POWER ENGINEERING

#07 THREE-PHASE AC POWER SYSTEMS

POWER MEASUREMENT (2)

2018

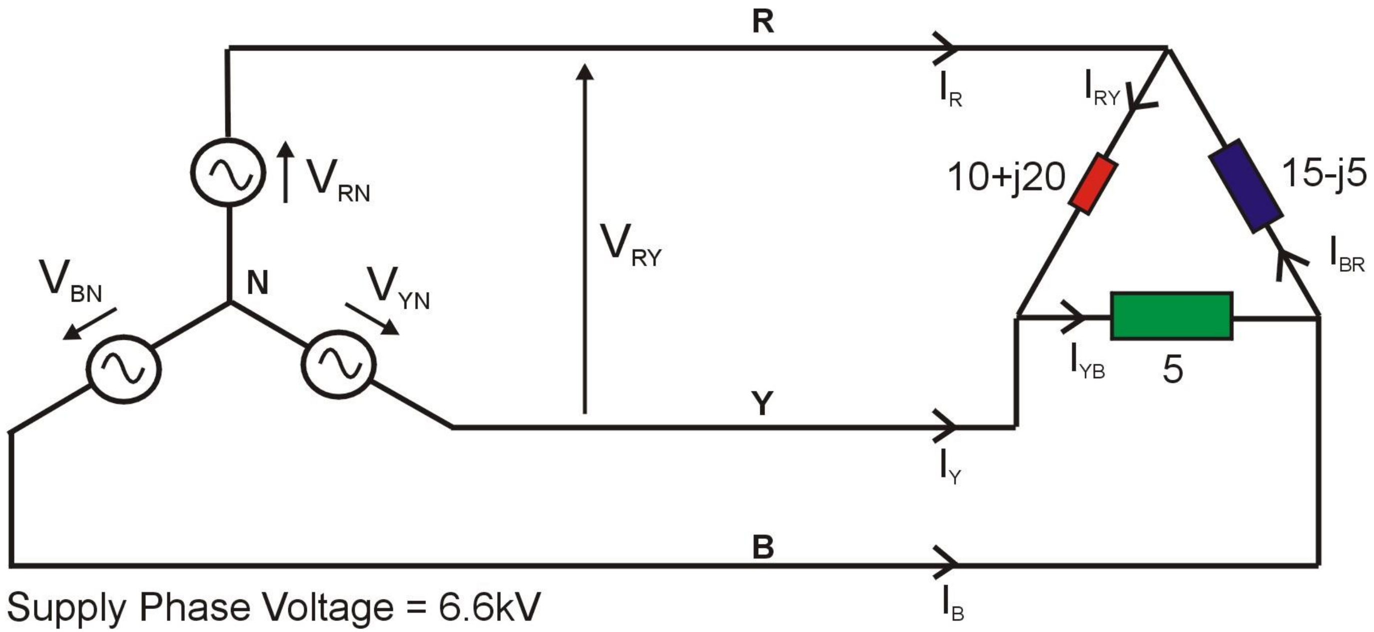
University of Glasgow

Unbalanced 3 Phase AC Systems

Today we will investigate:

- Unbalanced Delta connected load: Example #1 - continued
- Unbalanced Delta connected load: Example #2
- Unbalanced 3 wire Star connected load
- Unbalanced 4 wire Star connected load
- Unbalanced 4 wire Star connected load: Example
- Summary of application of 3 and 2 Wattmeter Methods

Unbalanced Delta connected load example #1 cont :



Determine:

1] All the load phase currents
2] Draw a phasor diagram (to scale) showing all line voltages and load phase currents. From this estimate the line currents.
3] The total 3 phase power (W) at the load

