GUJARAT TECHNOLOGICAL UNIVERSITY
BE- SEMESTER– PAPER SOLUTION – SUMMER 2024

Subject Name & Code:
Basic Electrical Engineering- 3110005

Marks

Q.1 (a) Define the following terms related to Electrical Circuits. **03**
1. Branch 2. Node or Junction point 3. Mesh or Loop

Answer:

1. Branch:
A **branch** is any part of an electrical circuit that **contains a single circuit element** like a resistor, inductor, capacitor, or voltage/current source.
It represents a **path for the flow of current** between two junctions.
Example: A resistor connected between two nodes forms one branch.

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2. Node (or Junction Point):
A **node** is a point in a circuit where **two or more circuit elements are connected**.
It is a common connection point for current to divide or combine.
Note: All terminals connected by a perfect conductor (zero resistance) are considered one node.

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3. Mesh or Loop:
A **loop** is any **closed path** in a circuit through which current can flow.
A **mesh** is a special type of loop that **does not contain any other loop within it**.
Example: In a simple circuit with three resistors connected in a triangle, each closed triangle is a loop, and each individual triangle without inner loops is called a mesh.

Conclusion:
Branches, nodes, and loops are the fundamental building blocks of any electrical network and are essential for circuit analysis using **Kirchhoff's Laws**.

(b) A 100 W,230 V lamp is connected in series with a 50W, 150 V lamp across 250 V supply mains. Calculate Voltage across each lamp. **04**

Answer:

Given:
- Lamp 1: P1=100 W, V1=230 V
- Lamp 2: P2=50 W, V2=150 V
- Supply voltage = 250 V
- Connection: **Series**

✅ **Step 1: Calculate Resistance of Each Lamp**
From the formula:

$$R = \frac{V^2}{P}$$

- For Lamp 1:

$$R_1 = \frac{230^2}{100} = \frac{52900}{100} = 529\,\Omega$$

- For Lamp 2:

$$R_2 = \frac{150^2}{50} = \frac{22500}{50} = 450\,\Omega$$

✅ **Step 2: Total Resistance in Series**

Rtotal=R1+R2=529+450=979 Ω

✅ **Step 3: Total Current in Circuit**

$$I = \frac{V_{supply}}{R_{total}} = \frac{250}{979} = 0.2553\text{ A}$$

✅ **Step 4: Voltage Across Each Lamp**

- Voltage across Lamp 1:
  V1′=I×R1=0.2553×529=135.1 V
- Voltage across Lamp 2:
  V2′=I×R2=0.2553×450=114.9 V

✅ **Final Answer:**

- **Voltage across 100W, 230V lamp** = 135.1 V
- **Voltage across 50W, 150V lamp** = 114.9 V

(c) Explain Superposition theorem with suitable example. **07**

Answer:

Superposition Theorem:
Statement:
In a linear, bilateral electrical network containing more than one independent source, the response (current or voltage) in any element of the circuit is equal to the algebraic sum of the responses caused by each independent source acting alone, while all other independent sources are replaced by their internal resistances.

- **Voltage sources** are replaced by **short circuits**.
- **Current sources** are replaced by **open circuits**.

Conditions for Applying Superposition Theorem:

- The circuit must be **linear** and **bilateral**.
- The theorem is applicable to both **AC** and **DC** networks.
- It is used to determine either **current** or **voltage**, not power.

Steps to Apply the Superposition Theorem:

1. Select one independent source and turn off all others:
   - Replace voltage sources with **short circuit**.
   - Replace current sources with **open circuit**.
2. Calculate the desired response (voltage or current) due to this one source.
3. Repeat the above step for each independent source.
4. **Add all individual responses algebraically** to find the total response.

Example:

Consider a simple circuit:

- A 10 V battery and a 5 V battery connected in a circuit with three resistors.
- **R_1 = 2 Ω**, **R_2 = 4 Ω**, and **R_3 = 6 Ω**.
- The 10 V battery is connected in series with R_1.
- The 5 V battery is connected in series with R_2.
- R_3 connects the two paths and current through R_3 is to be found.

Step 1: Consider only 10 V source

- Replace 5 V battery with a **short circuit**.
- Solve the circuit using any method (Ohm's Law, KVL, or mesh).

Step 2: Consider only 5 V source

- Replace 10 V battery with a **short circuit**.
- Again solve the circuit for current through R_3.

Step 3: Add the individual currents

- **Total current through $R_3 = I_1 + I_2$**

(For actual numerical example, values can be substituted and solved step-by-step.)

Conclusion:

The **Superposition Theorem** simplifies the analysis of electrical circuits with multiple sources by breaking them into simpler single-source problems. It is a fundamental tool in circuit analysis, especially in networks with both AC and DC sources.

