circuit.
- Held in **brush holders** with spring pressure.

8. Shaft:
- Made of steel.
- Transfers mechanical power (in motor) or is rotated by prime mover (in generator)

OR

Q.4 **(a)** Write applications of Auto Transformer. **03**

Answer:
An **auto transformer** is a single-winding transformer that is used where a

small voltage difference is required between primary and secondary. It is **cost-effective**, **compact**, and **efficient**, making it suitable for various applications.

Applications of Auto Transformer:

1. **Voltage Regulation in Distribution Systems:**
   - Used to **boost or reduce voltage** slightly in power distribution lines.
2. **Starting of Induction Motors:**
   - Used for **reduced voltage starting** of three-phase induction motors to limit starting current.
3. **Railway Applications:**
   - Employed in **electric traction systems** for voltage control in railway networks.
4. **Laboratories and Testing Equipment:**
   - Used in **variacs** or variable AC supplies for testing electrical devices.
5. **Audio Equipment:**
   - Used to match the **impedance between amplifier and loudspeaker** systems.
6. **Industrial Control Systems:**
   - Applied in **control panels** to provide different voltage levels from a single supply.

Conclusion:
Auto transformers are widely used in **power systems, motor control, testing equipment, and industrial applications** due to their simplicity, efficiency, and cost-effectiveness.

(b) Explain Working of capacitor start Single phase induction motor **04**

Answer:

A **Capacitor Start Single Phase Induction Motor** is a type of single-phase motor used where **high starting torque** is required. It uses a **capacitor** in series with the **starting winding** to produce a rotating magnetic field at the time of starting.

Main Parts:

1. **Main Winding (Running Winding)**
2. **Starting Winding (Auxiliary Winding)**
3. **Capacitor (Start Capacitor)**
4. **Centrifugal Switch**

Working Principle:

- When the motor is **switched ON**, single-phase AC is supplied to the **main winding** and to the **starting winding** through a **capacitor**.
- The capacitor causes the current in the starting winding to **lead** the current in the main winding by approximately 90°.
- This **phase difference** produces a **rotating magnetic field**, which helps the motor to start.
- As the motor reaches **75–80% of full speed**, a **centrifugal switch** automatically **disconnects the starting winding and capacitor** from the circuit.
- The motor then continues to run using **only the main winding**.

Applications:
Used in:

- Air conditioners
- Refrigerators
- Compressors
- Water pumps
- Washing machines

Conclusion:
The capacitor start motor provides **high starting torque** and reliable operation, making it suitable for applications with **heavy initial load**.

(c) Explain construction of synchronous generator with diagram. **07**

Answer:

Introduction:
A **synchronous generator**, also called an **alternator**, is a machine that converts **mechanical energy into electrical energy** in the form of alternating current (AC), based on the principle of **electromagnetic induction**.

Main Parts of a Synchronous Generator:
1. Stator:

- The stationary part of the machine.
- Consists of a **stator core** and **stator winding**.
- Made of **laminated silicon steel** to reduce eddy current losses.
- **Three-phase winding** is placed in the stator slots.
- **EMF is induced** in this winding when the rotor rotates.

2. Rotor:

- The rotating part of the machine.
- Carries the **field winding**, which produces the magnetic field.
- Two types of rotors:
    - **Salient Pole Rotor:**
        - Large diameter, short axial length.
        - Used in low-speed machines (e.g., hydro generators).
    - **Non-Salient (Cylindrical) Rotor:**
        - Uniform cylindrical structure.
        - Used in high-speed machines (e.g., turbo generators).

3. Field Windings:

- Placed on the rotor poles (salient type) or in slots (cylindrical type).
- Excited by **DC supply**, usually from an **exciter** or brushless system.
- Produces the required **rotating magnetic field**.

4. Slip Rings and Brushes:

- Provide DC excitation to the field winding in case of **wound rotor**.
- Not required in brushless excitation systems.