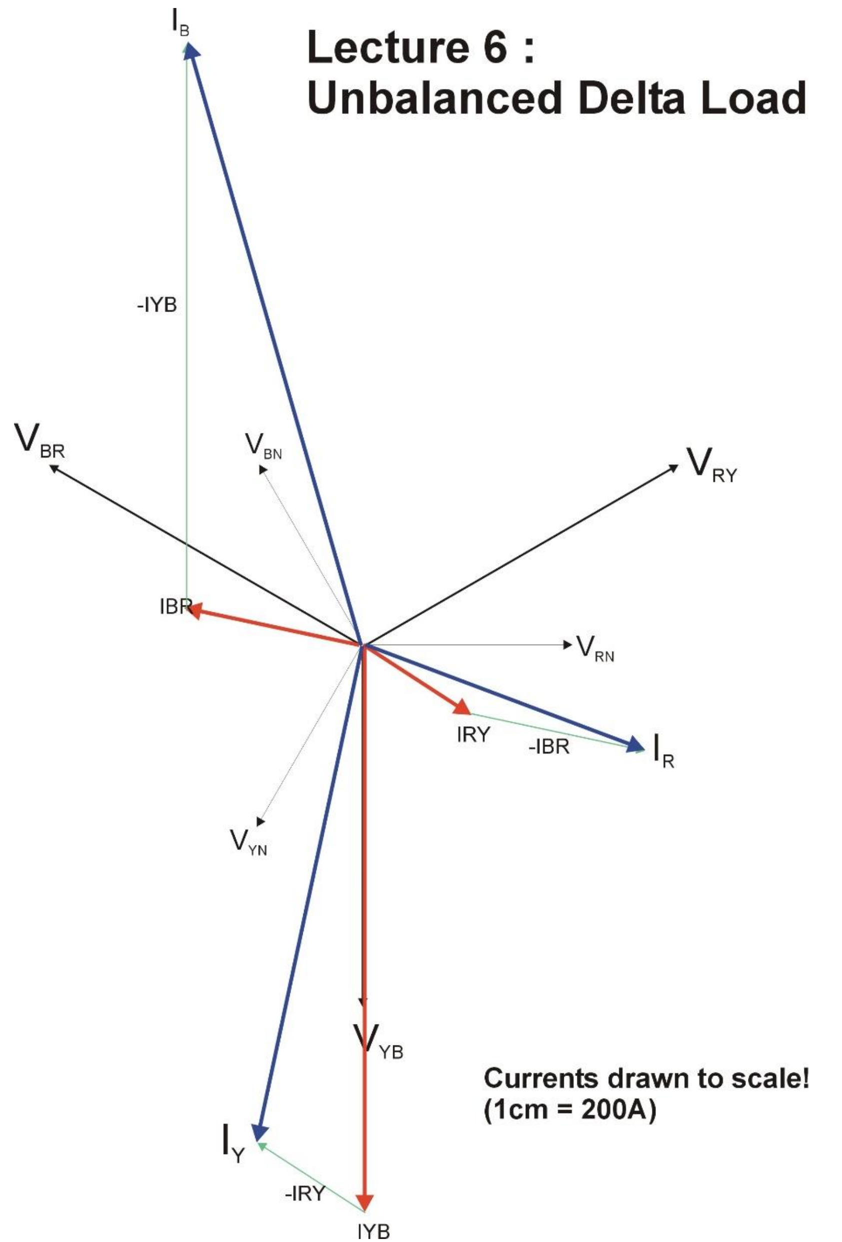
Solution done on Whiteboard

$$I_R = I_{RY} - I_{BR}$$

$$I_Y = I_{YB} - I_{RY}$$

$$I_B = I_{BR} - I_{YB}$$

Lecture 6 : Unbalanced Delta Load



Currents drawn to scale!
(1cm = 200A)

From Phasor Diagram:

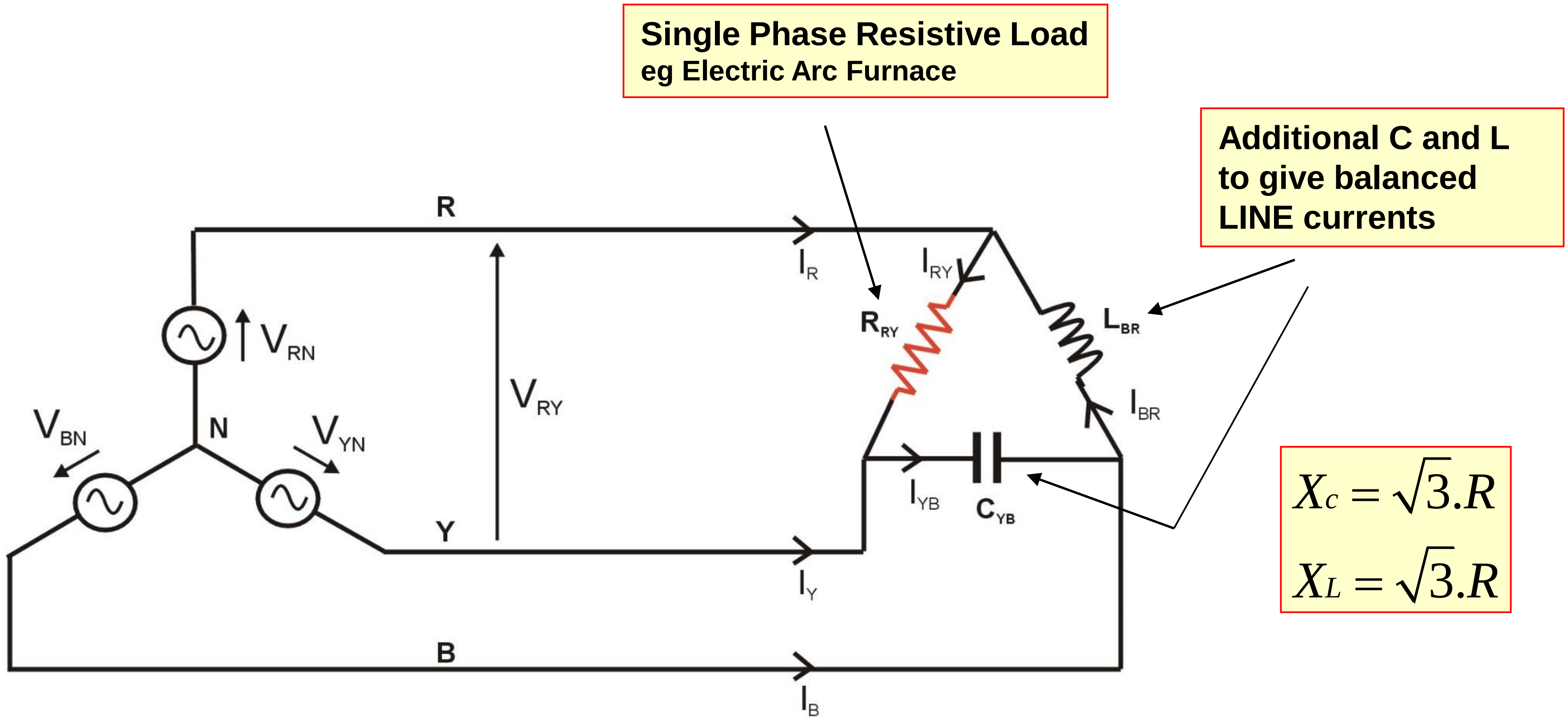
$$I_R = 1220\angle -20^o$$

$$I_Y = 2040\angle -102^o$$

$$I_B = 2520\angle 107^o$$

Unbalanced Delta connected load example #2:

