Ex. No. 7	**POWER MEASUREMENT IN BALANCED THREE PHASE SYSTEMS**
Date:	

AIM:

To measure the 3 phase power for a balanced Star connected source which is supplying power to a balanced Δ connected load.

(ii) To prove that the power consumed in the Δ network is three times that of its equivalent Y counterpart.

SOFTWARE REQUIRED:

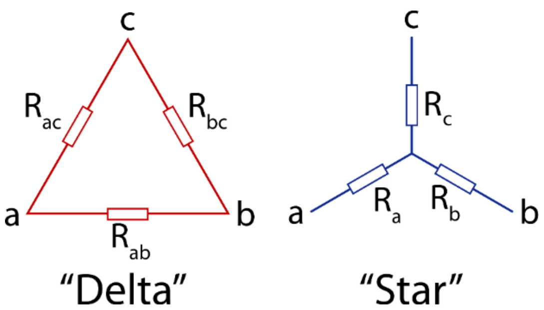
LT Spice software

THEORY

BALANCED THREE PHASE SYSTEMS

A three-phase system is an electrical power distribution system that uses three conductors carrying alternating current (AC) power at a fixed phase angle 120 degrees separation from each other. In this system, the AC power is generated and distributed in three phases.

In a balanced three-phase system, the loads on each phase are equal, and the current flowing through each phase is also equal.



In delta connected systems, the 3 phases are connected in a triangular configuration, forming a delta shape. In this system, each phase conductor is connected to the next in a loop, with no neutral point.

In star, one end of each phase conductor is connected to a central point, also known as the neutral point, forming a star or Y shape.

STAR CONNECTED SYSTEM

- In Star connected system we get 3-phase three wire system and also 3-phase, 4-wire system is taken out.
- Line current is equal to phase current and the line voltage is $\sqrt{3}$ times that of the phase voltage.
- Three phase power is $\sqrt{3}\, VL\ IL \cos\phi$ Or $3\ VPh\ Ph \cos\phi$

DELTA CONNECTED SYSTEM

- Only 3-phase three wire system is possible with Delta connected system.
- Line current is $\sqrt{3}$ times that of the phase current and the line voltage is equal to phase voltage.

- Three phase power is $\sqrt{3}\,VL\;IL\cos\phi$ Or $3\,VPh\;Ph\cos\phi$

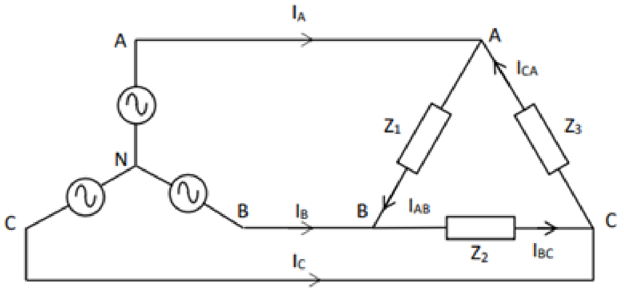
PART -1

To measure power in 3 phase star connected source with delta connected load.

A three phase balanced Delta Connected load is connected to a balanced three phase power source of phase voltage 230V, 50 Hz, (assume a positive phase sequence ABC as shown in figure.) The load impedance per phase is given by 9+j12.

Calculate the following

(i) Per phase voltage, current and power in Load side
(ii) 3 phase real and reactive power



Theoretical calculations

Zp – Impedance per phase

Ip- Current per phase

Vp – Voltage per phase

Given

1. Calculation of Impedance
   Zp = 9 + j12

   Zp = $\sqrt{9^2 + 12^2}$ = 15 Ω

2. Calculation of phase angle and circuit power factor
   $\emptyset = \tan^{-1}\frac{X}{R}$
   $\emptyset = \tan^{-1}\frac{12}{9}$ = 53.13 degrees
   $\text{pf} = \cos(\emptyset)$
   Pf = cos(53.13) = 0.6
3. Source side Vp=230 therefore $VL = \sqrt{3}Vp$
4. Source side VL is applied to the delta connected Load
5. For Delta connected load VL = Vp
6. $IP = \frac{398.37}{15}$ = 26.55 A
7. $Power\ per\ phase = VIcos\ \emptyset$
   398.37x26.55x0.6
   =6.35kW

8. 3 phase power = 3 x power/phase
   = 3 x 6.35
   = 19.044kW
9. phase reactive power = 3x398.37x26.55x0.8
   = 25.4 kVAr

PROCEDURE

1. Open a new schematic.
2. Select voltage source from components list and convert into AC voltage source by selecting’advanced’ option.
3. Create three instances.
4. Feed the parameters for the all the three sources as given in the figures 1,2 and 3 repectively.