5. Shaft and Bearings:

- The **shaft** transfers mechanical input from the prime mover (like a turbine).
- **Bearings** support the rotor and allow smooth rotation.

6. End Covers and Frame:

- The **frame** supports the machine parts and protects from external damage.
- **End covers** house the bearings and support the shaft.

Q.5 (a) Write advantages and disadvantages of ELCB. **03**

Answer:

An **ELCB (Earth Leakage Circuit Breaker)** is a safety device used to detect **earth (leakage) faults** and disconnect the power supply to prevent **electric shock or fire hazards**.

Advantages of ELCB:

1. **Provides Personal Safety:**
   - Protects people from **electric shock** due to leakage current.
2. **Prevents Fire Hazards:**
   - Quickly disconnects the supply if leakage occurs, reducing **risk of electrical fires**.
3. **Quick Operation:**
   - Operates within **milliseconds**, ensuring fast disconnection of faulty circuits.
4. **Easy Installation:**
   - Can be installed in **residential and commercial** systems with minimal wiring changes.

Disadvantages of ELCB:

1. **Does Not Detect Overload or Short Circuit:**
   - ELCB only senses earth leakage, not overload or line-to-line short circuits.
2. **Nuisance Tripping:**
   - May trip unnecessarily due to **minor leakage** or faulty appliances.
3. **Dependent on Proper Earthing:**
   - The effectiveness of ELCB is reduced if **earthing is poor or disconnected**.

(b) Draw the structure of underground cable with name of all sections. **04**

Answer:

An **underground cable** is used for transmission and distribution of electrical power below the surface of the earth. It consists of several concentric layers for **mechanical strength, insulation, and protection**.

Main Sections with Functions:

1. **Conductor:**
   - Made of copper or aluminum.
   - Carries electric current.
2. **Insulation:**
   - Encloses the conductor to prevent leakage of current.
   - Common materials: PVC, XLPE.

3. **Armour (Armouring):**
    - Metallic protection (usually steel wire).
    - Provides mechanical strength against external damage.
4. **Bedding:**
    - Layer of jute or PVC between insulation and armour.
    - Acts as a cushion and improves bonding.
5. **Outer Sheath:**
    - Final protective layer made of PVC or rubber.
    - Protects the cable from moisture, chemicals, and mechanical stress.

(c) Explain different methods of Power factor Improvement **07**

Answer:

Introduction:

$$\text{Power Factor (p.f.)} = \cos\phi = \frac{\text{Active Power (kW)}}{\text{Apparent Power (kVA)}}$$

- **Ideal value:** 1 (or unity)
- **Low power factor** causes:
    - Higher current
    - Increased copper losses
    - Reduced system efficiency
    - Poor voltage regulation

Hence, **power factor improvement** is necessary in electrical systems.

Methods of Power Factor Improvement:

1. Static Capacitors:
- Capacitors are connected **in parallel** with inductive loads (like motors).
- They **supply leading reactive power**, neutralizing lagging reactive power.
- **Advantages:**
    - Simple and economical
    - No moving parts, low maintenance
- **Application:** Used in offices, homes, small industries.

2. Synchronous Condensers:
- An **over-excited synchronous motor** runs without mechanical load and behaves like a **capacitor**.
- It delivers **leading reactive power** to the system.
- **Advantages:**
    - Power factor can be adjusted as required
    - Helps in voltage regulation
- **Used in:** Large substations, heavy industrial loads

3. Phase Advancers:
- Special devices used to improve p.f. of **induction motors**.
- Connected to the rotor circuit of the motor.
- They **provide excitation current** to the rotor externally.
- **Advantages:**
    - Used for large motors where capacitors aren't feasible.

4. Use of High Power Factor Equipment:
- Use **power factor corrected equipment**, such as **high-efficiency motors** and **LED lighting**, to minimize reactive power demand.
- **Example:** Energy-efficient 3-phase motors with built-in PFC circuits.

