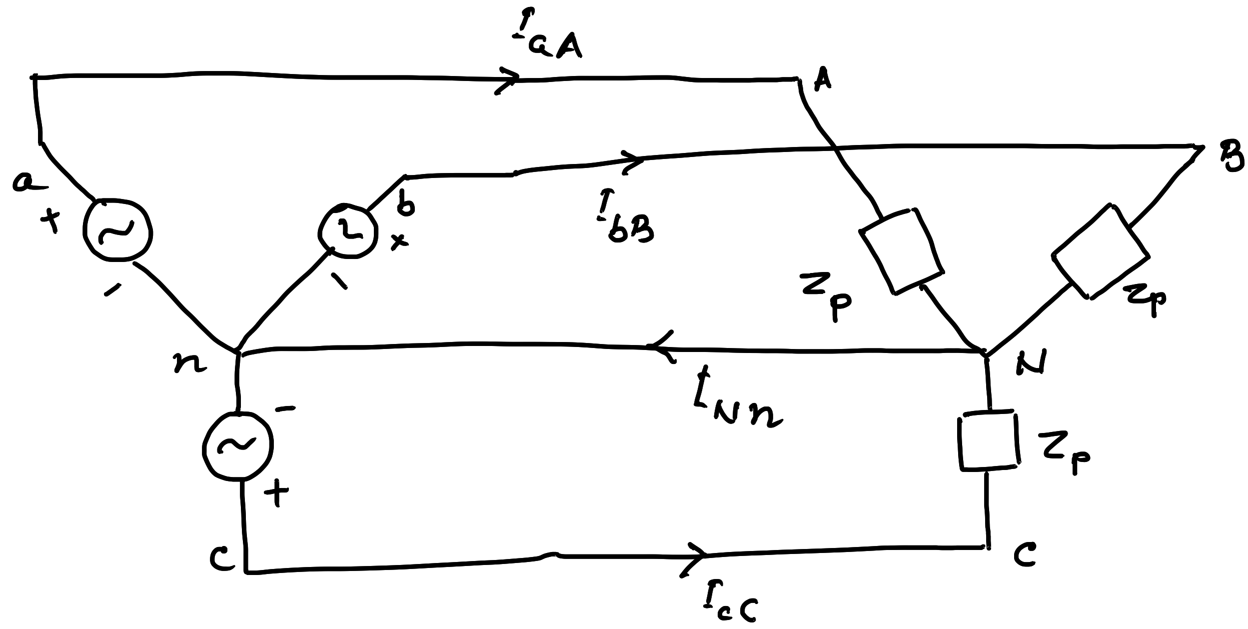
Balanced Three-Phase System

A balanced three-phase four-wire system consists of a balanced three-phase source connected to a balanced three-phase load. The fourth wire is the neutral wire.



The line current Iaa can be evaluated by applying KVL in the loop na ANn

$$I_{aA} = \frac{V_{an}}{Z_p}$$

$$I_{bB} = \frac{V_{bn}}{Z_p} = \frac{V_{an} \angle -120^\circ}{Z_p}$$

$$= I_{aA} \angle -120^\circ$$

$$I_{cC} = I_{aA} \angle -240^\circ$$

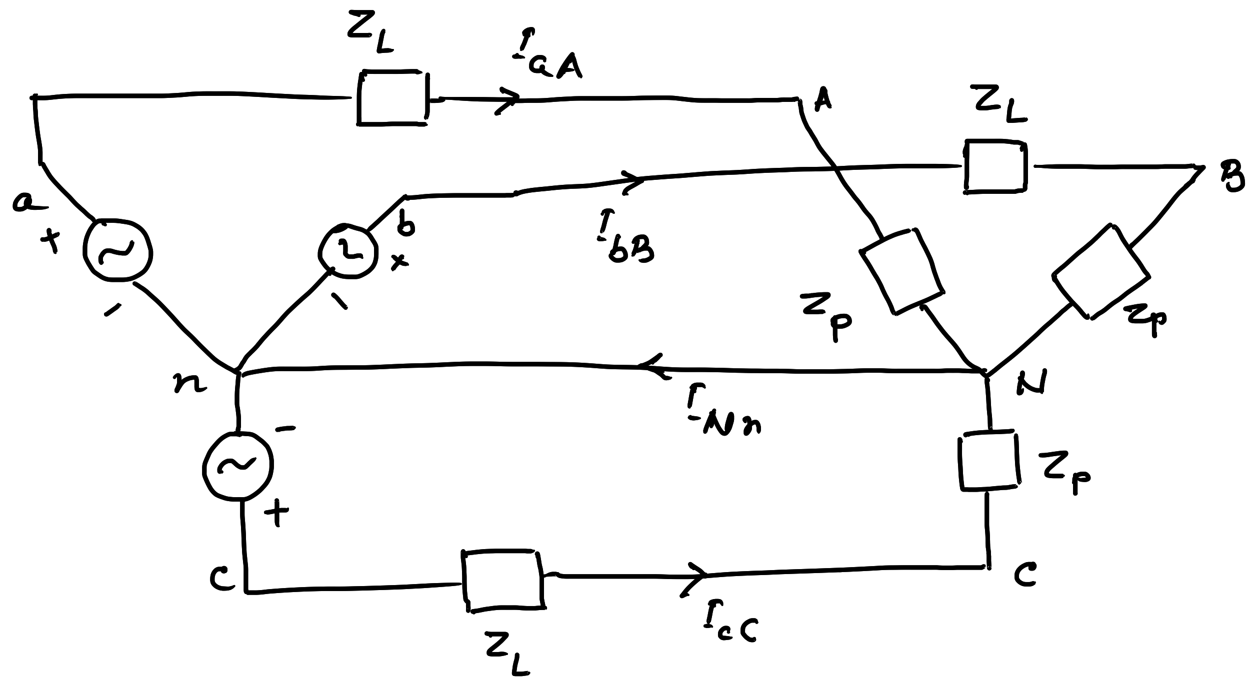
The three line currents have equal magnitude and they differ from each other by a phase angle of 120 degree. The current in the neutral wire is

