SRN

# PES University, Bengaluru

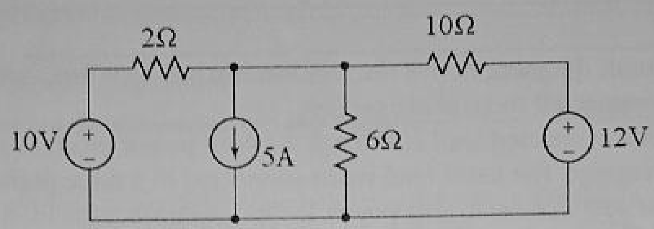
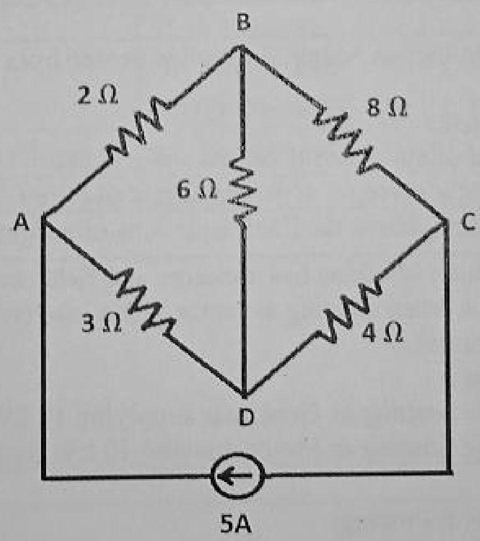
(Established under Karnataka Act No. 16 of 2013)

**UE20EE101**

## APRIL 2021: END SEMESTER ASSESSMENT (ESA) B TECH I SEMESTER

## UE20EE101 – Elements of Electrical Engineering

| Time: 3 Hrs | Answer All Questions | Max Marks: 100 |
|---|---|---|

| | | | |
|---|---|---|---|
| 1 | a) | Find the current in the 6 Ω resistor in the network shown using Superposition Theorem.<br><br> | 6M |
| | b) | With proper nomenclature, derive how a delta connected set of resistors is transformed to an equivalent star. | 6M |
| | c) | Find the magnitude and direction of current in the branch BD in the network shown below using Thevenin's Theorem.<br><br> | 8M |
| 2 | a) | A parallel RLC circuit has R = 23 Ω, L = 1 mH & C = 100 μF connected across 230 V, 50 Hz supply. Determine<br>i) Admittance of each branch<br>ii) Active power drawn | 4M |
| | b) | A series RLC circuit draws 400 W from a 200 V, 50 Hz supply. If the overall resistance is 4 Ω & the overall circuit behaves as inductive type, determine<br>i) Power factor of the network.<br>ii) Inductance in the network if capacitance is 1mF<br>iii) What must be the value of capacitance to bring the circuit into resonance? | 8M |

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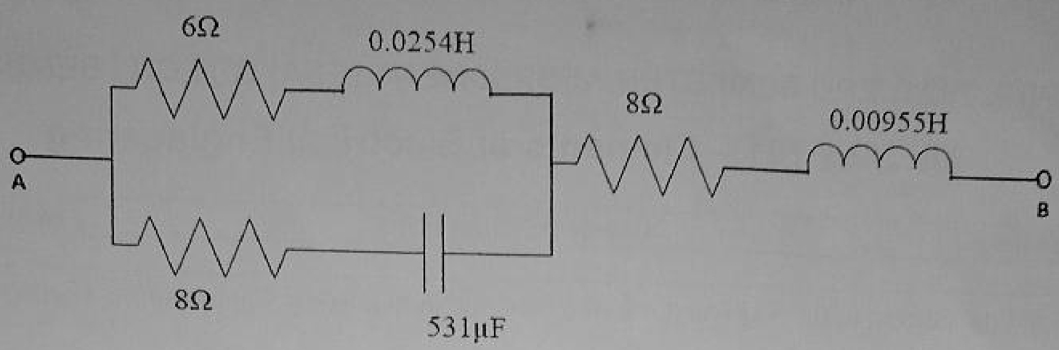
| | | | |
|---|---|---|---|
| | c) | In the circuit shown, what voltage of 50 Hz frequency is to be applied across A & B that will cause a current of 10 A to flow in the capacitor. Also draw the phasor diagram representing the circuit.   | 8M |
| 3 | a) | With a neat circuit diagram, derive the relationship between line voltage and phase voltage in a balanced star connected three phase system. | 6M |
| | b) | A balanced delta connected load consumes 4 kW of power when connected to a three phase, 415 V, 50 Hz supply. The same load when connected to a three phase 200 V, 50 Hz supply, draws a current of 5 A at a lagging power factor. Determine the load power factor and resistance and inductance per phase. | 6M |
| | c) | Determine the readings of the two wattmeters connected to measure the total power for a balanced delta-connected load, fed from a three phase, 400 V balanced supply with phase sequence as R-Y-B. The load impedance per phase is (6+j8) Ω. Also determine<br>i) Line and Phase currents<br>ii) Power factor of the Load<br>iii) Total Active, Reactive & Apparent Powers | 8M |
| 4 | a) | An 8 pole three phase Induction Motor is supplied power from 415 V, 50 Hz three phase supply. Determine<br>i) Synchronous speed<br>ii) Full load Speed of the motor if full load slip is 2%<br>iii) Frequency of rotor currents when running at 675 rpm. | 4M |
| | b) | With proper nomenclature, derive the EMF equations of a Transformer. | 6M |
| | c) | A 10 kW, 220 V, DC shunt Machine has armature and field resistances of 0.5Ω and 110 Ω respectively. It takes 4 A when running as motor on no load (when running light) at rated voltage and speed. Determine<br>i) Constant Losses<br>ii) Efficiency while running as Generator supplying 10 kW output<br>iii) Efficiency while running as Motor drawing 10 kW input | 10M |
| 5 | a) | Write a short note on the following:<br>i) RCCB<br>ii) Fuse<br>iii) Oil Pressure cables | 6M |
| | b) | The load connected across a single-phase AC supply consists of a heating load of 1.5 kW, a motor load of 2 kVA at a power factor 0.6 lag and a load of 2 kW at a power factor 0.8 lag. Calculate the total power drawn from the supply in kW & kVA and the overall power factor of the system.<br><br>What must be the KVAR rating of a capacitor to bring the power factor of the above system to unity? | 6M |