Q.2 (a) A R-L-C series circuit consists of R=10-ohm, L= 0.1 H and C= 50 µF. Find 1. Impedance 2. Current and 3. Active power, when it is connected to a a.c. source of 230V,50Hz. **03**

Answer:

Given:

- R=10 Ω
- L=0.1 H
- C=50 µF=50×10−6 F
- V=230 V
- f=50 Hz

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1. Impedance (Z):

First, calculate the **inductive reactance** X_L:

$$X_L = 2\pi fL = 2 \times \pi \times 50 \times 0.1 = 31.42\ \Omega$$

Then, calculate the **capacitive reactance** X_C:

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2 \times \pi \times 50 \times 50 \times 10^{-6}} = 63.66\ \Omega$$

Now, calculate **net reactance (X):**

$$X = X_L - X_C = 31.42 - 63.66 = -32.24\ \Omega$$

Now, calculate total **impedance (Z):**

$$Z = \sqrt{R^2 + X^2} = \sqrt{10^2 + (-32.24)^2} = \sqrt{100 + 1039.4} = \sqrt{1139.4} \approx 33.74\ \Omega$$

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2. Current (I):

$$I = \frac{V}{Z} = \frac{230}{33.74} \approx 6.82\ A$$

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3. Active Power (P):
Active power is given by:

P=V·I·cosϕ

First, find the **power factor cosϕ**:

$$\cos\phi = \frac{R}{Z} = \frac{10}{33.74} \approx 0.296$$

Now calculate power:

P=230×6.82×0.296≈463.5 W

Final Answers:
1. **Impedance (Z)** = **33.74 Ω**
2. **Current (I)** = **6.82 A**
3. **Active Power (P)** = **463.5 W**

(b) Draw the voltage and current waveforms of R-L and R-C series circuits. **04**

Answer:

In **AC circuits**, the **phase relationship** between voltage and current depends on the presence of resistive (R), inductive (L), or capacitive (C) elements.

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1. R–L Series Circuit:
- Contains a resistor (R) and inductor (L) connected in series.
- In this circuit, the **current lags the voltage** by a phase angle ϕ\phiϕ.

2. R–C Series Circuit:
- Contains a resistor (R) and capacitor (C) in series.
- In this circuit, the **current leads the voltage** by a phase angle ϕ\phiϕ.

(c) Derive the equation of three equivalent star connected resistances in terms of delta connected resistances. **07**

Answer:

Introduction:
Delta (Δ) and Star (Y) are two common methods of connecting three resistances in three-phase systems. These configurations can be converted into each other for simplification during network analysis.

Given:
Let the three delta-connected resistances be:

- RAB=R1
- RBC=R2
- RCA=R3

We need to convert these into equivalent star-connected resistances:

- RA, connected to node A
- RB, connected to node B
- RC, connected to node C

Objective:
Find the values of RA,RB,RC in terms of R1,R2,R3.

Derivation:
In the star connection, each resistance is connected between one terminal and the common star point. To find the star resistances, we use the following principle:
Each star resistance is equal to the **product of the two adjacent delta resistances divided by the sum of all delta resistances**.

Star Equivalent Resistances:

1. **For R_A:**
$$R_A = \frac{R_1 \cdot R_3}{R_1 + R_2 + R_3}$$
2. **For R_B:**
$$R_B = \frac{R_1 \cdot R_2}{R_1 + R_2 + R_3}$$
3. **For R_C:**
$$R_C = \frac{R_2 \cdot R_3}{R_1 + R_2 + R_3}$$

Explanation:

- The conversion preserves the impedance between any two terminals.
- The star network draws the same line currents and has the same terminal resistances as the original delta network.

Diagram:
(Draw both Delta and Star configurations sharing the same three nodes A, B, and C.)

- Label delta resistances as R1,R2,R3
- Label star resistances as RA,RB,RC

Conclusion:
The **star equivalent resistances** in terms of delta resistances are:

$$R_A = \frac{R_1 R_3}{R_1 + R_2 + R_3}, \quad R_B = \frac{R_1 R_2}{R_1 + R_2 + R_3}, \quad R_C = \frac{R_2 R_3}{R_1 + R_2 + R_3}$$

This relationship is useful in converting complex 3-phase circuits for simplified analysis.

