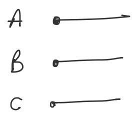
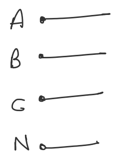
Lecture 6

Wednesday, 31 January 2024 9:29 AM

Three phase :-

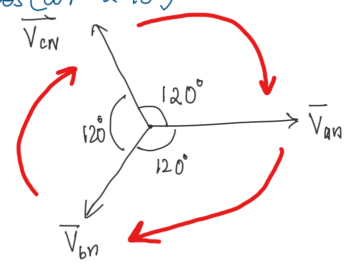




Three wire circuit Four wire circuit

$$v_{an} = V_p \cos(\omega t)$$
$$v_{bn} = V_p \cos(\omega t - 120^\circ)$$
$$v_{cn} = V_p \cos(\omega t - 240^\circ)$$

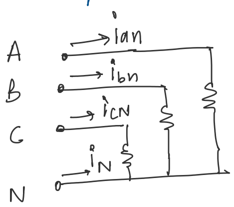
Phasor :-



Why 120° phase shift ??

(i) These 3 phase voltages are conventionally created by a generated. The generator has 3 phase coils placed 120° electrically apart. It naturally generates 3 phase voltage with 120° phase shift from each other

(ii) We can transfer maximum power using minimum conductor requirement.



$$v_{an} = V_p \cos(\omega t)$$
$$v_{bn} = V_p \cos(\omega t - 120^\circ)$$
$$v_{cN} = V_p \cos(\omega t - 240^\circ)$$

$$i_{an} = I_p \cos \omega t$$
$$i_{bn} = I_p \cos(\omega t - 120^\circ)$$
$$i_{cN} = I_p \cos(\omega t - 240^\circ)$$

$$i_N = 0$$

No current in neutral wire.

$$P_{3\phi} = 3 P_R = 3 V_R I_R = 3 \frac{V_p}{\sqrt{2}} \frac{I_p}{\sqrt{2}} = \frac{3}{2} V_p I_p$$

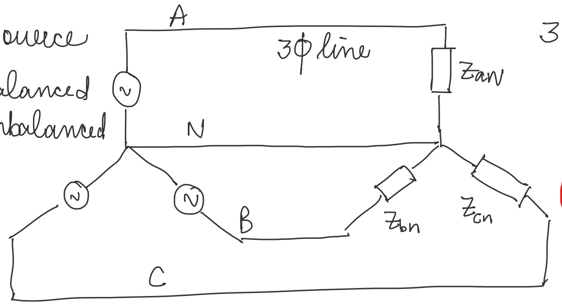
	3ϕ ckt	3 number of 1ϕ ckt
Cross section of conductor required	$3x$ mm^2	$6x$ mm^2 (neutral wire will be of $3x$ mm^2)

To transmit same amount of power more cross-sectional area of wire is required in case of 1-ϕ ckt

Why only 6 phase/4 phase? The power delivered remains the same. Three-phase is the minimum number of phases to achieve the above stated advantages.

The advantages are present if the system is balanced.

3φ source
→ balanced
→ unbalanced



3φ load
→ balanced
→ unbalanced

balanced
→ $Z_{an} = Z_{bn} = Z_{cn} = Z$

Balanced → magnitude of voltage is same
→ phase shifted by 120°

Balanced system :- when both load & source are balanced.

A balanced source is manageable because they are being generated by a single machine.

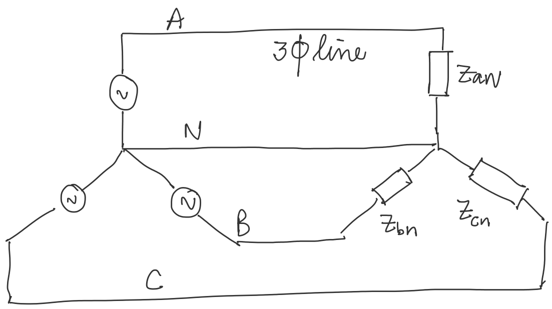
How to have a 3φ balanced load in real life??

There may be 3φ balanced load.

At home loads are mostly single phase load.

If the supply to the building is 3φ, we try to equally distribute the loads among all three phases.

In a very large system such as a city, the loads across the city are distributed equally among all three phases. The probability of the system being balanced becomes high. However there might still be some minor degree of unbalance.



