ELEMENTS OF ELECTRICAL ENGINEERING
Course Code : UE25EE141A/B

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ELEMENTS OF ELECTRICAL ENGINEERING

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Concept of Balanced Three Phase source and Load; Power Relations in Balanced Three Phase Systems

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Balanced Three Phase Supply

A Three phase supply is said to be balanced if

i) The three EMFs are equal in magnitude

ii) Phase displaced from one another by 120°

For example, $e_1 = 100\sin(\omega t)$

$e_2 = 100\sin(\omega t - 120°)$

$e_3 = 100\sin(\omega t + 120°)$

represents balanced three phase supply.

Examples of unbalanced three phase supply systems are:

i) $e_1 = 100\sin(\omega t)$, $e_2 = 110\sin(\omega t - 120°)$, $e_3 = 100\sin(\omega t + 120°)$

ii) $e_1 = 100\sin(\omega t)$, $e_2 = 100\sin(\omega t - 125°)$, $e_3 = 100\sin(\omega t + 120°)$

Balanced Three Phase Load

A Three phase Load can be either star connected type or delta connected type.

A Three phase Load is said to be balanced if in each phase of the load both resistance and reactance are exactly same.

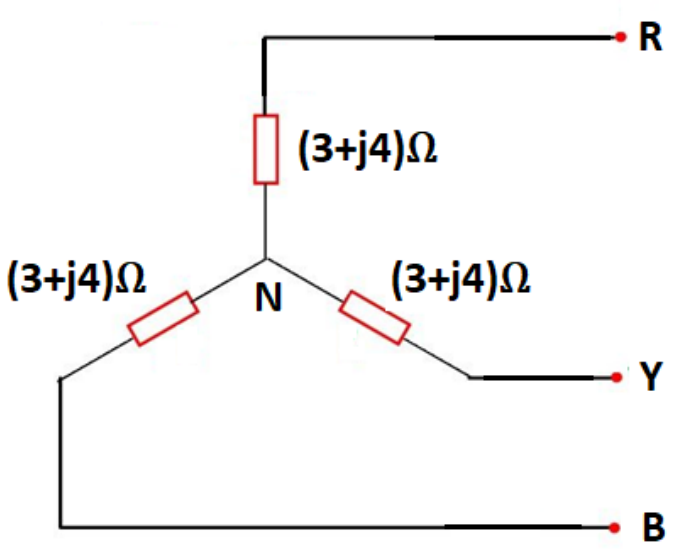

Fig 1: Balanced Star connected Load

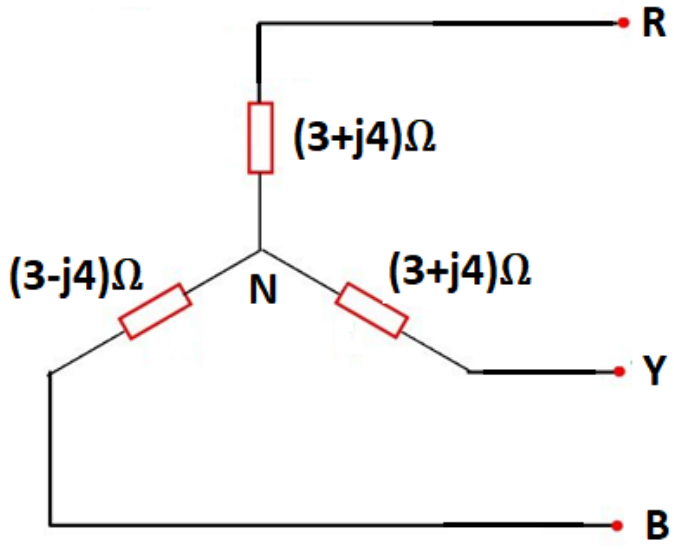

Fig 2: Unbalanced Star connected Load

Balanced Three Phase Load (contd..)