Connecting a large single phase load to a 3 phase system

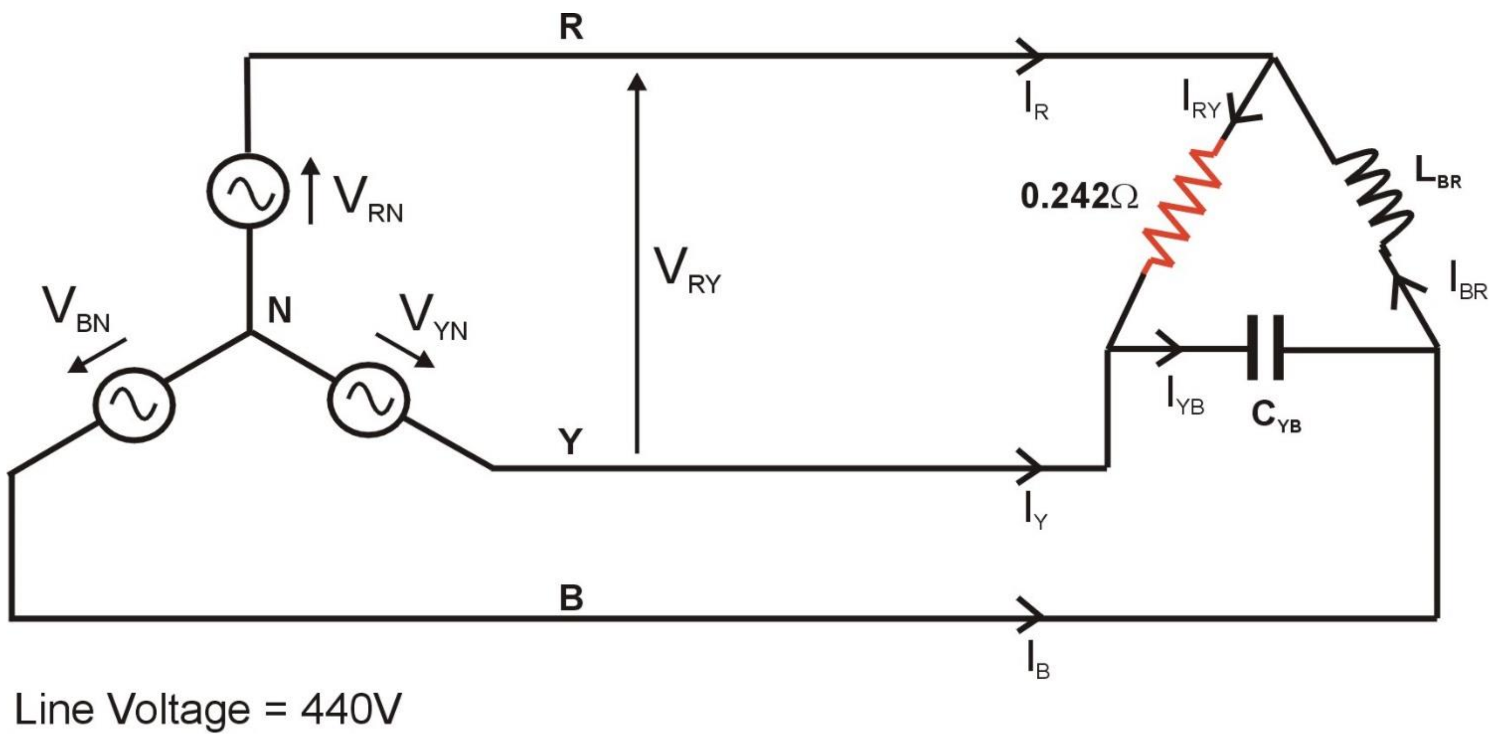


$$X_C = \sqrt{3}.R$$

$$X_L = \sqrt{3}.R$$

Note: the relative positions of L and C is essential for balanced operation

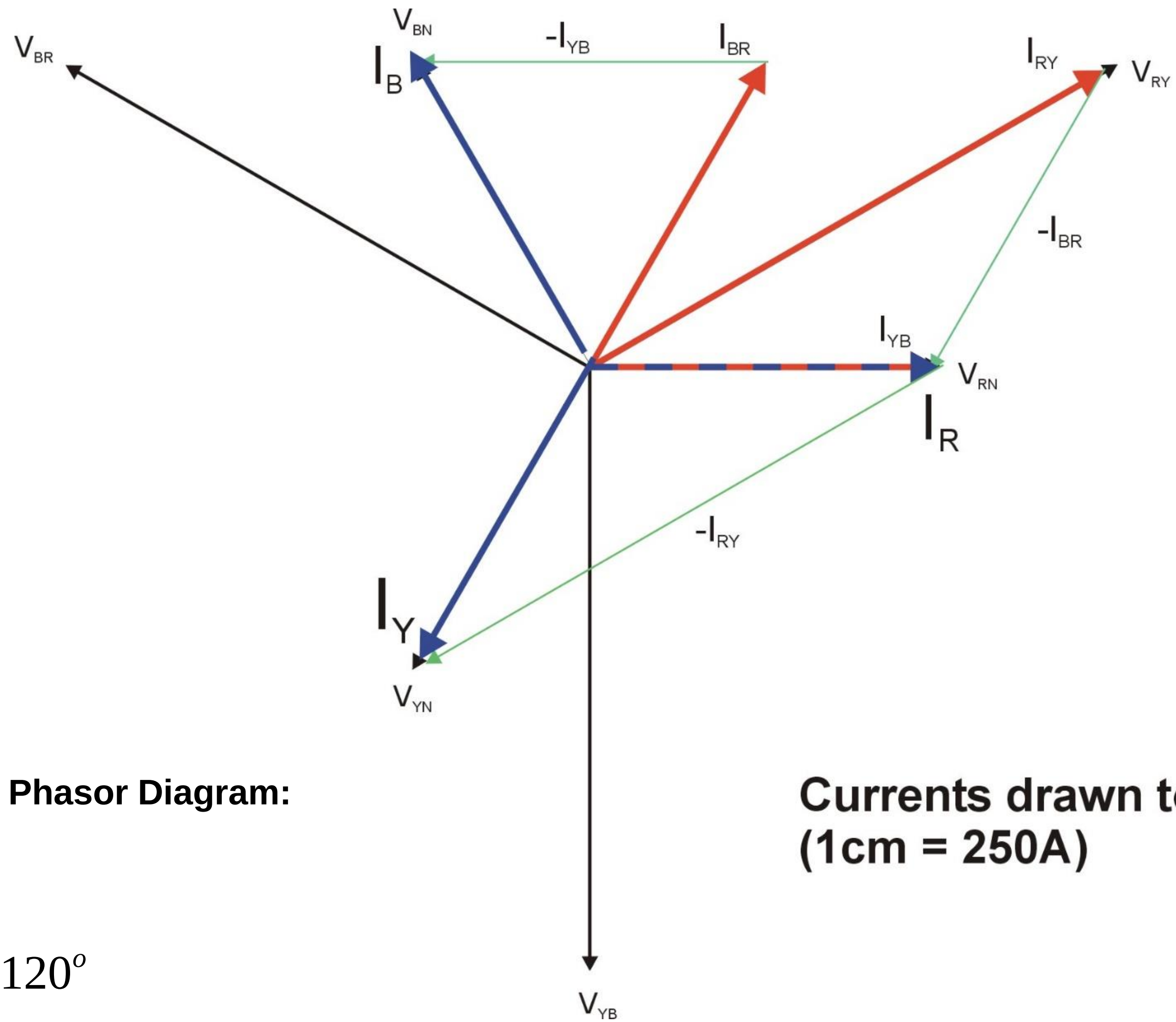
Example



Determine:

1] The Output Power (W) of the single phase load
2] The magnitude of the line currents for single phase load only connection
3] The line currents (phasors) for the balanced RCL configuration

Solution done on Whiteboard



Estimated from Phasor Diagram:

