ELEMENTS OF ELECTRICAL ENGINEERING
Course Code : UE25EE141A/B

PES UNIVERSITY

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ELEMENTS OF ELECTRICAL ENGINEERING

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Balanced Star Connected Three Phase System; Voltage and Current Relations

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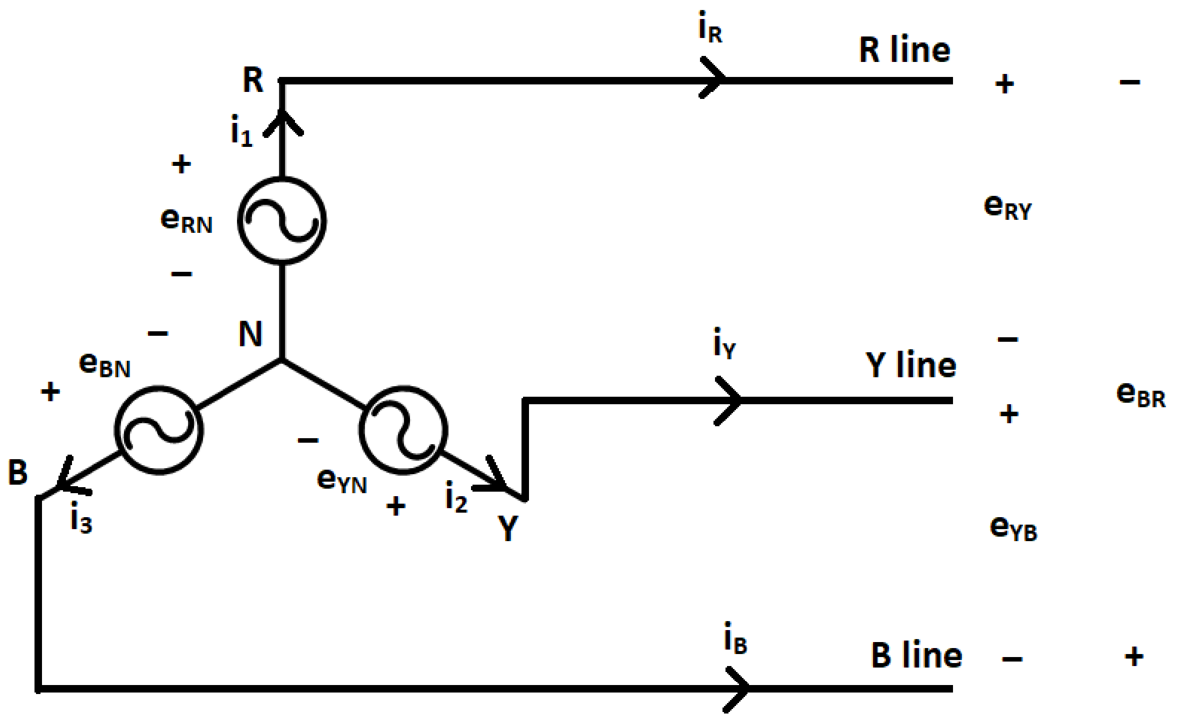
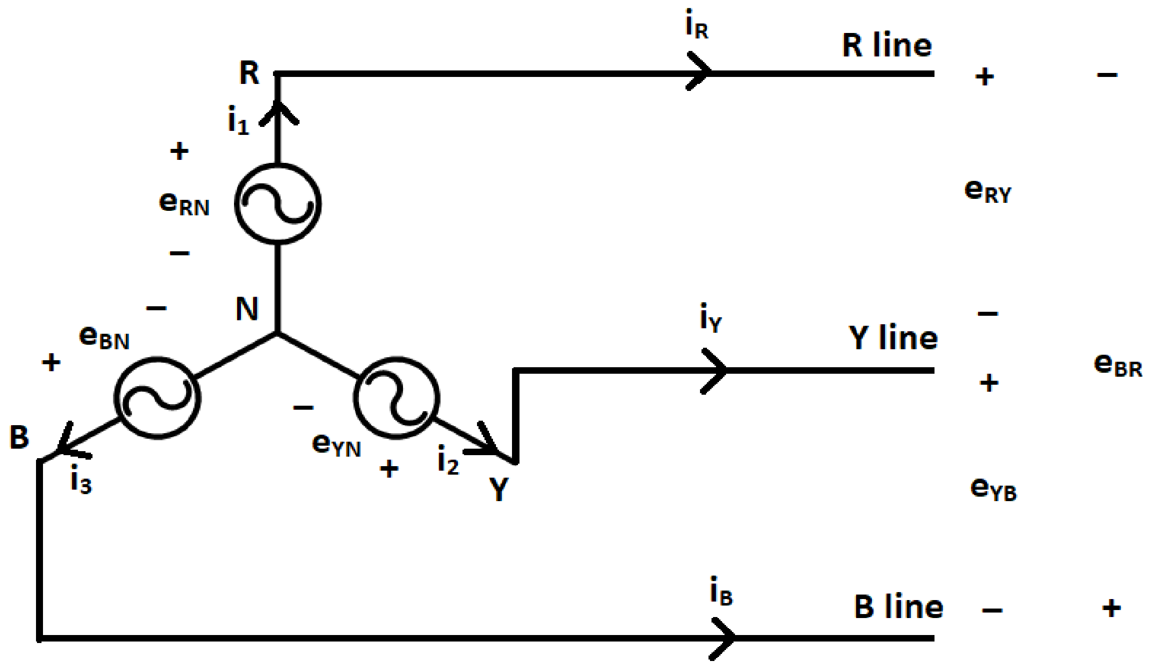
Balanced Star (or) WYE Connected Three Phase System