OR

(c) Using Thevenin's theorem find current in branch BD of the network shown in Fig. 1 **07**

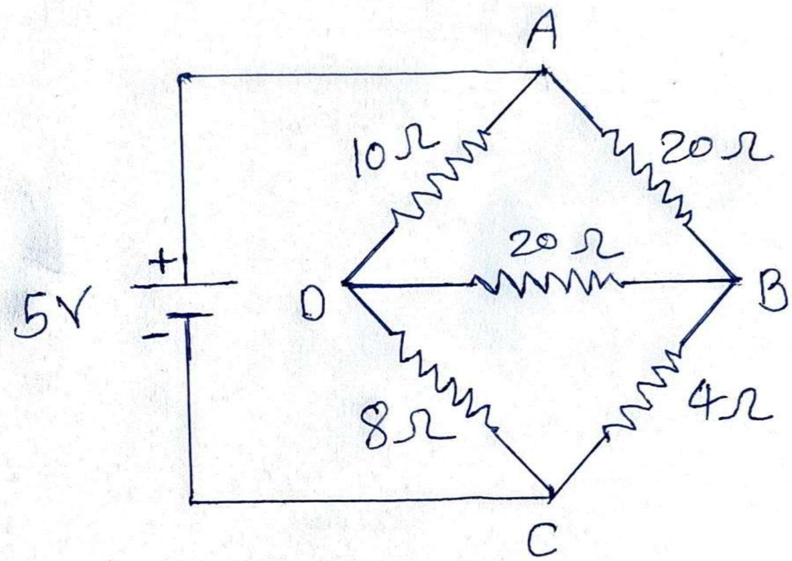

Fig: 1

Answer:

Given:

- Voltage source: 5 V
- Resistor network: as shown in the figure
- We need to find the **current through resistor BD (i.e., 20 Ω)** using **Thevenin's theorem**.

Step 1: Identify the branch of interest
We need current through **BD**, so:

- **Remove resistor BD (20 Ω)** temporarily from the circuit.
- We will now find the **Thevenin's equivalent across terminals B and D** (where BD was connected).

Step 2: Find Thevenin's Voltage (V_{th}) across B and D

- To find **V_{th}**, calculate the **open-circuit voltage** between terminals B and D.

Redraw the network:
Without BD, the circuit becomes two voltage dividers:

- Upper branch: O → A → B
- Lower branch: O → C → B

Apply **voltage division**:
Resistance in upper path:

- O → A: 10 Ω
- A → B: 20 Ω
- Total: 10 + 20 = 30 Ω

Resistance in lower path:

- O → C: 8 Ω
- C → B: 4 Ω
- Total: 8 + 4 = 12 Ω

Total parallel resistance between O and B:

Rupper = 30 Ω, Rlower = 12 Ω

This acts as two parallel paths powered by 5V at node O. Let's calculate voltage at point B through each path and then subtract to get **V_{BD}**.

Voltage at Point B via Upper Path (through A):

$$V_{B1} = V_O - \text{Drop across } 10\Omega \text{ and } 20\Omega = 5V \times \frac{20}{10+20} = 5 \times \frac{20}{30} = \mathbf{3.33\ V}$$

Voltage at Point D via Lower Path (through C):

$$V_{D1} = 5V \times \frac{4}{8+4} = 5 \times \frac{4}{12} = \mathbf{1.67\ V}$$

Now,

$$V_{BD} = V_B - V_D = 3.33\,V - 1.67\,V = \mathbf{1.66\ V}$$

This is the **Thevenin Voltage V_{th} = 1.66 V**

Step 3: Find Thevenin's Resistance (R_{th})

To find **R_{th}**, follow this procedure:

- **Remove the 20 Ω resistor** (BD)
- **Short the voltage source (replace 5V source with a wire)**
- Find equivalent resistance between terminals **B and D**

Path 1 (B to O to A to D):

- B → A: 20 Ω
- A → O: 10 Ω
- O → C: 8 Ω
- C → D: 4 Ω

But we analyze combinations more simply:

- From B: two resistors in series: 20 Ω (BA) + 10 Ω (AO) = 30 Ω
- From D: 4 Ω (DC) + 8 Ω (CO) = 12 Ω

Now, both 30 Ω and 12 Ω are **in parallel across BO-DO**:

So,

$$R_{th} = R_{BD} = \frac{30 \times 12}{30 + 12} = \frac{360}{42} = \mathbf{8.57\ \Omega}$$

Step 4: Connect the Thevenin Equivalent Circuit

- Now we replace the network between B and D with:
    - A voltage source **V_{th} = 1.66 V**
    - Series resistance **R_{th} = 8.57 Ω**
    - And connect the original 20 Ω resistor (BD) across it.