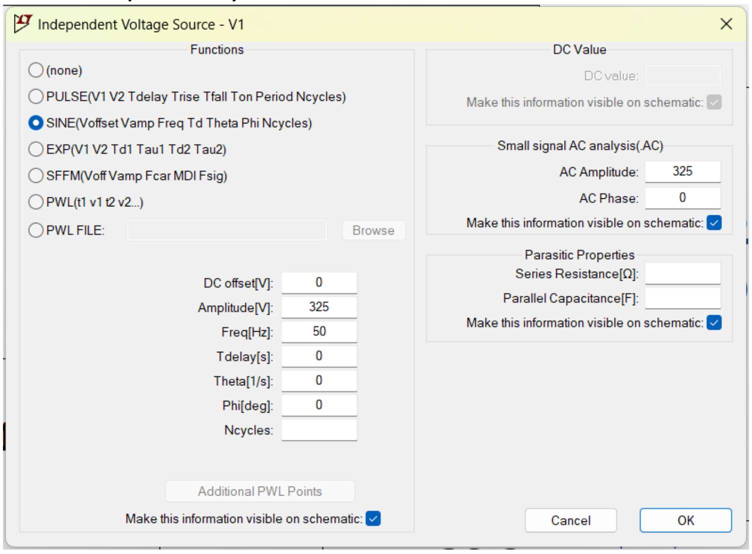


Figure 1

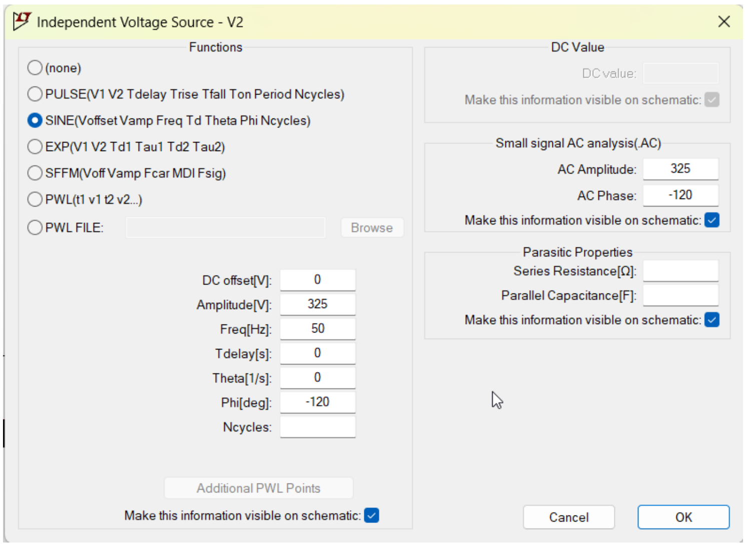


Figure 2

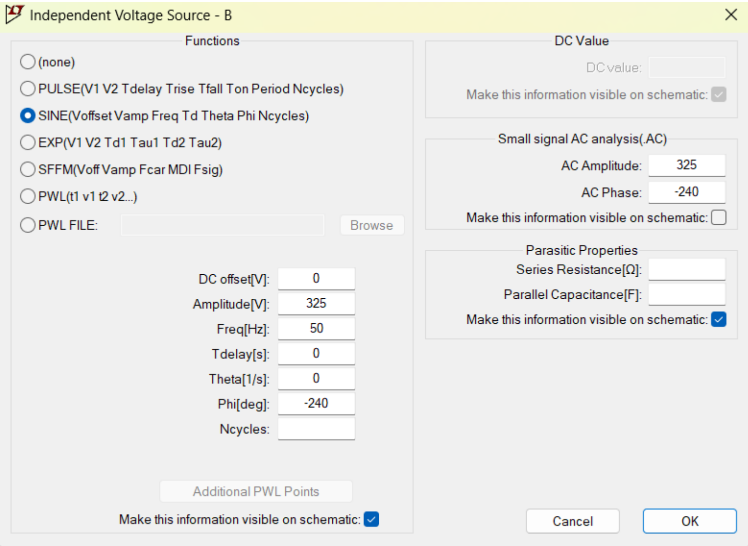


Figure 3

5. Interconnect the three sources to form a star network as shown inn figure 4

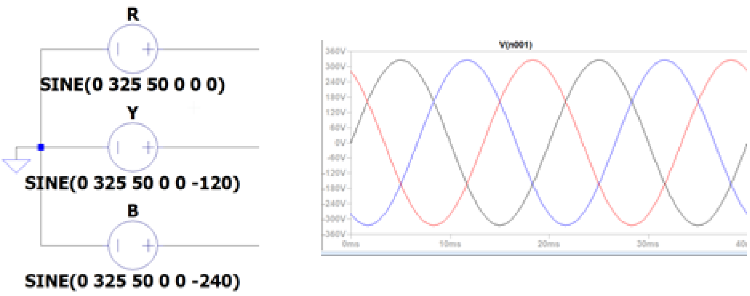
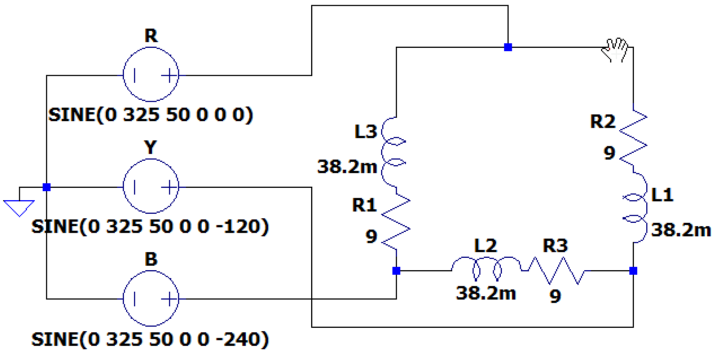


Figure 4

6. Complete the circuit by interconnecting RL delta connected load as show in figure below



7. To measure the instantaneous power dissipated or supplied by a component, hold the “alt” key and click on the component to be measured.
8. After selecting the instantaneous power of a component, hold the “ctrl” button and click on the name of the measurement in the measurement window. A new window will open displaying the average power.

9. Change the analysis to AC Analysis and verify your results with voltage/current magnitude/angle values displayed on the screen.

PART- 2

Repeat the experiment for a balanced star-connected resistive load of 9 ohms per phase and a balanced delta-connected resistive load of the same 9 ohms per phase. Compare the power in both cases.