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c) The following table gives average consumption hours for various loads in a typical household: 8M

| S.No. | Name of the Appliance | Wattage | Average consumption hours per day |
|---|---|---|---|
| 1. | Four LED Bulbs | 20 W per bulb | 8 hours each |
| 2. | LED TV | 60 W | 6 hours |
| 3. | Air conditioner | 2000 W | 2 hours |
| 4. | Refrigerator | 100 W | 24 hours |
| 5. | Water Pump | 750 W | 30 minutes |
| 6. | 3 Ceiling Fans | 75 W per fan | 10 hours each |

Considering a 30 day month, Determine

i) the total number of units consumed in a month.

ii) Monthly bill for the above consumption units considering a domestic connection of 5 kW sanctioned load with the tariff details listed in a table below

| S.No. | Type of Charges | Tariff Details |
|---|---|---|
| 1. | Fixed Charges for sanctioned load | Rs. 70/- for first kW<br>Rs. 80/- for every additional kW |
| 2. | Energy Consumption Charges | 0 to 30 units ----- Rs. 4/- per unit<br>31 to 100 units ----- Rs. 5.45/- per unit<br>101 to 200 units ----- Rs. 7/- per unit<br>Above 200 units ----- Rs. 8.05/- per unit |
| 3. | Fuel Adjustment Charges | 8 paisa per unit |
| 4. | Tax only on Energy consumption charges | @ 9% |

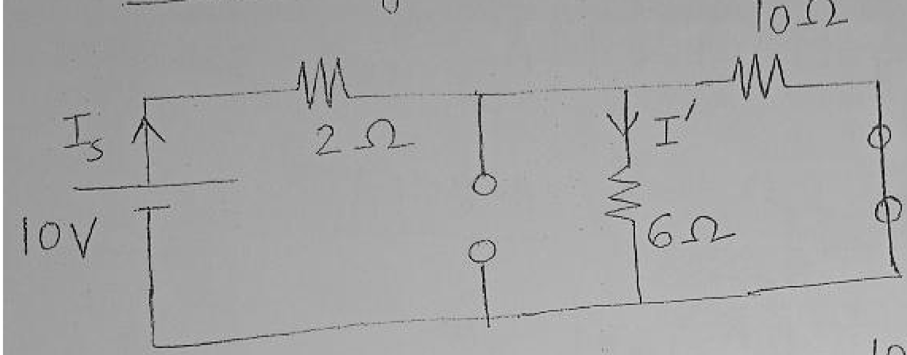
20EE101 – END SEMESTER ASSESSMENT – APRIL 2021