- 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.

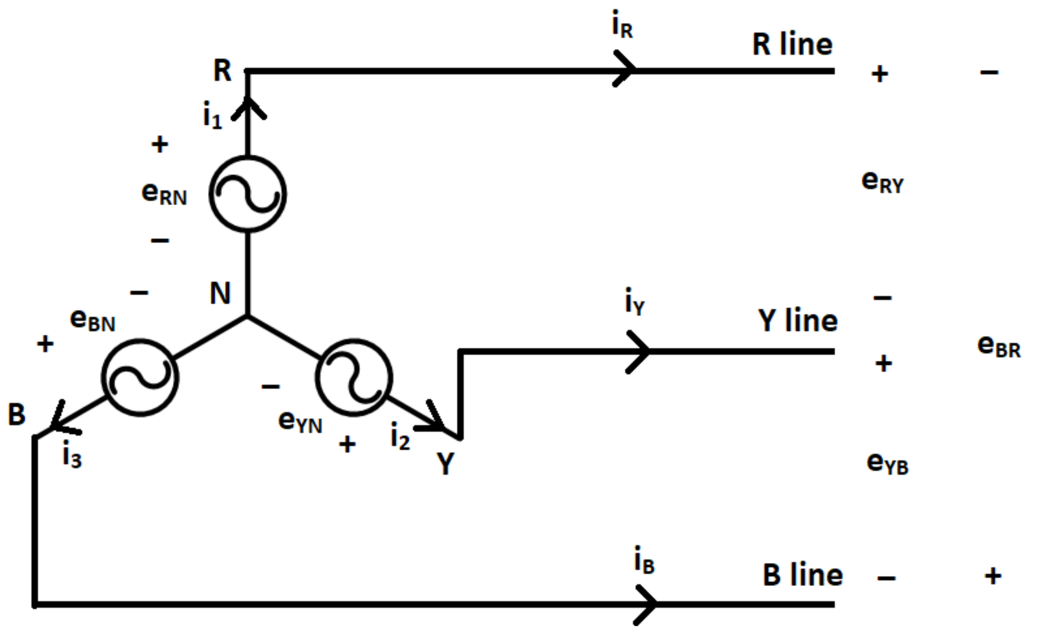
Balanced Star Connected Three Phase System



- e_{RY} , e_{YB} & e_{BR} represent Line (or) Line to line voltages.
- i_1 , i_2 & i_3 represent phase currents.
- i_R , i_Y & i_B represent line currents.