Step 5: Find the Current in BD using Ohm's Law

The total resistance = R_{th} + R_{BD}

$$R_{\text{total}} = 8.57 + 20 = 28.57\,\Omega$$

$$I_{BD} = \frac{V_{th}}{R_{\text{total}}} = \frac{1.66}{28.57} = \mathbf{0.0581\ A}$$

✅ **Final Answer:**

IBD=0.0581 A or 58.1 Ma

Q.3 **(a)** Define the following terms in connection with A.C. wave forms. **03**

1. Time period 2. R.M.S. Value 3. Average Value

Answer:

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

$$T=1/f$$

Where fff is the frequency in hertz (Hz).
For example, if frequency is 50 Hz, then T=1/50=0.02 s.

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2. R.M.S. Value (Root Mean Square Value):
R.M.S. value of an A.C. waveform is the **equivalent steady (DC) value** of current or voltage that would produce the **same heating effect** in a resistor.
For a sinusoidal waveform:

$$I_{rms} = \frac{I_m}{\sqrt{2}}, \quad V_{rms} = \frac{V_m}{\sqrt{2}}$$

Where Im and Vm are the peak values.

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3. Average Value:
The average value of an A.C. waveform is the **average of all instantaneous values** over **one half cycle** (since over a full cycle, the net average is zero).
For a sinusoidal waveform:

$$I_{avg} = \frac{2I_m}{\pi}, \quad V_{avg} = \frac{2V_m}{\pi}$$

Conclusion:
These values help in understanding and comparing A.C. quantities with D.C. equivalents in terms of power and energy.

(b) Three currents are represented by: $i_1 = 10 \sin \omega t$, $i_2 = 20 \sin (\omega t - \pi/6)$ and $i_3 = 30 \sin (\omega t + \pi/4)$. Find magnitude and phase angle of resultant current. **04**

Answer:

Step 1: Express each current in phasor (vector) form
Let's convert all sine functions to **phasors (complex form)**:

- $i1=10\sin(\omega t)=10\angle 0^\circ$
- $i2=20\sin(\omega t-\pi/6)=20\angle -30^\circ$
- $i3=30\sin(\omega t+\pi/4)=30\angle +45^\circ$

✅ **Step 2: Convert each phasor to rectangular form**

Use:

$$A\angle\theta = A\cos\theta + jA\sin\theta$$

- $i_1 = 10\angle 0^\circ = 10 + j0$
- $i_2 = 20\angle -30^\circ = 20\cos(-30^\circ) + j20\sin(-30^\circ)$

$$= 20 \times 0.866 - j20 \times 0.5 = 17.32 - j10$$

- $i_3 = 30\angle +45^\circ = 30\cos(45^\circ) + j30\sin(45^\circ)$

$$= 30 \times 0.707 + j30 \times 0.707 = 21.21 + j21.21$$

✅ **Step 3: Add all phasors**
Add real and imaginary parts:

- **Real Part:**

=10+17.32+21.21=48.53

- **Imaginary Part:**

=0−10+21.21=11.21

So the resultant phasor:

I=48.53+j11.21

✅ **Step 4: Find Magnitude of Resultant Current**

$$|I| = \sqrt{(48.53)^2 + (11.21)^2} = \sqrt{2356.5 + 125.7} = \sqrt{2482.2} \approx 49.82 \text{ A}$$

✅ **Step 5: Find Phase Angle**

$$\phi = \tan^{-1}\left(\frac{11.21}{48.53}\right) = \tan^{-1}(0.231) \approx 13^\circ$$

✅ **Final Answer:**

- **Magnitude of resultant current** = 49.82 A
- **Phase angle** = 13∘ leading

(c) Prove that current through pure inductor is always lagging by 90° to its voltage and power consumed is zero with necessary waveform and phasor diagram. **07**

Answer:

1. Introduction:
An inductor is a passive electrical component that opposes changes in current. When an AC voltage is applied to a pure inductor (with no resistance), the current **lags behind the voltage by 90 degrees**. Also, the average power consumed in a purely inductive circuit is **zero**.

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2. Circuit Diagram:

- Draw a simple circuit with:
  - AC voltage source.
  - Pure inductor L.
  - Current i(t) flowing through the inductor.

3. Voltage-Current Relationship in Inductor:

From the inductor's fundamental law:

$$v(t) = L\frac{di(t)}{dt}$$

Assume the applied AC voltage is:

$$v(t) = V_m \sin(\omega t)$$

Now integrate to find the current:

$$i(t) = \frac{1}{L}\int v(t)\,dt = \frac{1}{L}\int V_m \sin(\omega t)\,dt$$

$$i(t) = -\frac{V_m}{\omega L}\cos(\omega t)$$

$$i(t) = \frac{V_m}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right)$$

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4. Conclusion from Equation:

The current i(t) **lags the voltage v(t) by 90°** (or 2/π radians). This proves the phase difference.

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5. Phasor Diagram:

- Draw voltage phasor V as reference.
- Draw current phasor I 90° **behind** the voltage phasor.
- Indicate the lag clearly.