## Scheme & Solution



a)

with only 10V source active

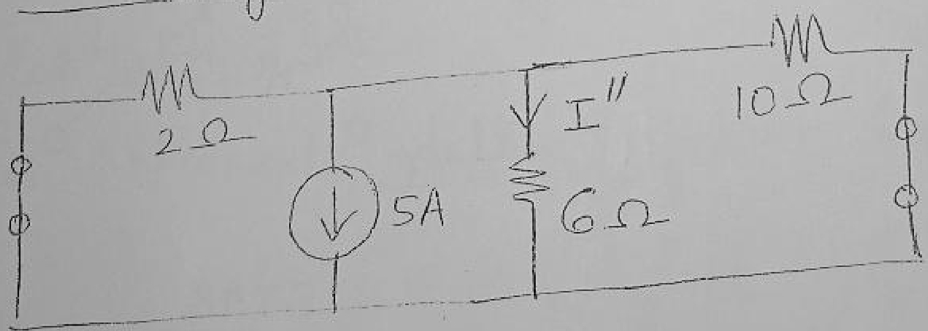



$R_{eq} = 5.75\,\Omega$ ; $I_s = \frac{10V}{5.75\,\Omega} = 1.74A$

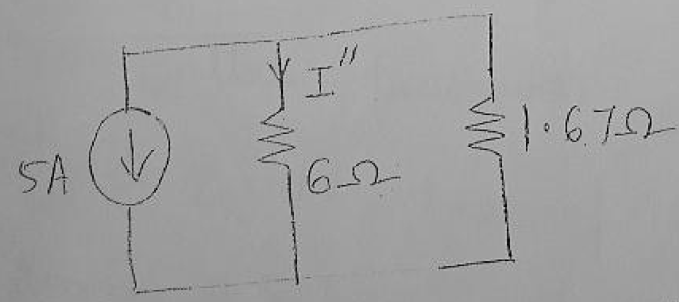
$\therefore I' = 1.74A * \frac{10\,\Omega}{16\,\Omega} = 1.087A$

[current Division]

with only 5A source active




$\simeq$

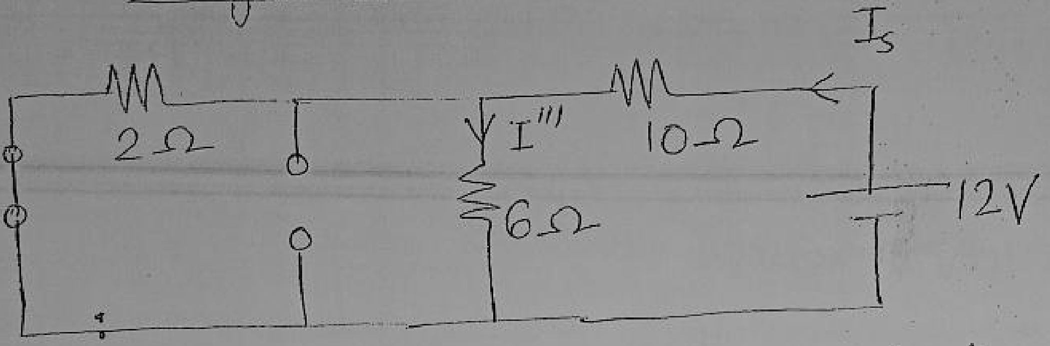



$\Rightarrow I'' = -5A * \frac{1.67}{7.67}$

$= -1.087A$

[current Division]

with only 12V source active



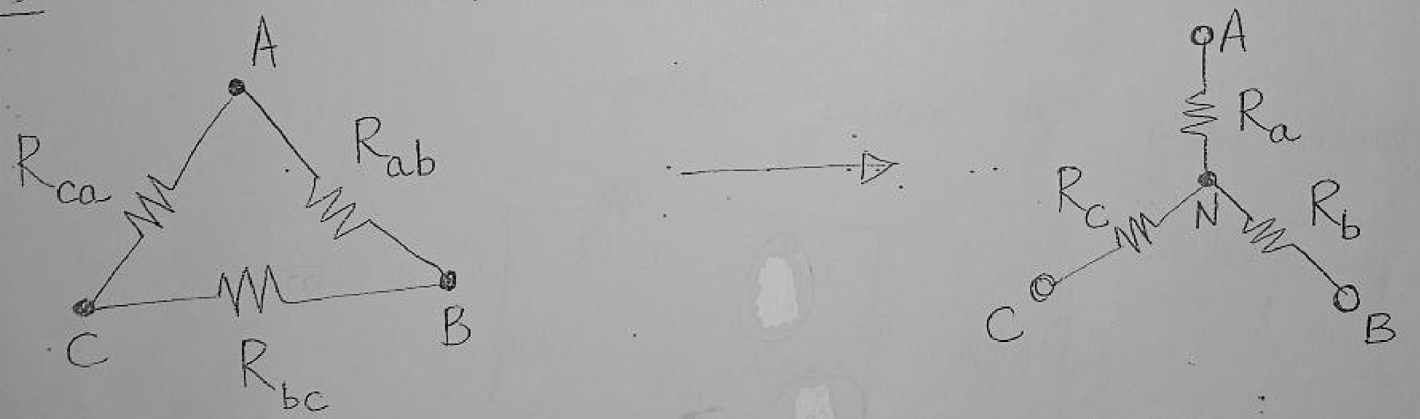

$$R_{eq} = 11.5\Omega \quad ; \quad I_s = 1.043A$$

$$I''' = 1.043A * \frac{2\Omega}{8\Omega} = \underline{0.261A}$$

By Superposition, $I = I' + I'' + I'''$

$$= \underline{\underline{0.261A}}$$

1 b)