RESULT

The power consumed by a 3-phase AC load is calculated theoretically and is verified using LTspice simulation.

Points to be noted for LT spice implementation

1. The magnitude of the voltage must be entered in terms of peak value, not rms value.
2. If the inductive or capacitive reactance is given in the problem, convert it into inductance and capacitance.
3. A neutral point, such as a star point, must be grounded.

In the problem statement, Vrms is given; convert it into a peak value.

$V_{rms} = 230V$

$V_p = \sqrt{2} \times 230$

$= 325.27V$

$X_L = 12\Omega$

$f = 50Hz$,

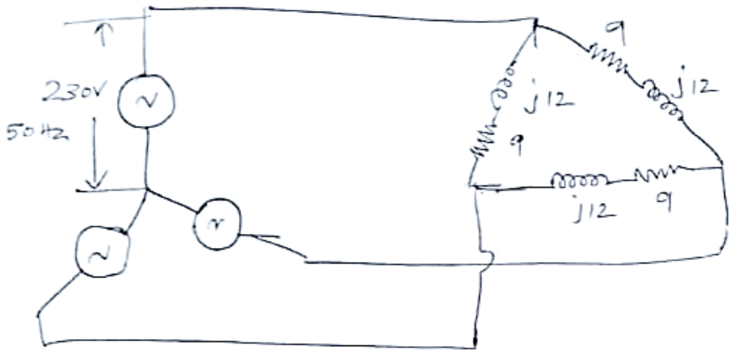
$X_L = 2\pi f L$

$\therefore L = \frac{X_L}{2\pi f} = \frac{12}{2 \times \pi \times 50}$

$= 38.2mH$

R Phase voltage assignment.

Part – 1 (Theoretical Calculations)



Given $V_{rms} = 230V$ in Source Side.

For Star Connected Source $V_L = \sqrt{3}\, V_p$

$V_L = \sqrt{3} \times 230$

$= 398.37\,V$

In Load Side.