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6. Power Consumed by Pure Inductor:

Instantaneous Power:

Instantaneous Power:

$$p(t) = v(t)\cdot i(t) = V_m \sin(\omega t)\cdot \frac{V_m}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right)$$

$$p(t) = \frac{V_m^2}{\omega L}\sin(\omega t)\cdot(-\cos(\omega t)) = -\frac{V_m^2}{\omega L}\sin(\omega t)\cos(\omega t)$$

Use identity:

$$\sin(2x) = 2\sin(x)\cos(x) \Rightarrow \sin(x)\cos(x) = \frac{1}{2}\sin(2x)$$

So:

$$p(t) = -\frac{V_m^2}{2\omega L}\sin(2\omega t)$$

Average Power over one cycle:

Since sin(2ωt) is a sinusoidal function, its average value over a complete cycle is zero.

Average power=0

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7. Waveform:

- Draw **voltage waveform** as a sine wave.
- Draw **current waveform** as a sine wave lagging 90° behind the voltage.
- Label time axis and amplitude.

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8. Final Conclusion:

- In a pure inductive AC circuit, **current lags voltage by 90°**.
- The **average power consumed is zero**.
- Energy is **alternately stored and returned** to the supply.

OR

Q.3 **(a)** Write the characteristics of Series Resonant Circuit. **03**

Answer:

A **series resonant circuit** is an R-L-C circuit in which a resistor (R), inductor (L), and capacitor (C) are connected in **series** across an alternating voltage source. Resonance occurs when the **inductive reactance (XL)** is equal to the **capacitive reactance (XC)** at a specific frequency called the **resonant frequency (fr)**.

Characteristics of Series Resonant Circuit:

1. **Resonant Frequency:**

   At resonance,

   $$X_L = X_C \quad \text{or} \quad 2\pi f_r L = \frac{1}{2\pi f_r C}$$

   Hence, the **resonant frequency** is:

   $$f_r = \frac{1}{2\pi\sqrt{LC}}$$

2. **Minimum Impedance:**
   At resonance, the impedance Z of the circuit is minimum and equal to the resistance R only.
   $$Z=R$$
3. **Maximum Current:**
   Since the impedance is minimum, the **current is maximum** at resonance.
   $$I=V/R$$
4. **Unity Power Factor:**
   At resonance, the circuit behaves like a **purely resistive** circuit. Hence,
   Power Factor (p.f.)=1
5. **Voltage Magnification:**
   The voltages across the inductor and capacitor are individually large, though they cancel each other out.
   This is called **voltage magnification**.

(b) Give advantages and disadvantages of Two Wattmeter method. **04**

Answer:
Two Wattmeter Method:
It is a widely used technique to measure **total power** in a **3-phase balanced or unbalanced system** using **two wattmeters**.

Advantages of Two Wattmeter Method:

1. **Applicable for both balanced and unbalanced loads.**
   – Works even when the load is not symmetrical.
2. **Can measure power in a 3-phase, 3-wire system.**
   – No need for neutral wire connection.
3. **Can measure total power with just two wattmeters.**
   – Economical and convenient setup.
4. **Power factor of the load can also be determined.**
   – Angle between power factor can be calculated using readings.

Disadvantages of Two Wattmeter Method:

1. **Less accurate at low power factor.**
   – One wattmeter may show negative or small readings, leading to errors.
2. **Difficult to interpret when one wattmeter shows negative value.**
   – Reversal of coil connection is required for correct reading.
3. **Not suitable for 4-wire systems directly.**
   – Cannot be used without modification in systems with neutral wire.
4. **Instrument errors affect accuracy.**
   – Errors in wattmeters affect total power reading directly.

Conclusion:

The two wattmeter method is highly **practical and efficient** for measuring power in 3-phase systems, especially in **industrial settings**, though it needs care in interpretation at low power factor

(c) Derive the relationship of voltages and currents for Star connection in 3-phase a.c. circuit. **07**

Answer:

1. Introduction:

In a **star (Y)** connection, one end of each of the three windings is connected together to form the **neutral point (N)**. The other ends are connected to the **line conductors**. This type of connection is common in power systems for both generation and distribution.

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2. Notations:

Let:

- VL = Line Voltage
- Vph = Phase Voltage
- IL = Line Current
- Iph = Phase Current

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3. Star Connection Diagram:

- Draw three windings connected at a common neutral point.
- Name the phases R, Y, B.
- Connect line wires to outer ends of each winding.
- Show line voltages between R-Y, Y-B, B-R.
- Show phase voltages between each line and neutral (N).