DELTA

STAR

Let $R_{ab}$, $R_{bc}$ & $R_{ca}$ represent delta resistors

Let $R_a$, $R_b$ & $R_c$ represent Star resistors

Equivalent resistance between A & B terminals:

According to Delta : $R_{ab} \,//\, (R_{bc} + R_{ca})$

$[R \quad (R + R)] / (R + R + R)$

ording to Star : $R_a + R_b$

ince they are equivalent,

$$R_a + R_b = \frac{R_{ab}(R_{bc} + R_{ca})}{R_{ab} + R_{bc} + R_{ca}} \quad \text{— (1)}$$

imilarly,

$$R_b + R_c = \frac{R_{bc}(R_{ab} + R_{ca})}{R_{ab} + R_{bc} + R_{ca}} \quad \text{— (2)}$$

$$R_c + R_a = \frac{R_{ca}(R_{ab} + R_{bc})}{R_{ab} + R_{bc} + R_{ca}} \quad \text{— (3)}$$

$$\frac{) - (2) + (3)}{2} \Rightarrow R_a = \frac{R_{ab} R_{ca}}{R_{ab} + R_{bc} + R_{ca}} \quad \text{— (4)}$$

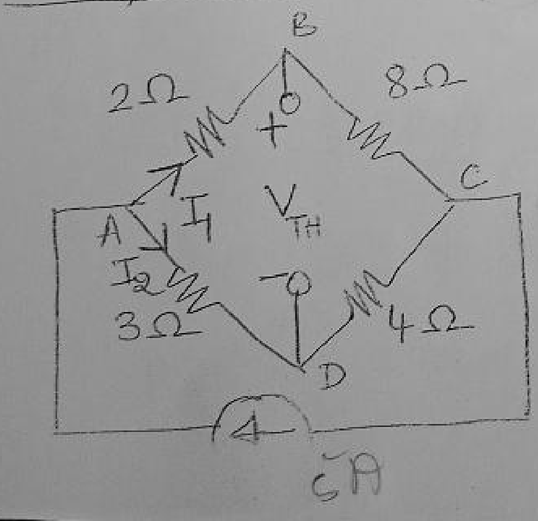
ilarly,

$$= \frac{R_{bc} R_{ab}}{R_{ab} + R_{bc} + R_{ca}} \quad \text{— (5)} \; ; \quad R_c = \frac{R_{ca} R_{bc}}{R_{ab} + R_{bc} + R_{ca}} \quad \text{— (6)}$$

(5), (6) represent delta to star transformation

)

To find $V_{TH}$ :




$$I_1 = 5A * \frac{7\Omega}{17\Omega}$$

$$= 2.059A$$

$$\Rightarrow I_2 = 5 - I_1$$

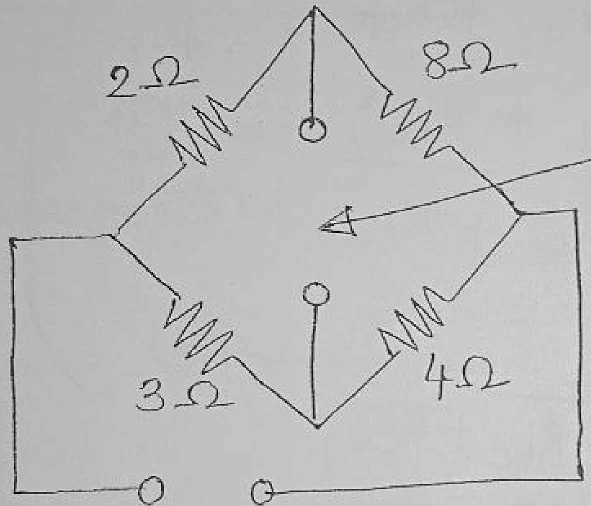
$$= 2.941 \text{ A}$$

KVL in the path ABDA

$$-2I_1 - V_{TH} + 3I_2 = 0$$

$$V_{TH} = 4.705\text{ V}$$

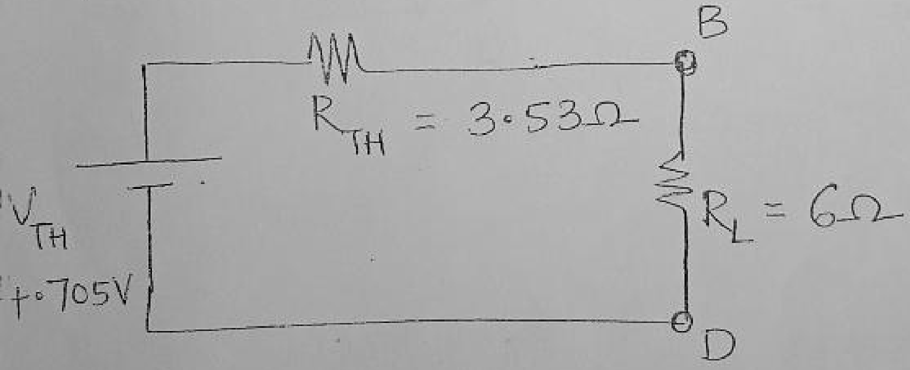
To find $R_{TH}$ :