Relation between Line & Phase currents – Balanced Star System

In a balanced star connected three phase system,



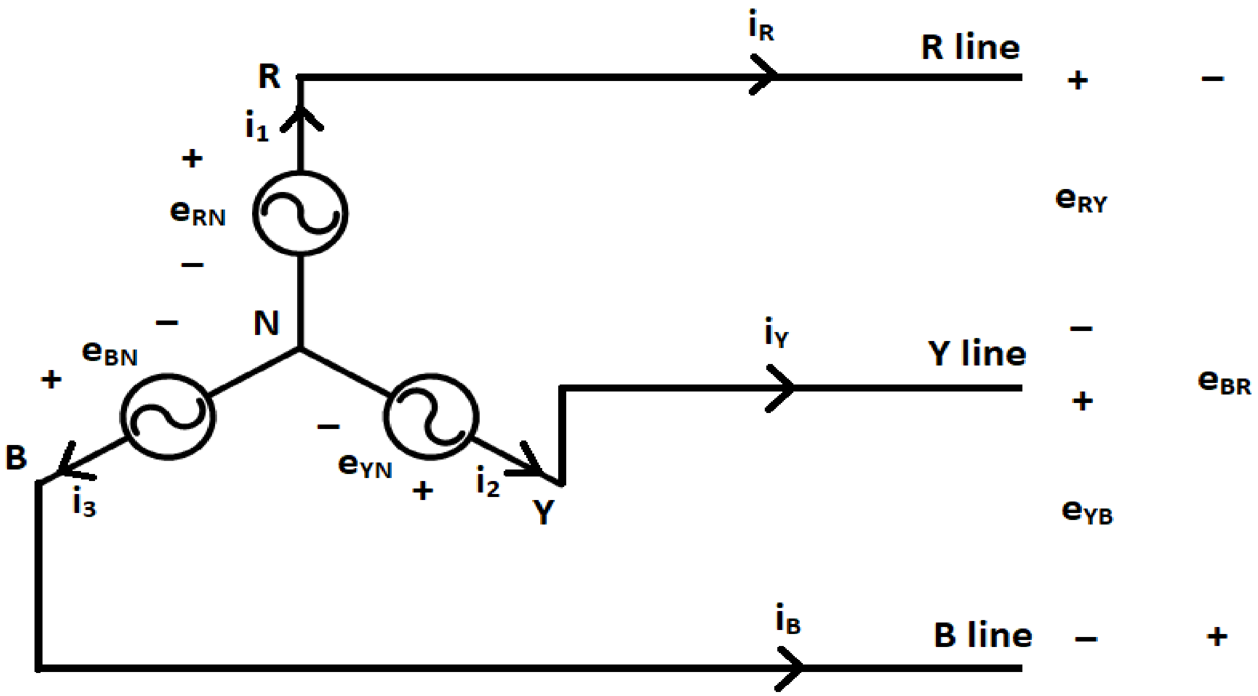
Line current = Phase current

i.e., $\mathbf{i_1 = i_R}$

$\mathbf{i_2 = i_Y}$

$\mathbf{i_3 = i_B}$

Relation between Line & Phase voltages – Balanced Star System



By KVL in the path RYNR, $- e_{RY} - e_{YN} + e_{RN} = 0$

Hence, $e_{RY} = e_{RN} - e_{YN}$

Relation between Line & Phase voltages – Balanced Star System

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

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

where, E_{ph} is the RMS value of phase voltage.