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4. Voltage Relationship in Star Connection:

Line voltage is the voltage between any two lines:

Let's calculate V_{RY}:

$$V_{RY} = V_{RN} - V_{YN}$$

In a balanced system:

$$V_{RN} = V_{ph}\angle 0^\circ \quad \text{and} \quad V_{YN} = V_{ph}\angle -120^\circ$$

$$V_{RY} = V_{ph}\angle 0^\circ - V_{ph}\angle -120^\circ$$

Using vector subtraction:

$$|V_{RY}| = \sqrt{3} \cdot V_{ph} \quad \text{at an angle of} \quad 30^\circ$$

Hence,

$$\boxed{V_L = \sqrt{3} \cdot V_{ph}} \quad \text{and} \quad \boxed{\text{Line voltage leads phase voltage by } 30^\circ}$$

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5. Current Relationship in Star Connection:
In star connection, each line conductor is connected to one phase winding directly, so:

IL=Iph

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6. Summary of Relationships:

Quantity	**Relationship**
Line Voltage	VL=-3·Vph
Line Current	IL=Iph

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7. Phasor Diagram:
- Plot three phase voltages VRN,VYN,VBN at 120° intervals.
- Then plot line voltages VRY,VYB,VBR as the vector difference between corresponding phase voltages.
- Clearly show that line voltage is √3 times phase voltage and leads it by 30°.

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8. Conclusion:
In a **balanced 3-phase star connection**:
- Line voltage is √3 times the phase voltage and leads it by 30°.
- Line current is equal to phase current.

These relationships are fundamental in analyzing and designing 3-phase power systems.

Q.4 **(a)** Derive E.M.F. equation of single-phase transformer. **03**

Answer:

Let,
- ϕm = Maximum magnetic 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 in the transformer core varies sinusoidally.
So,

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

The **rms value of induced emf** in a winding is given by **Faraday's law** of electromagnetic induction:

$$E=4.44fN\phi m$$

Therefore,

- **Primary emf (E_1):**

$$E1=4.44fN1\phi m$$

- **Secondary emf (E_2):**

$$E2=4.44fN2\phi m$$

Conclusion:
The **E.M.F. equation of a transformer** is:

$$E=4.44fN\phi m$$

where E is the rms value of the induced emf, N is the number of turns, f is the frequency, and ϕm is the maximum flux.

(b) Compare core type and shell type transformers. **04**

Answer:

Point of Comparison	Core Type Transformer	Shell Type Transformer
1. **Construction**	Windings surround the core limbs	Core surrounds the windings (winding in the center limb)
2. **Magnetic Flux Path**	Single magnetic circuit	Double magnetic circuit
3. **Size and Shape**	Compact and taller in shape	More compact and shorter
4. **Winding Arrangement**	Cylindrical windings placed on two limbs	Both windings placed on the central limb
5. **Ease of Insulation**	Easier to insulate and cool	Slightly more complex to insulate
6. **Cooling**	Better air circulation for natural cooling	Lesser cooling efficiency
7. **Mechanical Strength**	Lower mechanical protection to windings	Windings are well protected inside the core
8. **Usage**	Common in distribution transformers	Used in low-voltage and high-current applications

(c) Describe an auto transformer with its advantages, limitations and applications. **07**

Answer:

1. Definition:
An **autotransformer** is a type of transformer that has **only one winding**, which is common to both the **primary and secondary sides**. Instead of two separate windings as in a conventional transformer, part of the winding is shared for input and output.

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2. Construction:

- A single continuous winding is wound on a laminated magnetic core.
- This winding is tapped at a certain point to provide the required voltage.
- The portion of the winding between the input terminals is the **primary**.
- The portion between one end and the tap point serves as the **secondary**.

3. Working Principle:
The autotransformer works on the **principle of electromagnetic induction**. When alternating current flows through the primary winding, it creates a varying magnetic field in the core. This varying magnetic flux links the secondary winding (which is part of the same coil), inducing a voltage across it.
There are **two modes of power transfer**:
1. **Inductive transfer** – through mutual induction.
2. **Conductive transfer** – through direct electrical connection.

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4. Diagram:
(Draw a simple schematic showing a single winding with taps at primary and secondary terminals. Label core, input voltage V1V_1V1, output voltage V2V_2V2, and common winding.)

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5. Advantages of Autotransformer:
1. **Smaller size –** requires less copper and iron compared to a two-winding transformer.
2. **More efficient** – fewer losses due to less winding resistance.
3. **Better voltage regulation** – because of lower leakage reactance.
4. **Economical** – cheaper when the voltage ratio is close to 1.

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6. Limitations of Autotransformer:
1. **No electrical isolation** between primary and secondary – can be unsafe in some applications.
2. **Limited use** when large voltage difference is required.
3. **Not suitable** for high-voltage applications due to insulation issues.