5. Automatic Power Factor Controllers (APFC Panels):

- These are intelligent systems that sense power factor in real-time and switch ON/OFF capacitor banks accordingly.
- Used in modern **industrial plants and commercial buildings**.

Conclusion:
Improving the power factor results in:
- Lower electricity bills
- Reduced losses in the system
- Improved voltage level
- Better system capacity utilization

Thus, **power factor improvement** is essential for the **economic and efficient** operation of electrical systems.

OR

Q.5 **(a)** Write safety precautions for electrical Applications **03**

Answer:

Electrical safety is essential to **prevent electric shocks, fires, and equipment damage** during the use of electrical appliances and systems. The following are important safety precautions to follow:

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1. Proper Insulation and Earthing:
- Ensure all wiring and appliances have **proper insulation**.
- Always use **proper earthing** to avoid leakage currents and shocks.

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2. Use of Correct Protective Devices:
- Install **fuses, MCBs, ELCBs**, and **surge protectors** to protect against overcurrent, short circuits, and leakage.

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3. Avoid Overloading:
- Do not connect too many appliances to a single socket or circuit.
- Overloading can cause overheating and fire.

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4. Dry Hands and Footwear:
- Always operate electrical switches and appliances with **dry hands** and preferably with **insulated footwear**.

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5. Periodic Maintenance and Inspection:
- Check wiring, plugs, and equipment regularly for any **wear, damage, or loose connections**.

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6. Turn Off Power Before Work:
- Always **switch off the main supply** before repairing or touching any electrical installation.

(b) Compute the monthly energy charges for an air conditioner having Power consumption of 3 kW and daily uses 10 hours. Energy charges Rs. 5 per unit **04**

Answer:

Given:
- Power consumption = 3 kW
- Daily usage = 10 hours
- Energy charges = Rs. 5 per unit
- 1 unit = 1 kWh
- Assume 30 days in a month

Step 1: Daily Energy Consumption

$$\text{Daily Energy (kWh)}=\text{Power (kW)}\times\text{Time (hours)}$$
$$3kW\times10hours=30kWh \text{ (units)}$$

Step 2: Monthly Energy Consumption

$$\text{Monthly Energy}=30\text{ units/day}\times30\text{ days}=900\text{ units}$$

Step 3: Monthly Energy Charges

$$\text{Total Charges}=900\text{ units}\times\text{Rs.}5/\text{unit}=\text{Rs. }4500$$

Final Answer:

Monthly Energy Charges = Rs. 4500

(c) Classify different types Earthing and explain any one in detail. **07**

Answer:

Classification of Different Types of Earthing:
Earthing is the process of connecting the non-current carrying parts of the electrical system to the earth to ensure safety. The main types of earthing are:

1. **Plate Earthing**
2. **Pipe Earthing**
3. **Rod Earthing**
4. **Strip or Wire Earthing**
5. **Earthing through Water Mains** *(not preferred nowadays)*

Explanation of One Type in Detail: (Pipe Earthing)
1. Pipe Earthing:
This is the **most commonly used method** of earthing, especially for domestic and industrial installations due to its effectiveness and low cost.

Construction:

- A **galvanized iron (GI) pipe** of diameter 38 mm and length about 2.5 to 3 meters is vertically placed into the earth pit.
- The pipe has **holes drilled** along its length to allow moisture to enter.
- The earth pit is about **3 meters deep** and filled with **alternate layers** of **charcoal** and **salt** (each about 15 cm thick).
- A **GI strip** or wire is connected at the top of the pipe and brought above ground to connect to electrical installations.
- A **funnel** with a mesh is provided at the top of the pipe to **pour water** periodically to maintain moisture level

Advantages of Pipe Earthing:

- Suitable for **high soil resistivity** areas.
- **Efficient and long-lasting**
- **Low maintenance** if water is poured periodically

Conclusion:
Among various earthing methods, **pipe earthing** is widely used due to its **simplicity, cost-effectiveness, and good conductivity**. Proper earthing ensures safety of both human life and electrical equipment.

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