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

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

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

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

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

Relation between Line & Phase voltages – Balanced Star System

$$= \sqrt{3}E_{ph}(\cos 30° + j\sin 30°)$$

$$= \sqrt{3}E_{ph}\angle 30°$$

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

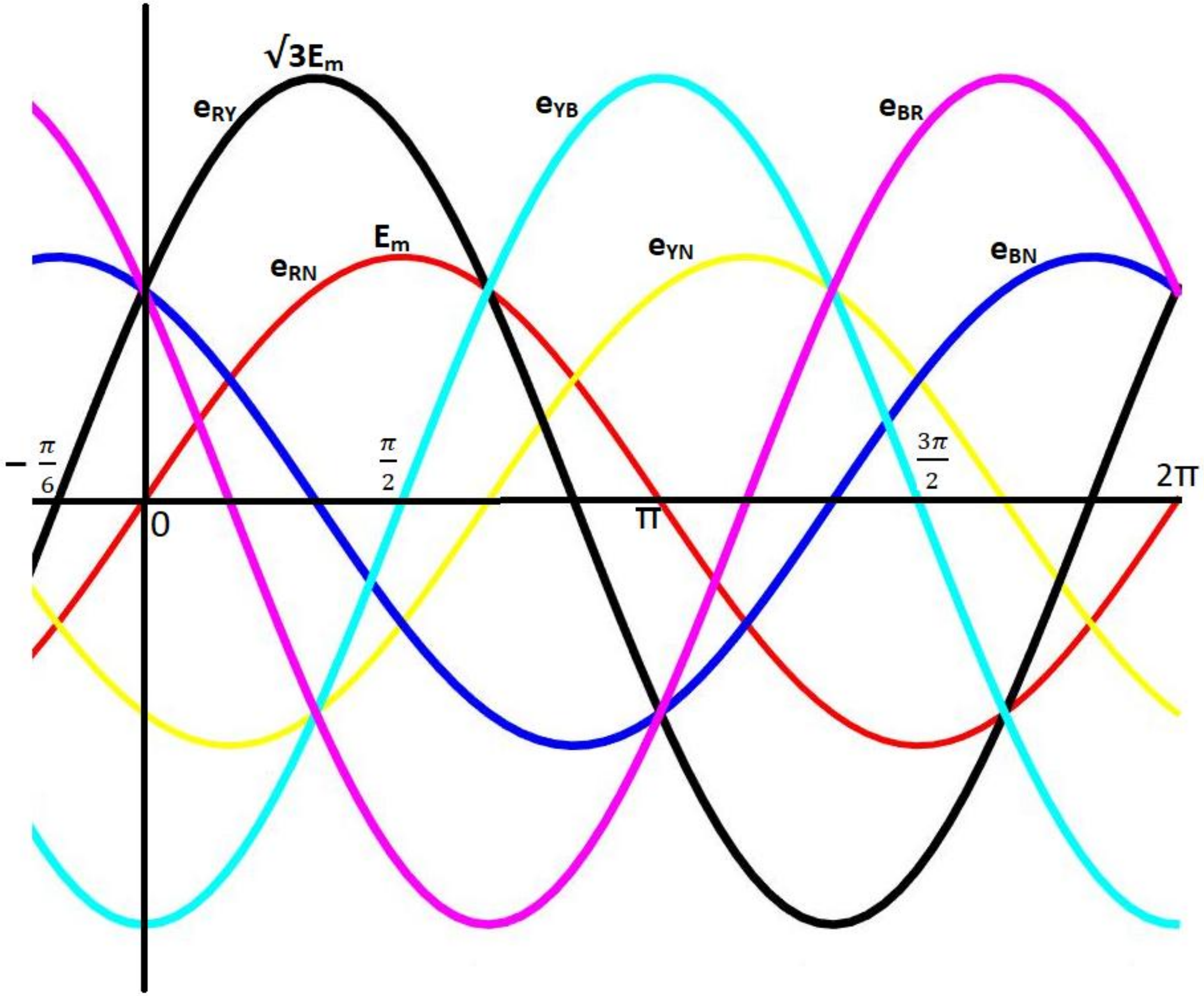
$$\overline{E_{BR}} = \overline{E_{BN}} - \overline{E_{RN}} = \sqrt{3}E_{ph}\angle -210^{\circ}$$