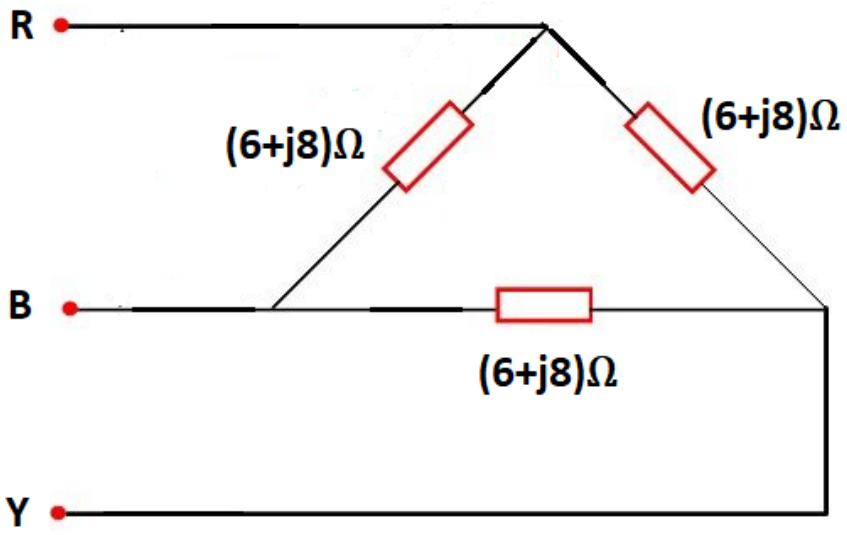

Fig 1: Balanced Delta connected Load

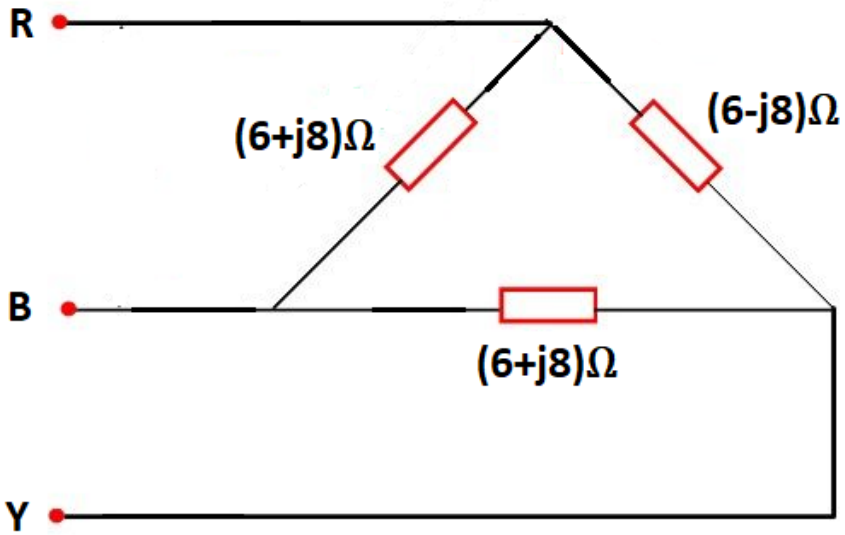

Fig 2: Unbalanced Delta connected Load

When a balanced three phase load is connected across a balanced three phase supply, the three phase currents drawn will also be balanced in nature.

When a balanced three phase load is connected across a balanced three phase supply, the three phase currents drawn will also be balanced in nature.

This leads to an advantage that balanced three phase systems can be analysed per phase basis and the results can be extended to all three phases.

Thus, in balanced three phase systems, power can be calculated for any one phase and the total three phase power will be thrice that of any one phase.

Active Power in Balanced Three Phase Systems

Three phase Active Power,

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

For a balanced star connected three phase system,

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

$= \sqrt{3}*(V_L)*I_L*\cos\phi$

For a balanced delta connected three phase system,

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

$= \sqrt{3}*V_L*(I_L)*\cos\phi$

Thus, alternatively either for star (or) delta system,

$P_{3\text{-phase}} = \sqrt{3}*V_L*I_L*\cos\phi$

Also, Alternatively, $P_{3\text{-phase}} = 3*(I_{ph}^2*R)$

Reactive Power in Balanced Three Phase Systems

Three phase Reactive Power,

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

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

Also, Alternatively,

$Q_{3\text{-phase}} = 3*(I_{ph}^2*X_L)$ for inductive loads

(or)

$Q_{3\text{-phase}} = -3*(I_{ph}^2*X_C)$ for capacitive loads

(or)

$Q_{3\text{-phase}} = 3*(I_{ph}^2*(X_L - X_C))$ for series RLC type of loads

Apparent Power in Balanced Three Phase Systems

Three phase Apparent Power,

$S_{3\text{-phase}} = 3*S_{1\text{-phase}} = 3*(V_{ph}*I_{ph})$

Alternatively, $S_{3\text{-phase}} = \sqrt{3}*V_L*I_L$

Also, Alternatively,

$S_{3\text{-phase}} = 3*(I_{ph}^2*|Z|)$

Apparent power can also be found as

$$S_{3\text{-phase}} = \sqrt{P_{3-phase}^{\ 2} + Q_{3-phase}^{\ 2}}$$

Power factor of a balanced three phase system is

$$\cos\phi = \frac{P_{3-phase}}{S_{3-phase}}$$

Numerical Problem

1) A balanced delta connected load of impedance (8-j6) Ω per phase is connected to a three phase 230V , 50Hz supply. Calculate i) Line current ii) power factor iii) reactive power.

Text Book & References

Text Book:

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2. "Basic Electrical Engineering", D. C. Kulshreshta, 2nd Edition, 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.

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THANK YOU

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