$$I_{Nn} = I_{aA} + I_{bB} + I_{cC} = 0$$

as the three currents have an equal phase difference of 120 degree. The Zero current in the neutral wire can be visualized as the neutral wire has an infinite impedance or it is an open circuit condition.

There will be no effect on the line currents if the neutral wire is taken out from the circuit. This can save the cost of the transmission line.

If we introduce a line impedance, the currents will be



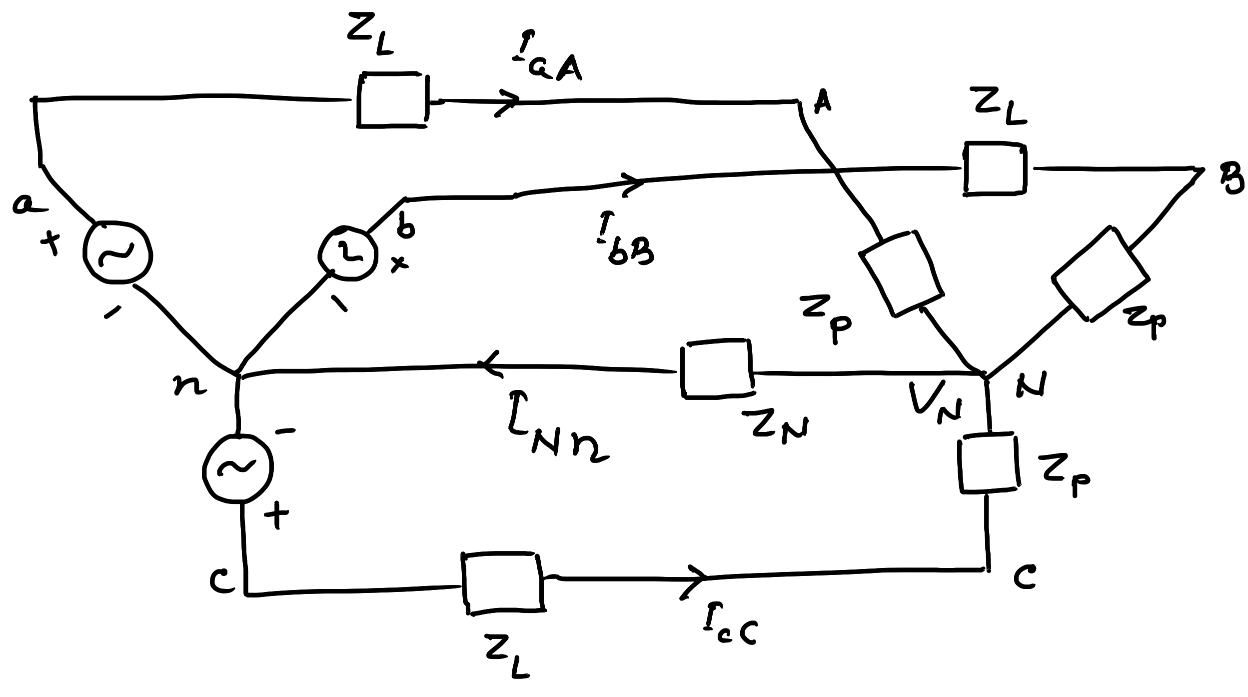
$$I_{aA} = \frac{V_{an}}{Z_L + Z_P}$$

$$I_{bB} = \frac{V_{bn}}{Z_L + Z_P} = I_{aA} \angle -120^\circ$$

$$I_{cC} = I_{aA} \angle -240^\circ$$

$$I_{Nn} = I_{aA} + I_{bB} + I_{cC} = 0$$

The three line currents have the same relationship as seen earlier. Now considering an impedance in the neutral wire, the circuit can be analyzed using Kinch offs' current law at node N. The votage at node n is zero as this is the common reference point for the three voltage sources.