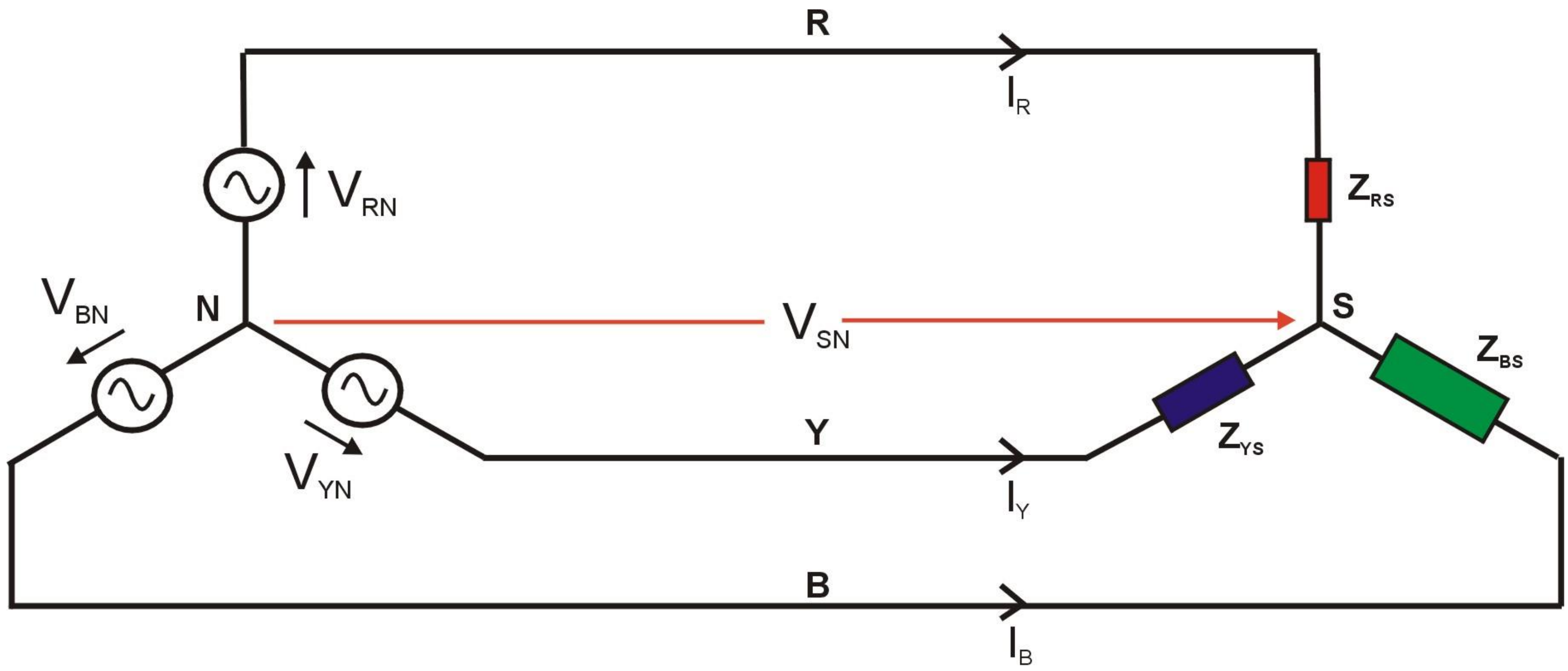
$$I_R = 1050\angle 0^o$$

$$I_Y = 1050\angle -120^o$$

$$I_B = 1050\angle 120^o$$

Currents drawn to scale!
(1cm = 250A)

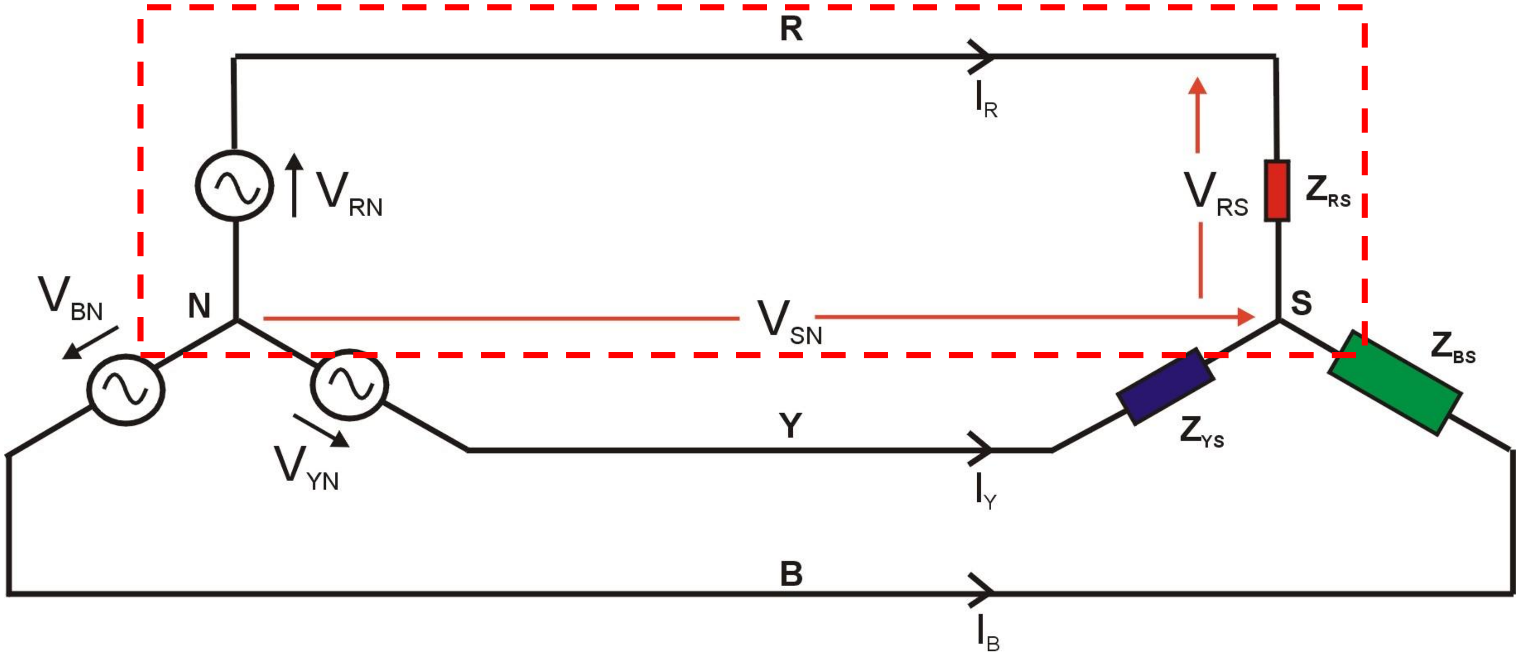
Unbalanced 3 wire Star connected load:



For the Unbalanced load: $Z_{RS} \neq Z_{YS} \neq Z_{BS}$

Therefore: $I_R \neq I_Y \neq I_B$ AND $\mathbf{V_{SN} \neq 0}$

Unbalanced 3 wire Star connected load:



$\mathbf{V_{RN} = V_{RS} + V_{SN}}$ $\mathbf{V_{YN} = V_{YS} + V_{SN}}$ $\mathbf{V_{BN} = V_{BS} + V_{SN}}$

Note: these are PHASORS

First of all we need to find an equation for V_{SN}

?????????????