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7. Applications of Autotransformer:
1. **Starting induction motors** with reduced voltage.
2. **Voltage step-up or step-down** in laboratories and workshops.
3. **Stabilizers** and **boosters** for voltage correction.
4. **Railway electrification systems** (traction).

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8. Conclusion:
Autotransformers are **efficient, compact, and cost-effective** for applications requiring **small voltage differences**. However, the lack of electrical isolation limits their use in sensitive and high-voltage environments.

OR

Q.4 **(a)** Give classification of D.C. Motors. **03**

Answer:

DC motors are classified based on the **type of field excitation** used to produce the magnetic field. The main classification is as follows:

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1. Separately Excited D.C. Motor:
- In this type, the **field winding is powered by an independent external source**.
- Armature and field circuits are separate.

2. Self-Excited D.C. Motor:

- In this type, the **field winding is energized by the armature itself**.
- It is further classified into:

(a) Series D.C. Motor:

- The **field winding is connected in series** with the armature.
- Suitable for applications requiring high starting torque.

(b) Shunt D.C. Motor:

- The **field winding is connected in parallel** (shunt) with the armature.
- Known for constant speed operation.

(c) Compound D.C. Motor:

- Contains **both series and shunt field windings**.
- Further divided into:
    - **Cumulative Compound Motor:** Series and shunt field assist each other.
    - **Differential Compound Motor:** Series field opposes the shunt field.

Conclusion:
DC motors are mainly classified into **separately excited** and **self-excited** types. Self-excited motors include **series**, **shunt**, and **compound** motors, each suited for specific applications.

(b) Prepare list of different parts of D.C. machine and explain any one part with figure. **04**

Answer:

◆ **Main Parts of a D.C. Machine:**

1. **Yoke**
2. **Field Poles**
3. **Field Windings**
4. **Armature Core**
5. **Armature Windings**
6. **Commutator**
7. **Brushes**
8. **Shaft**
9. **Bearings**
10. **End Covers**

Explanation of One Part: ***Commutator***

◆ **Commutator:**

- The **commutator** is a cylindrical structure made of **copper segments**, each insulated from the others by **mica**.
- It is mounted on the shaft and connected to the **armature winding**.
- Its function is to **convert the alternating voltage** generated in the armature winding into **direct voltage** across the brushes.
- In motors, it also ensures **unidirectional torque**.

(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) List the various safety devices used for domestic purpose. **03**

Answer:

The following **safety devices** are commonly used in domestic electrical installations to **protect people and appliances** from electrical faults:

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1. Fuse:

- A fuse is a **protective device** that melts and disconnects the circuit in case of **overcurrent or short circuit**.
- It prevents damage to appliances by breaking the circuit when current exceeds a safe limit.

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2. Miniature Circuit Breaker (MCB):

- An MCB is an **automatic switch** that trips and disconnects the circuit during overload or short circuit.
- It is **resettable**, unlike a fuse.

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3. Earth Leakage Circuit Breaker (ELCB) or Residual Current Circuit Breaker (RCCB):

- These devices detect **leakage current to earth** and disconnect the supply instantly to **prevent electric shocks**.

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4. Earthing (Grounding):

- Provides a **safe path for leakage current** to flow into the earth, preventing electric shocks.

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5. Surge Protector:

- Protects electronic devices from **voltage spikes** caused by lightning or switching surges.

Conclusion:
The use of devices like **fuses, MCBs, ELCBs, proper earthing, and surge protectors** ensures safety in domestic electrical systems by preventing accidents and equipment damage.

(b) Explain necessity of earthing. **04**

Answer:

◆ **Necessity of Earthing:**
Earthing is the process of connecting the metallic parts of an electrical installation (like the body of appliances or machinery) to the **ground (earth)**. It provides a low-resistance path for **fault current** to safely flow into the earth.

Importance and Necessity of Earthing:

1. **Protection of Human Life:**
   - Prevents electric shock by ensuring that exposed metal parts do not rise to dangerous voltages during a fault.
2. **Protection of Equipment:**
   - Safeguards electrical appliances and machines from damage due to voltage surges, lightning, or insulation failure.
3. **Maintains System Stability:**
   - Helps in maintaining a **stable voltage level** in the power system by discharging excessive current.
4. **Quick Operation of Protective Devices:**
   - Assures fast activation of circuit breakers or fuses during faults by allowing **fault current** to flow to the ground efficiently.
5. **Prevention of Fire Hazards:**
   - Reduces the risk of fire due to leakage current or short-circuits by providing a path to ground.