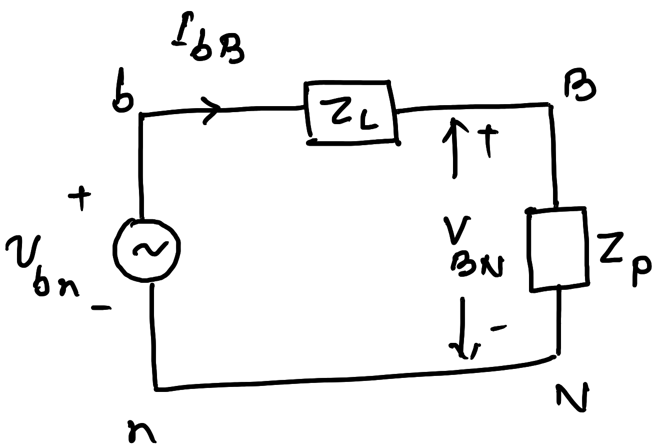
$$\frac{V_N}{Z_N} = \frac{v_{an} - V_N}{Z_L + Z_P} + \frac{v_{bn} - V_N}{Z_L + Z_P} + \frac{v_{cn} - V_N}{Z_L + Z_P}$$

$$\Rightarrow V_N \left[\frac{1}{Z_N} + \frac{3}{Z_L + Z_P} \right] = \frac{v_{an} + v_{bn} + v_{cn}}{Z_L + Z_P}$$

$$v_{an} + v_{bn} + v_{cn} = 0 \Rightarrow V_N = 0$$

The voltage of node N is zero. The current in the neutral wire will be zero in this case.

These analysis show that the current in the neutral wire is always zero for a balanced three phase system. This is true for any impedance in the neutral wire even for short circuit (zero impedance) ote open circuit (infinite impedance) case. A short circuit or zero impedance neutral wire enable us to analyze the footy phase circuit on a pen phase basis. The phase-B (B) equivalent circuit will be

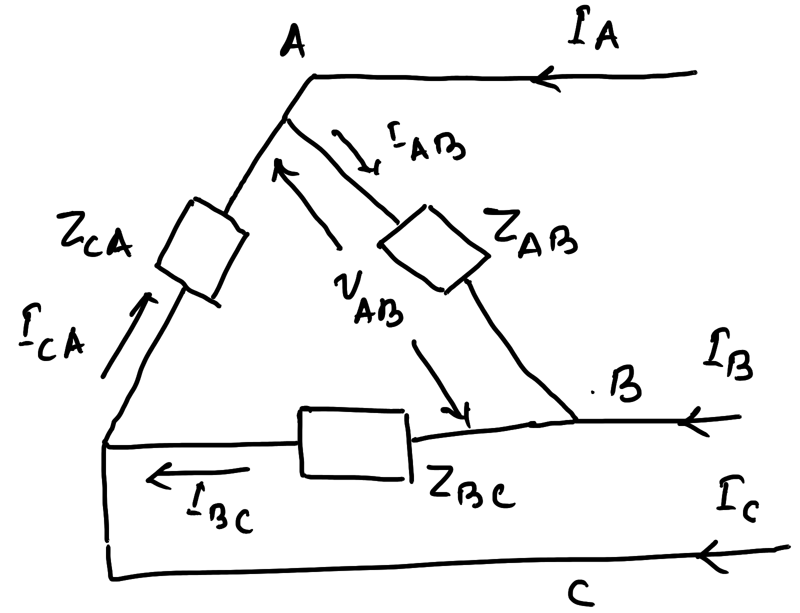


In a state connected network the line and phase currents are same . In fact, they are not distinguishable. In a Y-connected system

$$V_L = \sqrt{3}\, V_P$$

$$I_L = I_P$$

A delta connected load will look like



I_A , I_B , I_C are line currents (I_L)

I_{AB} , I_{BC} , I_{CA} are phase currents (I_P)

$$
\begin{aligned}
I_A &= I_{AB} - I_{CA} \\
&= I_P \angle 0^\circ - I_P \angle -240^\circ \\
&= I_P \sin \omega t - I_P [\sin \omega t \cdot \cos 240^\circ - \cos \omega t \cdot \sin 240^\circ] \\
&= I_P \left(\sin \omega t + \tfrac{1}{2} \sin \omega t - \tfrac{\sqrt{3}}{2} \cos \omega t \right) \\
&= \sqrt{3}\, I_P \left(\tfrac{\sqrt{3}}{2} \sin \omega t - \tfrac{1}{2} \cos \omega t \right) \\
&= \sqrt{3}\, I_P \left(\sin \omega t \cdot \cos 30^\circ - \sin 30^\circ \cos \omega t \right) \\
&= \sqrt{3}\, I_P \sin(\omega t - 30^\circ)
\end{aligned}
$$

Line current is $\sqrt{3}$ times the phase current ($I_L = \sqrt{3}\, I_P$).

The phase and line voltages are same $V_L = V_P$

Normally delta connected sources are not practically used. Sometimes delta connected load is used. In those cases, we can convert a delta connected load to an equivalent state connected load and follow the analysis of a Y-Y system.