Solution:

Step 1: Calculate V_{SN} using Millman's Theory:

$$V_{SN} = \frac{V_{RN}Y_R + V_{YN}Y_Y + V_{BN}Y_B}{Y_R + Y_Y + Y_B}$$

Note: Y are admittances

Step 2: Calculate load phase voltages:

$V_{RS} = V_{RN} - V_{SN}$

$V_{YS} = V_{YN} - V_{SN}$

$V_{BS} = V_{BN} - V_{SN}$

Step 3: Calculate line currents:

$$I_R = \frac{V_{RS}}{Z_{RS}} \qquad I_Y = \frac{V_{YS}}{Z_{YS}} \qquad I_B = \frac{V_{BS}}{Z_{BS}}$$

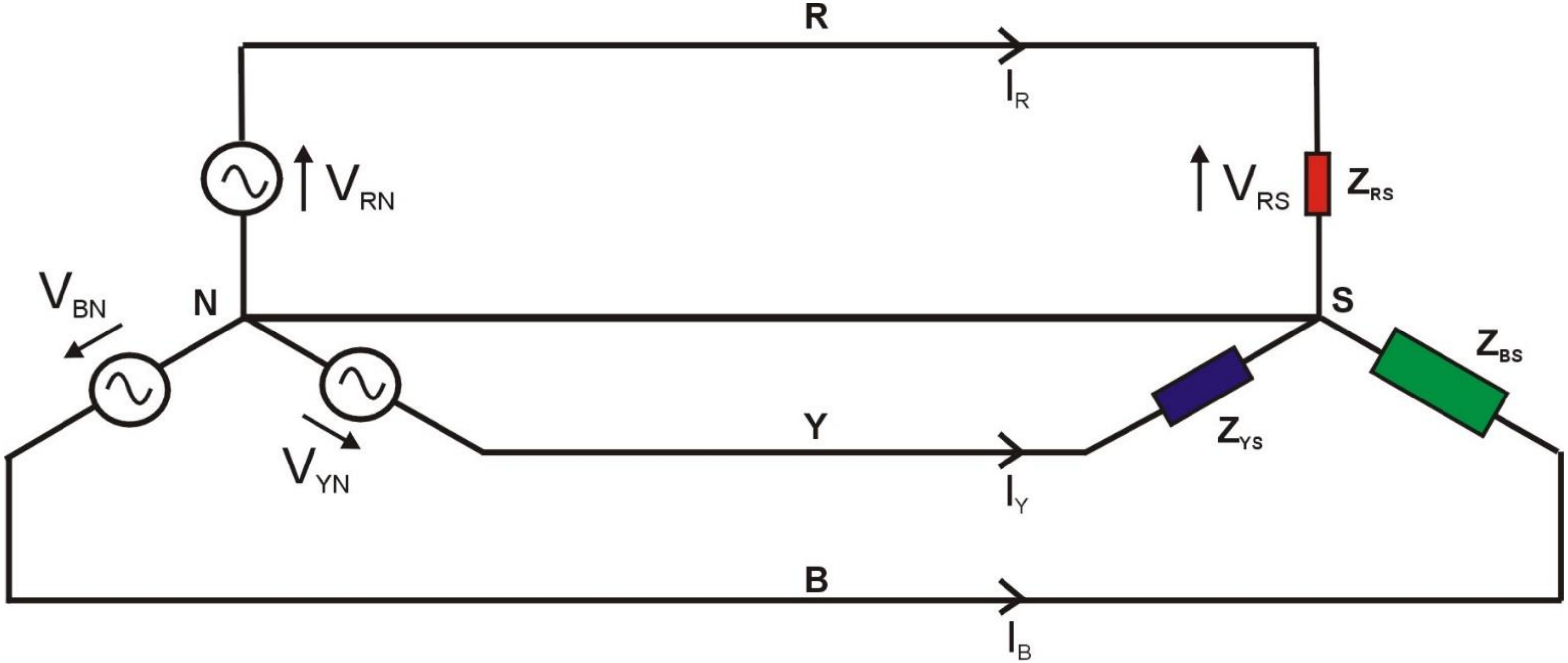
Step 4: Calculate Total Real Power:

$$P_T = |V_{RN}|.|I_R|.\cos\Phi_R + |V_{YN}|.|I_Y|.\cos\Phi_Y + |V_{BN}|.|I_B|.\cos\Phi_B$$