$$R_{TH} = [2\Omega + 3\Omega] \parallel [8\Omega + 4\Omega]$$

$$= 3.53\,\Omega$$

Thevenin's Equivalent Circuit :




$$I_{6\Omega} = \frac{V_{TH}}{R_{TH} + R_L}$$

$$= 0.493\text{A}$$

Current in the branch BD is 0.493A & flows from B to D.

a) Parallel RLC Circuit

i) $Y_R = G = \frac{1}{R} = 0.0435 ℧$

$Y_L = -jB_L = -j3.183 ℧$

$Y_C = +jB_C = +j0.0314 ℧$

ii) Active Power drawn, $P = \frac{V^2}{R} = 2.3 KW$

2b) Series RLC Circuit

Given, $P = 400W$, $V = 200V$

$R = 4\Omega$

$P = I^2R \Rightarrow I = 10A$

$\Rightarrow |Z| = \frac{V}{I} = 20\Omega$

i) $PF = \frac{R}{|Z|} = 0.2$ Lag

ii) $X_T = \sqrt{Z^2 - R^2} = 19.59\Omega = X_L - X_C$

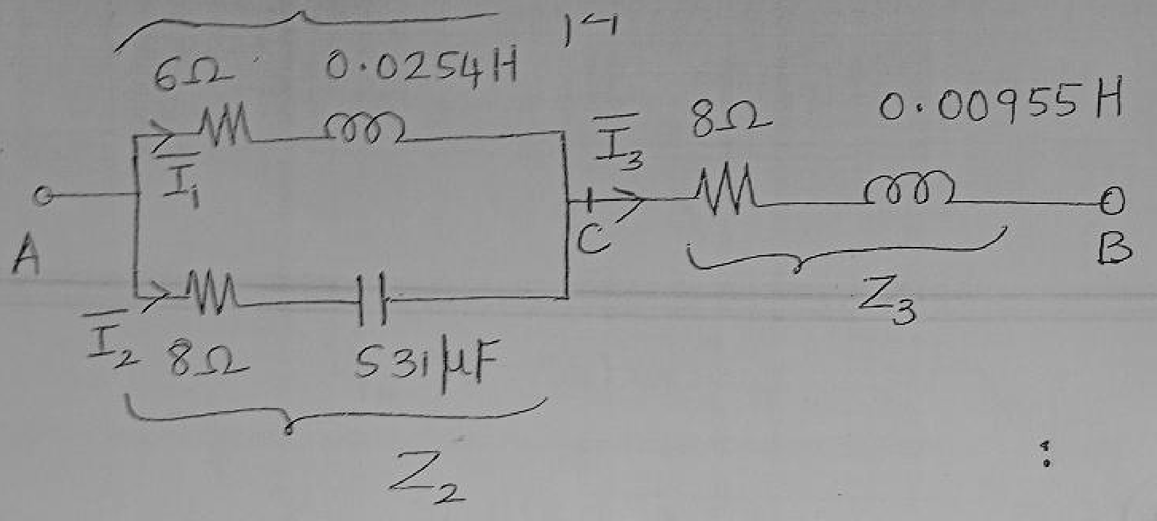
$X_C = \frac{1}{2\pi fC} = 3.183\Omega$

$\Rightarrow X_L = X_T + X_C = 22.773\Omega \Rightarrow L = 72.49$ mH.

iii) $X_C$ must be equal to $X_L$ for series resonance

$= 22.773\Omega \Rightarrow C = 139.77 \mu F$

1c)