Thus, in a balanced star connected three phase system,

(i) Magnitude (RMS value) of Line Voltage = √3*(Magnitude of Phase Voltage)

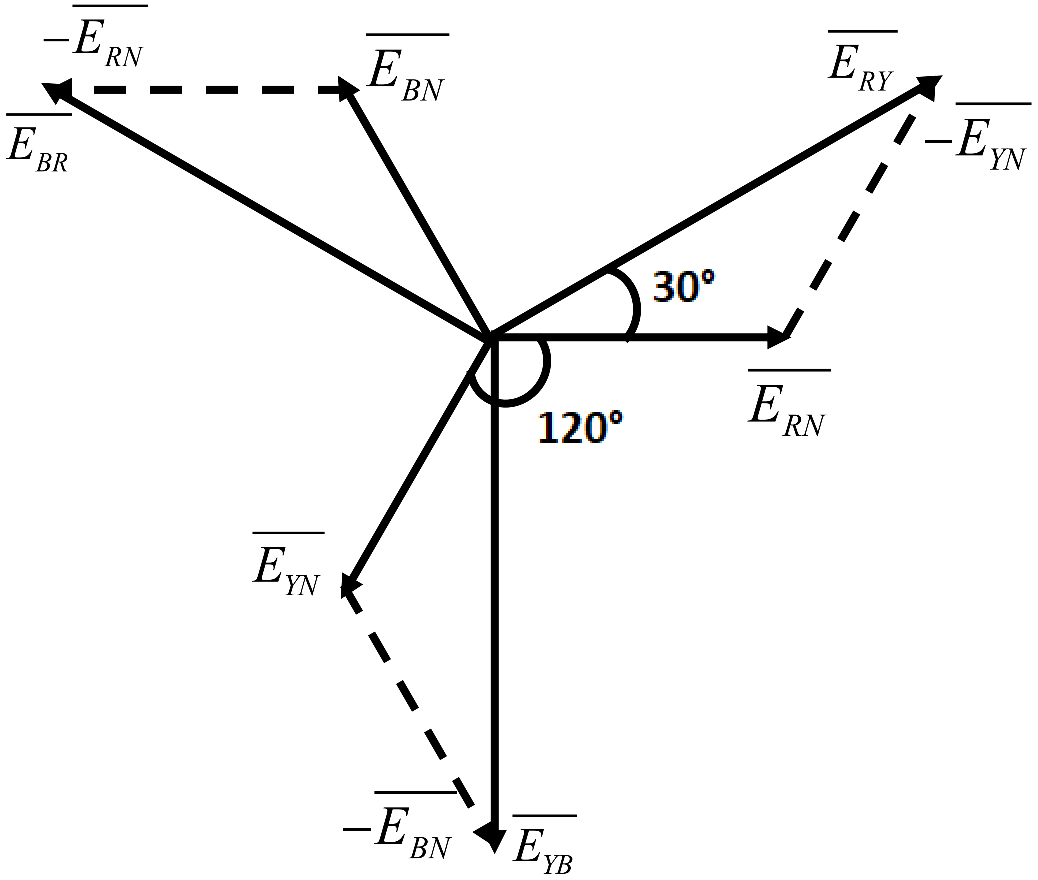
(ii) Each line voltage leads the corresponding phase voltage by 30°

Balanced Star System – Line and Phase Voltage Waveforms



Balanced Star System – Phasor diagram

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



Numerical Example 1

Question:

A balanced 3 phase load consists of three coils, each of 4Ω resistance and 0.02H inductance. Determine the total active and reactive power when the coils are connected in star, if the supply voltage is 400V, 50 Hz.