Conclusion:
Earthing is essential for **safety of people**, **protection of equipment**, and **reliable operation** of electrical systems. It is a fundamental practice in every residential, commercial, and industrial electrical installation.

(c) Explain different methods for 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)** What is MCCB? Where it is used? **03**

Answer:

MCCB (Moulded Case Circuit Breaker):
An **MCCB** is an **electromechanical device** used to protect an electrical circuit from **overload, short circuit, and earth faults**. It functions as an **automatic switch** that disconnects power when the current exceeds the rated value.

Key Features:

- Operates at **higher current ratings** than MCBs (typically from **100 A to 1000 A or more**).
- Can be **reset manually** after tripping.
- Provides **adjustable trip settings** for current and time delays.

Applications / Where It Is Used:

1. **Industrial and Commercial Electrical Panels** – for protecting heavy machinery and distribution boards.
2. **Large Power Distribution Systems** – where higher current and adjustable settings are required.
3. **Capacitor Banks, Generators, and Motor Protection** – to prevent equipment damage due to faults.
4. **Backup Protection** – in power systems where high fault levels may occur.

Conclusion:
MCCBs are essential protective devices used in **medium and high-power electrical circuits**, especially in **industrial and large commercial installations**, where they ensure safety and reliability under fault conditions

(b) State the advantages and applications of underground cables. **04**

Answer:

Advantages of Underground Cables:

1. **Improved Safety:**
   - No risk of electric shock due to exposed wires as cables are buried underground.
2. **Aesthetic Appeal:**
   - No visual clutter of overhead lines; preferred in urban and residential areas.
3. **Reliable Performance:**
   - Less affected by weather conditions like storms, rain, or lightning.
4. **Reduced Maintenance:**
   - Lower chances of faults due to external damage; thus, maintenance frequency is reduced.
5. **Longer Life Span:**
   - Underground cables are better protected from mechanical damage, hence longer durability.

Applications of Underground Cables:

1. **Urban Power Distribution:**
   - Used in cities where space is limited and visual pollution must be avoided.
2. **Railways and Airports:**
   - Ideal in areas where overhead lines may obstruct operations or pose hazards.
3. **Industrial Complexes:**
   - Used for safe and reliable internal power distribution.
4. **Defense and Sensitive Installations:**
   - Employed in military zones, data centers, or nuclear plants for added security and stealth.

Conclusion:
Underground cables are preferred in areas demanding **safety, reliability, and**

aesthetics, especially in **modern urban and critical infrastructure** settings.

(c) Calculate the electricity bill amount for a month of March, if 5 bulbs of 40 W for 5 h, 6 tube lights of 60 W for 5 h, a TV of 100 W for 6 h, a washing machine of 400 W for 2 h, a water pump of 0.5 HP for 30 minutes are used per day. The cost per unit is Rs 3.50. Consider 1 HP = 746 watts **07**

Answer:

1. Given:

- **Month:** March → 31 days
- **Electricity rate:** Rs 3.50 per unit (1 unit = 1 kWh)
- **1 HP = 746 W**

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2. Daily Energy Consumption:

Let us calculate the energy consumed by each appliance per day:

(a) 5 Bulbs of 40 W for 5 hours:

$$\text{Energy} = 5 \times 40 \times 5 = 1000 \text{ Wh} = 1.0 \text{ kWh}$$

(b) 6 Tube lights of 60 W for 5 hours:

$$\text{Energy} = 6 \times 60 \times 5 = 1800 \text{ Wh} = 1.8 \text{ kWh}$$

(c) 1 TV of 100 W for 6 hours:

$$\text{Energy} = 100 \times 6 = 600 \text{ Wh} = 0.6 \text{ kWh}$$

(d) Washing machine of 400 W for 2 hours:

$$\text{Energy} = 400 \times 2 = 800 \text{ Wh} = 0.8 \text{ kWh}$$

(e) Water pump of 0.5 HP for 0.5 hour:

$$0.5 \text{ HP} = 0.5 \times 746 = 373 \text{ W}$$
$$\text{Energy} = 373 \times 0.5 = 186.5 \text{ Wh} = 0.1865 \text{ kWh}$$

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4. **Total Daily Energy Consumption:**

$$\text{Total (per day)} = 1.0 + 1.8 + 0.6 + 0.8 + 0.1865 = 4.3865 \text{ kWh}$$

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5. **Monthly Energy Consumption (for March - 31 days):**

$$\text{Total energy} = 4.3865 \times 31 = 135.9815 \text{ kWh}$$

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5. Total Electricity Bill:

$$\text{Bill amount} = 135.9815 \times 3.50 = \text{Rs } 475.94$$

Final Answer:

Total electricity bill for the month of March = ₹ 475.94