$Z_1 = (6 + j7.98)\,\Omega$

$Z_2 = (8 - j6)\,\Omega$ ; $Z_3 = (8 + j3)\,\Omega$

Given $|I_2| = 10A$, taking it as reference,

$\overline{I}_2 = 10\angle 0^\circ$ A

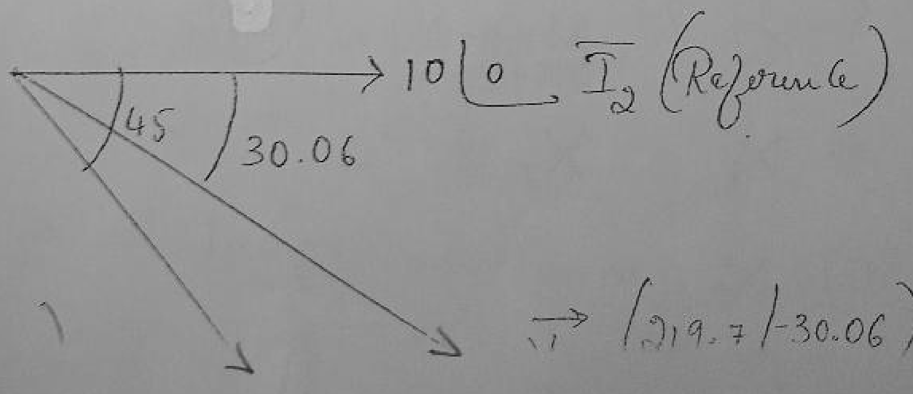
$\therefore\ \overline{V}_{AC} = \overline{I}_2 Z_2 = 100\angle -36.86^\circ$ V

$\Rightarrow \overline{I}_1 = \dfrac{\overline{V}_{AC}}{Z_1} = 10.02\angle -89.93^\circ$ A

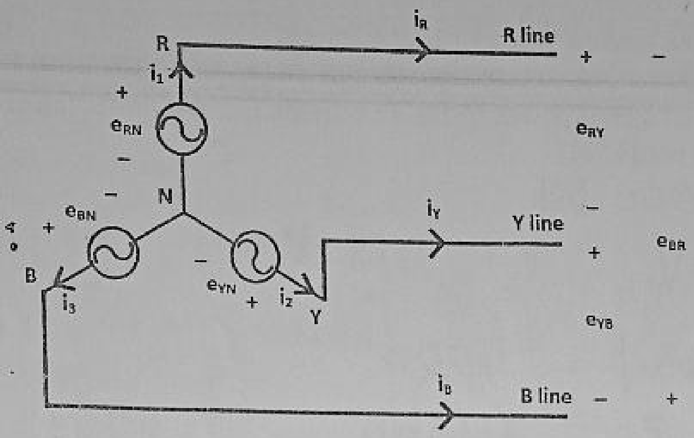
$\Rightarrow \overline{I}_3 = \overline{I}_1 + \overline{I}_2 = \overline{I}_S = 14.16\angle -45^\circ$ A

$\Rightarrow \overline{V}_{CB} = \overline{I}_S Z_3 = 121\angle -24.45^\circ$ V

$\Rightarrow \overline{V}_{AB} = \overline{V}_{AC} + \overline{V}_{CB} = 219.7\angle -30.06^\circ$ V



| | | | |
|---|---|---|---|
| 3 | a) | With a neat circuit diagram, derive the relationship between line voltage and phase voltage in a balanced star connected three phase system. | 6M |




- R', Y' & B' are connected together to form the **'Neutral'** point of the system denoted by 'N'.
- $e_{RN}$ , $e_{YN}$ & $e_{BN}$ represent phase voltages.

Line current = Phase current

$i_1 = i_R$

$i_2 = i_Y$

$i_3 = i_B$

By KVL $e_{RY} = e_{RN} - e_{YN}$

$$\overline{E_{RY}} = \overline{E_{RN}} - \overline{E_{YN}}$$

$$\overline{E_{RN}} = \frac{E_m}{\sqrt{2}}\angle 0^\circ = E_{ph}\angle 0^\circ$$

$$\overline{E_{YN}} = \frac{E_m}{\sqrt{2}}\angle -120^\circ = E_{ph}\angle -120^\circ$$

$$\overline{E_{BN}} = \frac{E_m}{\sqrt{2}}\angle -240^\circ = E_{ph}\angle -240^\circ$$

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

$$= E_{ph}(1-(\cos 120^\circ - j\sin 120^\circ))$$

$$= E_{ph}(\frac{3}{2} + j\frac{\sqrt{3}}{2})$$

$$\boxed{= \sqrt{3}E_{ph}\angle 30^\circ}$$

$$\overline{E_{YB}} = \overline{E_{YN}} - \overline{E_{BN}} = \sqrt{3}E_{ph}\angle -90^\circ$$

$$\overline{E_{BR}} = \overline{E_{BN}} - \overline{E_{RN}} = \sqrt{3}E_{ph}\angle -210^\circ$$

| | | |
|---|---|---|
| b) | A balanced delta connected load consumes 4 KW of power when connected to a three phase, 415 V, 50Hz supply. The same load when connected to a three phase 200 V, 50 Hz supply, draws a current of 5 A at a lagging power factor. Determine the load power factor and resistance and inductance per phase. | 6M |