Solution :

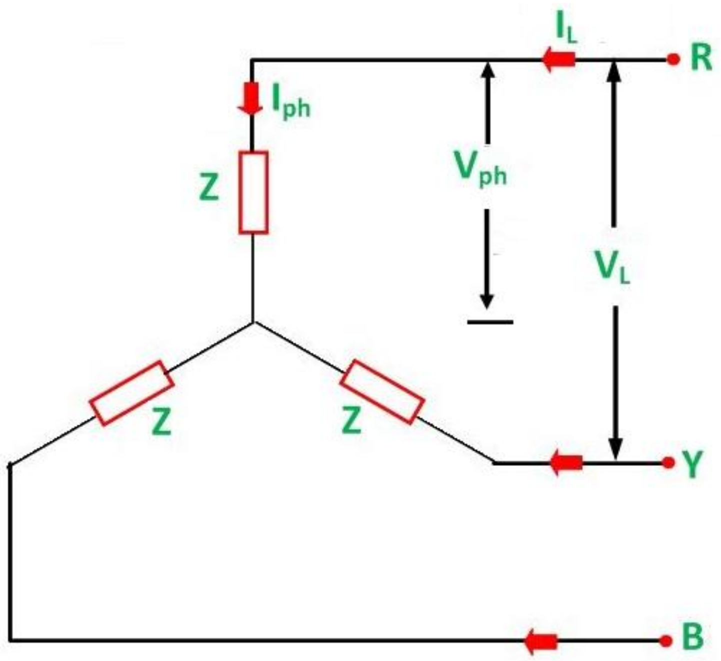
Note:

In three phase systems, by default, the voltages and currents given are line voltage and line current respectively.

Similarly, power given is three phase power by default.

Numerical Example 1 (contd..)

Given Data:
Line voltage, V_L = 400V ; f = 50Hz



Given Data:

Line voltage, V_L = 400V ; f = 50Hz

Resistance per phase, R = 4Ω

Inductance per phase, L = 0.02H

Numerical Example 1 (contd..)

Calculations:

Inductive reactance per phase, $X_L = 2\pi fL = 6.28\Omega$

Impedance per phase, $Z = R + jX_L = (4+j6.28)\Omega$

Hence, $|Z| = 7.45\Omega$; Phase Angle, $\phi = 57.5°$

Since star connected system,

Phase voltage, $V_{ph} = \frac{V_L}{\sqrt{3}} = 230.94V$

Hence, Phase current, $I_{ph} = \frac{V_{Ph}}{|Z|} = 31A$

Therefore, Line current, $I_L = I_{ph} = 31A$

Numerical Example 1 (contd..)

Three phase Active Power,

$P_{3\text{-phase}} = 3*P_{1\text{-phase}} = 3*V_{ph}*I_{ph}*\cos(\phi) = 11.54KW$

Alternatively, $P_{3\text{-phase}} = \sqrt{3}*V_L*I_L*\cos(\phi) = 11.54KW$

Alternatively, $P_{3\text{-phase}} = 3*I_{ph}^2*R = 11.54KW$

Similarly, Three phase Reactive Power,

$Q_{3\text{-phase}} = 3*Q_{1\text{-phase}} = 3*V_{ph}*I_{ph}*\sin(\phi) = 18.11KVAR$

Alternatively, $Q_{3\text{-phase}} = \sqrt{3}*V_L*I_L*\sin(\phi) = 18.11KVAR$

Alternatively, $Q_{3\text{-phase}} = 3*I_{ph}^2*X_L = 18.11KVAR$

Text Book & References

Text Book:

1. "Basic Electrical Engineering" S.K Bhattacharya, 1stEdition Pearson India Education Services Pvt. Ltd., 2017
2. "Basic Electrical Engineering", D. C. Kulshreshta, 2ndEdition, McGraw-Hill. 2019

3. "Special Electrical Machines" E G Janardanan, PHI Learning Pvt. Ltd., 2014

Reference Books:

1. "Engineering Circuit Analysis" William Hayt, Jack Kemmerly, Jamie Phillips and Steven Durbin, 10th Edition McGraw Hill, 2023

2. "Electrical and Electronic Technology" E. Hughes (Revised by J. Hiley, K. Brown & I.M Smith), 12th Edition, Pearson Education, 2016.

THANK YOU

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