$V_L = 398.37V$

For Delta Connected Network.

$V_L = V_p$

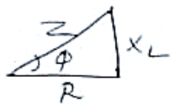
$\therefore V_L = 398.37 = V_p$

Per phase current $I_p = \frac{V_p}{Z_p} = \frac{398.37}{\sqrt{9^2+12^2}} = 26.558A$.

In Delta Network.

$I_L = \sqrt{3}\, I_p = \sqrt{3} \times 26.558 \simeq 46A$.

$\cos\phi = \frac{R}{Z} = \frac{9}{15} = 0.6$



$\cos\phi = \frac{R}{Z}$

Per phase Power $= V_p I_p \cos\phi$

$= 398.37 \times 26.558 \times 0.6$

$= 6{,}347.95W$

$\sin\phi = \frac{X_L}{Z}$

$= \frac{12}{15}$

$= 0.8$

3 phase power $= 3 \times V_p I_p \cos\phi$

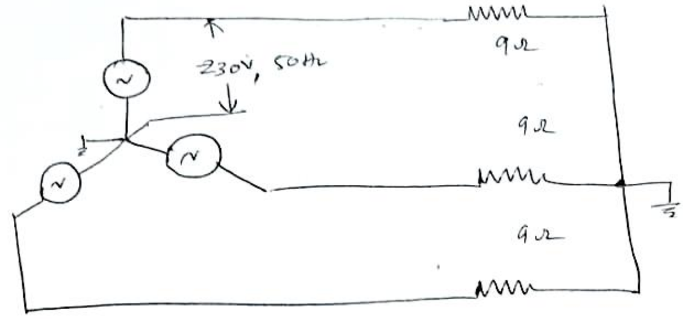
(True power) $= 3 \times 6.347.95 = 19.044\,kW$.

3 phase Reactive power $= 3 \times V_p I_p \sin\phi$

$= 3 \times 398.37 \times 26.558 \times 0.8$

$= 25.4\,kVAr$

Part- 2 (Theoretical calculations)



Source side

$V_P = 230V \quad f = 50Hz.$

$V_L = \sqrt{3} V_P = \sqrt{3} \times 230$

$= 398.37V$

In Load side.

$V_L = \sqrt{3} V_P \quad \therefore V_P = 230V$

$Z_P = 9\Omega$

In star

$I_P = \frac{V_P}{Z_P} = \frac{230}{9} = 25.56A \qquad I_P = I_L$

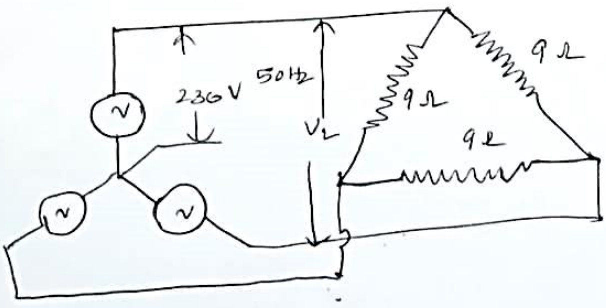
per phase Power = $V_P I_P \cos\phi$ (Resistive load $\cos\phi = 1$)

$\therefore = 230 \times 25.56 \times 1$

$\boxed{\text{Power /phase} = 5.878 \text{ Watts}}$

Three phase power = $5.873 \times 3 = 17.633kW$.

When the Load is reconnected into a Delta Load.



V_L is applied as Phase voltage to the Δ Connected Load.

In the Load Side(Δ)

$V_L = V_P$

$\therefore 398.37 = V_L = V_P$

$V_L = V_P = 398.37$

Perphase impedance $Z_P = 9\Omega$

$$I_P = \frac{V_P}{Z_P} = \frac{398.37}{9} = 44.26A$$

In Δ networks $I_L = \sqrt{3} I_P$

$I_L = \sqrt{3} \times 44.26 A$

$= 76.666 A.$

Power per phase $= V_P I_P \cos\phi$ ~ p.f unity $= 1$

$= 398.37 \times 44.26 \times 1$

$= 17.63 \, kW$

Three phase power (Real power) $= 3 V_P I_P \cos\phi$

$= 3 \times 17.63$

$= 52.896 \, kW$

Three phase reactive power $= 3 \times V_P I_P \sin\phi$

$= 0 \, KVAr$