Sol

$P_{3\phi} = 4000\ W$

delta $\Rightarrow$ $V_{ph} = V_L = 415\ V$

$3 V_{ph} I_{ph} \cos\phi = 4000$

$3 V_{ph} \frac{V_{ph}}{Z} \frac{R}{Z} = 4000$

$\frac{R}{Z^2} = 0.00774 \quad —\ (1)$

case(ii) $V_L = V_{ph} = 200\ V$

$I_L = 5\ A$

$I_{ph} = I_L/\sqrt{3} = 2.89\ A$

$Z = \frac{V_{ph}}{I_{ph}} = 69.284\ \Omega$

using (1)

$\boxed{R = 37.168\ \Omega}$

$X_L = \sqrt{Z^2 - R^2} = 58.44\ \Omega$

$\boxed{L = X_L/\omega = 0.186\ H}$

$\boxed{\cos\phi = \frac{R}{Z} = 0.53\ \text{lag.}}$

| | | |
|---|---|---|
| c) | Determine the readings of the two wattmeters connected to measure the total power for a balanced delta-connected load, fed from a three phase, 400 V balanced supply with phase sequence as R-Y-B. The load impedance per phase is (6+j8) Ω. Also determine<br>i) Line and Phase currents<br>ii) Power factor of the Load<br>iii) Total Active, Reactive & Apparent Powers | 8M |

Sol

$Z = (6 + j8)\,\Omega$

$|Z| = 10\,\Omega$  Phase angle $= 53.13^\circ$

$V_{ph} = V_L = 400\,V$

(i) $\boxed{I_{ph} = \frac{V_{ph}}{|Z|} = 40\,A}$

$\boxed{I_L = 40 \times \sqrt{3} = 69.28\,A}$

$$\boxed{\begin{aligned} W_1 &= V_L I_L \cos(30 + \phi) \\ &= 3.315\,kW \end{aligned}}$$

$$\boxed{\begin{aligned} W_2 &= V_L I_L \cos(30 - \phi) \\ &= 25.484\,kW \end{aligned}}$$

(ii) $\cos(53.13) = 0.6$ lag

(iii) $P_{3\phi} = W_1 + W_2$

$= 3.315 + 25.484$

$\boxed{P_{3\phi} = 28.8\,kW}$

$Q_{3\phi} = \sqrt{3}\,(W_2 - W_1)$

$\boxed{Q_{3\phi} = 38.398\,kVAR}$

$\boxed{S_{3\phi} = 48\,kVA}$

| 4 | a) | An 8 pole three phase Induction Motor is supplied power from 415V, 50 Hz three phase supply. Determine<br>i) Synchronous speed<br>ii) Full load Speed of the motor if full load slip is 2%<br>iii) Frequency of rotor currents when running at 675 rpm. | 4M |
|---|---|---|---|

$P = 8 \quad f = 50\,Hz$

(i) $N_s = \frac{120f}{P} = \frac{120 \times 50}{8} = 750\ rpm$

(ii) $S = \frac{N_s - N_r}{N_s} \Rightarrow N_r = 735\ rpm$

(iii) $f_r = Sf \qquad S = \frac{N_s - N_r}{N_s} = 0.1$

$f_r = \underline{5\ Hz}$

| | b) | With proper nomenclature, derive the EMF equations of a Transformer. | 6M |
|---|---|---|---|

Let $N_1$ = Number of turns in the primary winding

$N_2$ = Number of turns in the secondary winding

Let the primary winding current be sinusoidal current given by

$I_0 = I_m \sin(\omega t)$ Amperes

This sets up a magnetic flux in the transformer core which is given by

Flux, $\Phi = \frac{MMF}{Reluctance}$

Flux will also be sinusoidal in nature of the form

$\Phi = \Phi_m \sin(\omega t)$ where $\Phi_m$ represents maximum value of flux.

This time varying flux linking with the primary winding induces a self-induced EMF in itself given by,

$e_1 = N_1 \frac{d\Phi}{dt}$ -----------(1) as per Faraday's Law

substituting for $\Phi$ in equation (1),

$e_1 = N_1 \Phi_m \omega \cos(\omega t)$ Volts

**RMS Value of primary induced EMF,**

**$E_1 = e_1/\sqrt{2} = 4.44 f \Phi_m N_1$ Volts --- (2)**

| | | |
|---|---|---|
| c) | A 10 KW, 220 V, DC shunt Machine has armature and field resistances of 0.5Ω and 110 Ω respectively. It takes 4A when running as motor on no load (when running light) at rated voltage and speed. Determine<br>i) Constant Losses<br>ii) Efficiency while running as Generator supplying 10KW output<br>iii) Efficiency while running as Motor drawing 10KW input | 10M |