Only for balanced sources

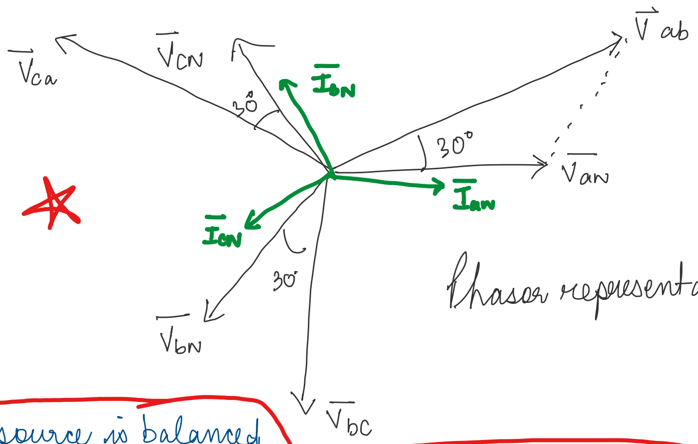
Source Voltage

Phase voltage → V_{an}, V_{bn}, V_{cn}

Line voltage → V_{ab}, V_{bc}, V_{ca}

$$V_{ab} = V_{AN} - V_{BN} = \sqrt{3} V_{AN} \angle 30^\circ$$

$$v_{ab} = v_{aN} - v_{bN}$$
$$= V_p \cos(\omega t) - V_p \cos(\omega t - 120^\circ)$$
$$= V_p [\cos\omega t - \cos(\omega t - 120^\circ)]$$
$$v_{ab} = \sqrt{3}\, V_p \cos(\omega t + 30^\circ)$$



Phasor representation

If source is balanced
(i) Line voltage leads the phase voltage by 30°
(ii) $|\vec{V}_{ab}| = \sqrt{3}\,|\vec{V}_{aN}|$

Only in star connected sources.

$i_{aN} + i_{bN} + i_{cN} = 0$ if both source & loads are balanced (system is balanced)

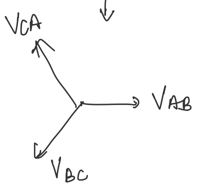
\# 400 V system ?? What do you mean by that ?

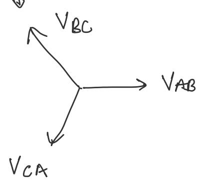
3 ϕ RMS voltage is 400 V

In 3ϕ system we may not have a neutral wire. Very common in high power transmission system.
4 wire system → distribution system.

\# Why only $\underbrace{v_{ab}, v_{bc}, v_{ca}}$ & not $\underbrace{v_{ac}, v_{ba}, v_{cb}}$?

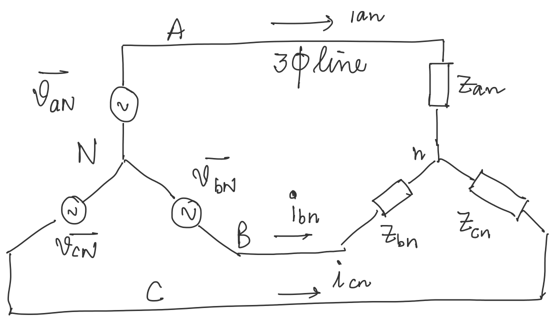
Phase sequence → ABC B lags A by 120°, C lags B by 120°
→ CBA B lags C by 120°, A lags B by 120°





\# Do you need a neutral wire in balanced system to ensure voltage across the load is same as source voltage?

We don't need the 4[th] wire.



$$\bar{V}_N + \vec{v}_{aN} - \bar{I}_{aN} Z_{aN} = V_n \quad (i)$$

$$\bar{V}_N + \vec{v}_{bN} - \bar{I}_{bN} Z_{aN} = V_n \quad (ii)$$

$$\bar{V}_N + \vec{v}_{cN} - \bar{I}_{cN} Z_{aN} = V_n \quad (iii)$$

Add the 3 equations :-

$$3\bar{V}_N + \underbrace{(\bar{V}_{aN} + \bar{V}_{bN} + V_{cN})}_{0} - Z_{aN}\underbrace{(\bar{I}_{aN} + \bar{I}_{bn} + \bar{I}_{cn})}_{0} = 3\bar{v}_n$$

$$\boxed{\bar{V}_N = \bar{V}_n}$$

Solve assignment 2 till question 6 (3φ questions).