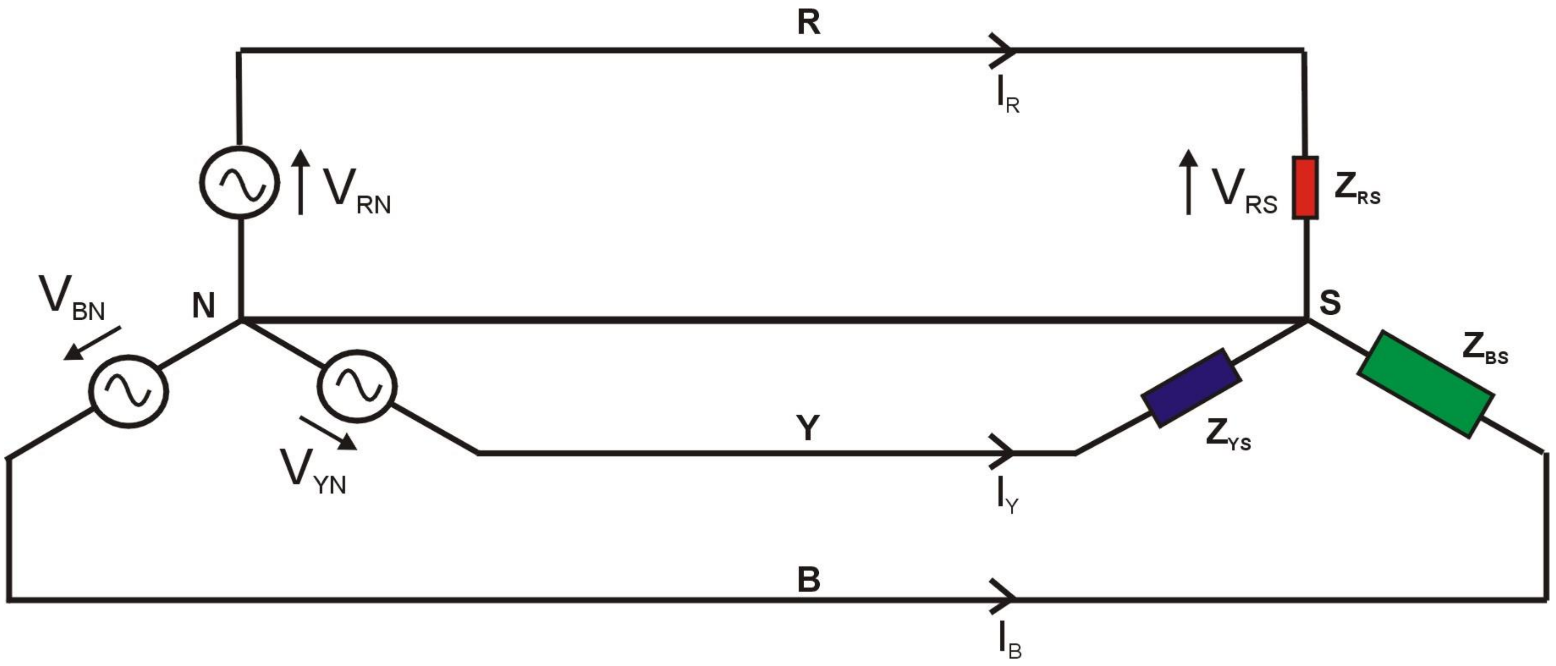
Unbalanced 4 wire Star connected load:

The most important result of an unbalanced 3 wire Star connected load is that the load phase voltages are no longer equal to the supply phase voltages which could result in dangerous over-voltage conditions in one or more of the phases.

A solution is to have a physical connection between the generator neutral and the load star point:



Unbalanced 4 wire Star connected load:



For the Unbalanced load: $Z_{RS} \neq Z_{YS} \neq Z_{BS}$

Therefore: $I_R \neq I_Y \neq I_B$ BUT $V_{SN} = 0$ AND $V_{RS} = V_{RN}$, $V_{YS} = V_{YN}$ & $V_{BS} = V_{BN}$

Solution:

Step 1: Calculate individual line currents:

$$I_R = \frac{V_{RN}}{Z_{RS}} \qquad I_Y = \frac{V_{YN}}{Z_{YS}} \qquad I_B = \frac{V_{BN}}{Z_{BS}}$$

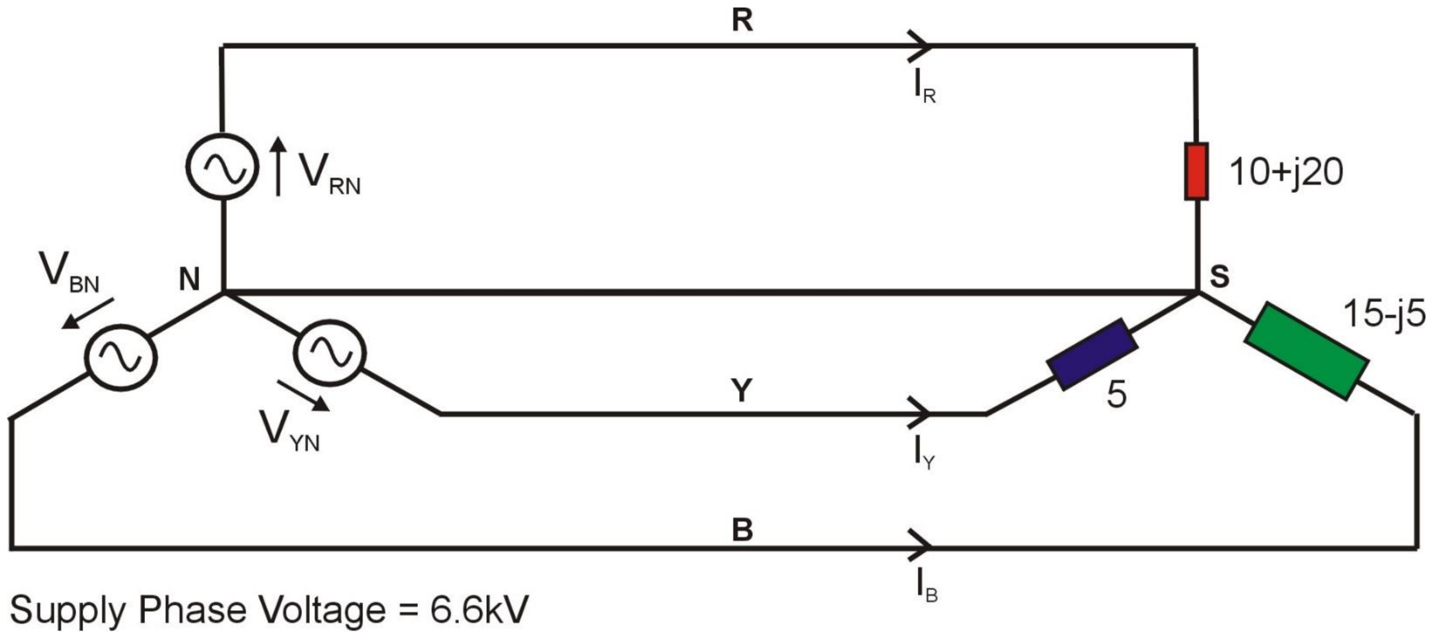
Step 2: Calculate Total Real Power:

$$P_T = |V_{RN}|.|I_R|.\text{Cos}\Phi_R + |V_{YN}|.|I_Y|.\text{Cos}\Phi_Y + |V_{BN}|.|I_B|.\text{Cos}\Phi_B$$