→ $R_a = 0.5 \quad R_f = 110\,\Omega$

$I_f = \frac{V}{R_f} = 2\,A$

$I_a = 4 - 2 = 2\,A$

constant Total Loss $= VI_L - (2^2)(0.5)$

$= (4\times220) - 2$

(i) $\boxed{W_c = 878\,W}$

(ii) $\eta_g = \frac{P_o}{P_o + \text{Losses}}$

$P_o = 10\,KW$

$I_L = 10\times10^3/220 = 45.45\,A$

$I_a = I_L + I_f = 47.45\,A$

$W_V = 1125.97\,W$ ; $W_t = 2003.97$

$\boxed{\eta_g = 83.31\%}$

(iii) $\eta_m = \frac{P_{in} - \text{losses}}{P_{in}}$

$I_a = I_L - I_f = 43.45\,A$

$W_V = 944.45\,W$

$\boxed{\eta_m = 81.78\%}$

| | | | |
|---|---|---|---|
| 5 | a) | Write a short note on the following: (any)<br>i) RCCB<br>• It detects the earth leakage current<br>• Protects the humans and other living beings from Electric shock.<br>• Protects the electrical appliances from arc-over.<br>• It consists of sensing coil, secondary coil, primary coil wherein the difference in current between line and neutral is sensed by sensing coil and the signal is sent to relay to trip the circuit.<br>ii) Fuse<br>• A fuse is an electric / electronic device, which is used to protect circuits from over current, overload and make sure the protection of the circuit.<br>• The principle of a fuse is based on the heating effect of the electric current.<br>• It is always placed in series with the circuit.<br>• Rated Current (or) current rating<br>• Fusing current<br>• Fusing Factor $= \frac{Fusing\ current}{Rated\ current}$ (>1)<br>iii) Oil Pressure cables<br>• In case of oil filled cables, channels or ducts are provided in the cable for oil circulation<br>• Oil under pressure is constantly supplied to the channels by means of external reservoirs<br>• Oil under pressure compresses the layers of insulation and avoids voids | 6M |
| | b) | The load connected across a single-phase AC supply consists of a heating load of 1.5kW, a motor load of 2kVA at a power factor 0.6 lag and a load of 2kW at a power factor 0.8 lag. Calculate the total power drawn from the supply in kW & kVA and the overall power factor of the system.<br><br>What must be the KVAR rating of a capacitor to bring the power factor of the above system to unity?<br><br>Sol (i) Load 1 = 1.5 kW = $P_1$<br>$\cos\phi = 1$<br>$Q_1 = 0$<br>(ii) $S_2 = 2$ KVA<br>$\cos\phi_2 = 0.6$ lag<br>$P_2 = S_2 \cos\phi_2 = 1.2$ KW<br>$Q_2 = S_2 \sin\phi_2$<br>$= 1.6$ KVAR<br>(iii) $P_3 = 2$ KW<br>$\cos\phi_3 = 0.8$ lag<br>$Q_3 = P_3 \tan\phi_3$<br>$= 1.5$ KVAR<br>Total real Power<br>$= 4.7$ KW<br>Total reactive Power<br>$= 3.1$ KVAR<br>Total apparent Power<br>$= \sqrt{4.7^2 + 3.1^2}$<br>$= 5.63$ KVA<br>$\cos\phi = \frac{P}{S} = 0.835$ lag<br>∴ a capacitor of 3.1KVAR should be connected to make the pf to unity. | 6M |

c) The following table gives average consumption hours for various loads in a typical household: 8M

| S.No. | Name of the Appliance | Wattage | Average consumption hours per day | Number of Units/day |
|---|---|---|---|---|
| 1. | Four LED Bulbs | 20 W per bulb | 8 hours each | 640 Whr |
| 2. | LED TV | 60 W | 6 hours | 360 Whr |
| 3. | Air conditioner | 2000 W | 2 hours | 4000 Whr |
| 4. | Refrigerator | 100 W | 24 hours | 2400 Whr |
| 5. | Water Pump | 750 W | 30 minutes | 375 Whr |
| 6. | 3 Ceiling Fans | 75 W per fan | 10 hours each | 2250 Whr |
| | | | Total (units) | 10.025 units |

Per month = 10.025×30 = 300.75 units

| S.No. | Type of Charges | Tariff Details | Tariff |
|---|---|---|---|
| 1. | Fixed Charges for sanctioned load | Rs. 70/- for first KW<br>Rs. 80/- for every additional KW | 70×1<br>80×4 } = 390/- |
| 2. | Energy Consumption Charges | 0 to 30 units ----- Rs. 4/- per unit<br>31 to 100 units ----- Rs. 5.45/- per unit<br>101 to 200 units ----- Rs. 7/- per unit<br>Above 200 units ----- Rs. 8.05/- per unit | 30×4 + 70×5.45<br>+ 100×7<br>+ 100.75×8.05<br>= 2012.54/- |
| 3. | Fuel Adjustment Charges | 8 paisa per unit | 24.06/- |
| 4. | Tax only on Energy consumption charges | @ 9% | 181.13/- |
| | | Total | 2607.73/- |