Note we can also calculate the current flowing down the Star-Neutral connection:

$$I_{SN} = I_R + I_Y + I_B$$

Example: **a contractor is required to install a Star/Neutral connection. They are proposing using 10mm diameter wire – will this be sufficient?**



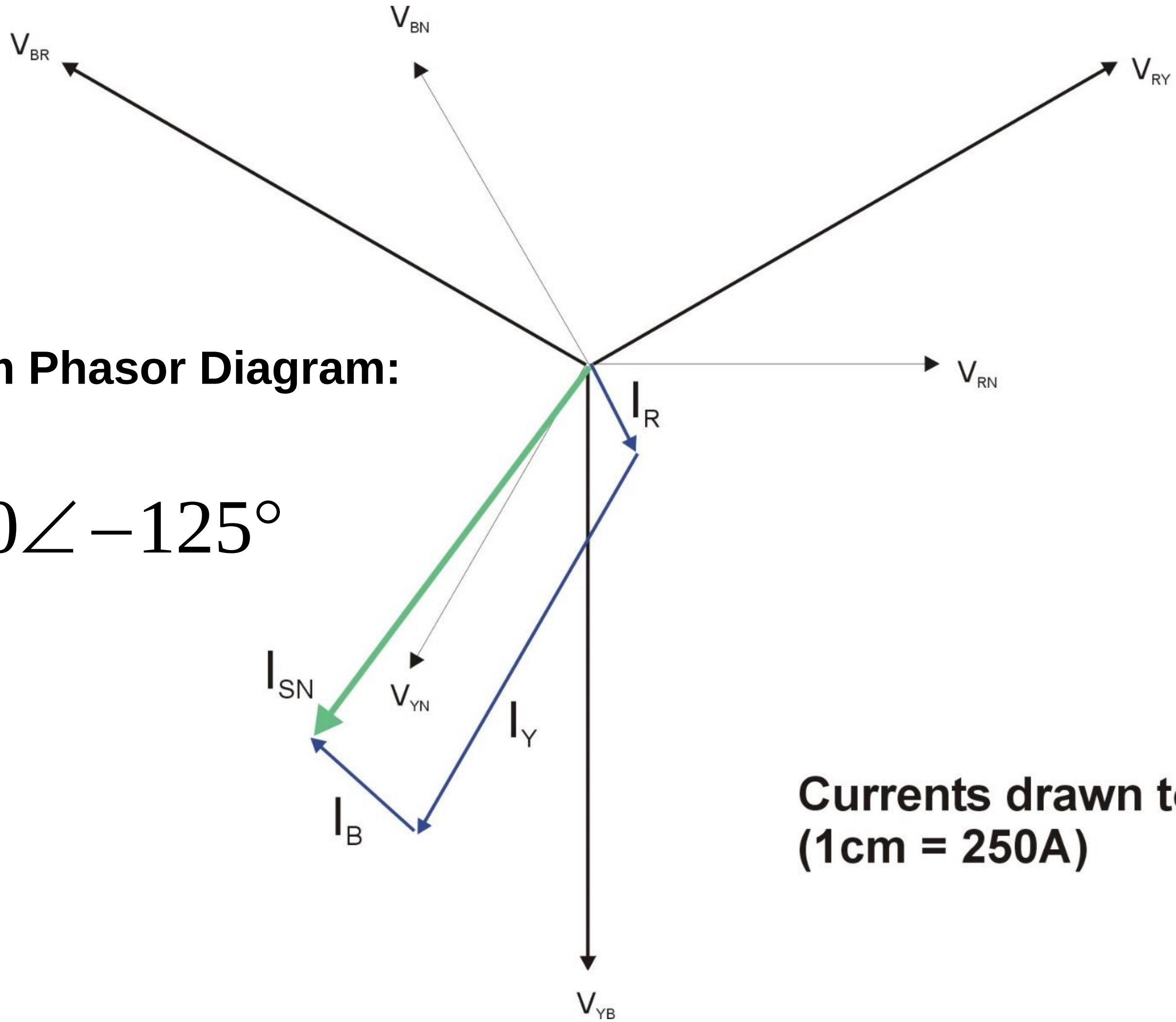
Determine:

1] All the line currents
2] The Star/Neutral line current
3] The current density (A/mm^2) in the Star/Neutral connection

Solution done on Whiteboard

Estimated from Phasor Diagram:

$$I_{SN} = 1400\angle -125°$$



Currents drawn to scale!
(1cm = 250A)

Application of 3 Wattmeter and 2 Wattmeter Methods

	3 Wattmeter	2 Wattmeter
Balanced Star Load	✓	✓
Balanced Delta Load	✓	✓
Unbalanced Delta Load	✓	✓
Unbalanced 3 wire Star Load	✓	✓
Unbalanced 4 wire Star Load	✓