FACULATY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Basic Electrical Engineering Lab (ENEE 2101)

Report of Experiment 10

“Three Phase Circuits”

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Abstract:

This experiment explores the behavior of three-phase circuits, focusing on star (Y) and delta (Δ) configurations. It analyzes voltage, current, and power relationships under balanced and unbalanced conditions.

Theory:

Alternating current generators with specific coil configurations, such as those in three-phase synchronous generators, produce a three-phase (3ϕ) system. The generated waveforms are sinusoidal and offset by 120° relative to each other, ensuring continuous and balanced power delivery. Depending on the relationship between phase and line-to-line voltages.

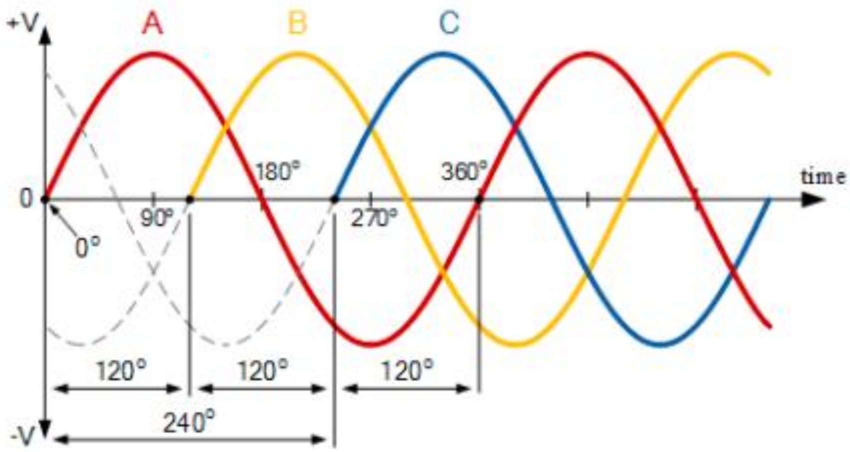

Figure 1: Three Phase voltages

Two primary connection types star (Y) and delta (Δ) are commonly employed in generator setups. These configurations are essential for the efficient distribution and transfer of electrical power.

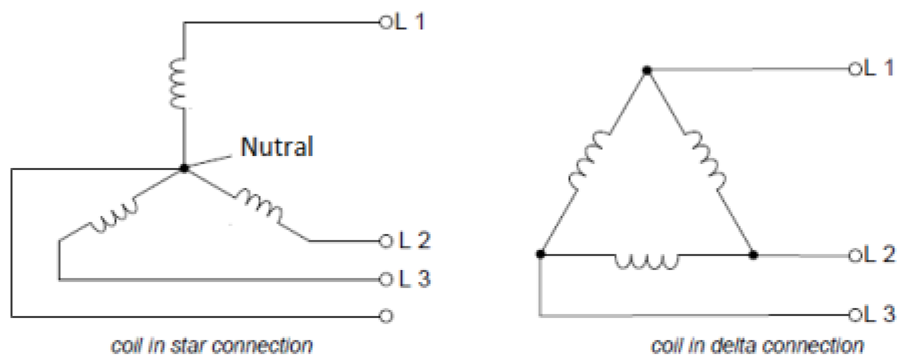

Figure 2:Star and Delta Connections

The relationships between phase (ph) and line-to-line connections in star and delta configurations are shown in the table below.

Star (Y) connection	Delta (Δ) connection
$V_L = \sqrt{3}V_{ph}\angle 30°$	$V_L = V_{ph}$
$I_L = I_{ph}$	$I_L = \sqrt{3}I_{ph}\angle -30°$

Table 1: phase and line to line voltages in Star and Delta connections

Three phase power:

The power in a three-phase system is given by:

$$P_{3phase} = P_{phase1} + P_{phase2} + P_{phase3}$$

In a balanced three-phase system, real power can be calculated using two methods:

Using Line Quantities

When the line voltage (V_l) and line current (I_l) are known, the total real power is computed as:

$$P_{3ph} = \sqrt{3} V_{Line} I_{Line}$$

Using Phase Quantities

When the phase voltage (V_p) and phase current (I_p) are known, the total real power is computed as:

$$P_{3ph} = 3 V_{ph} I_{ph}$$

Procedure:

- ***Part A: Source***

In this section, the phase voltages of a three-phase system will be measured using an oscilloscope. Then, the corresponding voltage waveforms will be plotted to analyze the system's behavior.

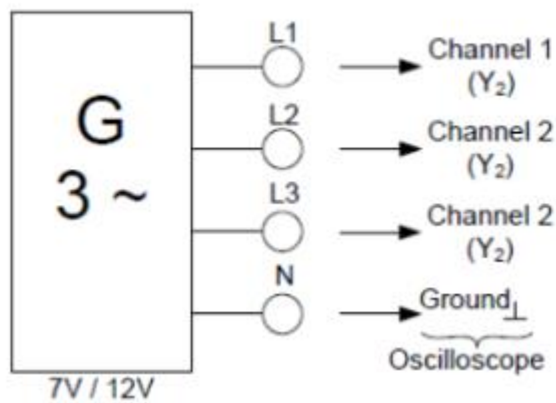

Figure 3: source connection

First, connect the oscilloscope channels: channel 1 to L1-N and channel 2 to L2-N. Then, measure the time period (T) and the time shift between the two waveforms (Δt), and record the results in Table 10.1

After that, swap channel 2 to L3-N and determine if the sequence is {abc} or {acb}, and record the answer in Table 10.2.

Then using oscilloscope math function $(\boldsymbol{V_{L1.L2} = V_{L1,N} - V_{L2.N}})$ to calculate the relation between line-to-line voltage $\boldsymbol{V_{L1.L2}}$ with the phase voltage $\boldsymbol{V_{L1,N}}$ finally phase and line voltages are measured with multimeter and recorded the results it table1e 10.3

- ***Part B: Star-Star system***

In this part, we must connect the circuit in two ways. First, for a balanced load, this means the three resistances are equal, each being 1kΩ. Then, measure the phase currents, phase voltage, and line voltage. After that, we must connect the circuit in an unbalanced load, where the three resistances are not equal (1kΩ, 680Ω, 330Ω), and measure the same parameters, then record the results in Table 10.4

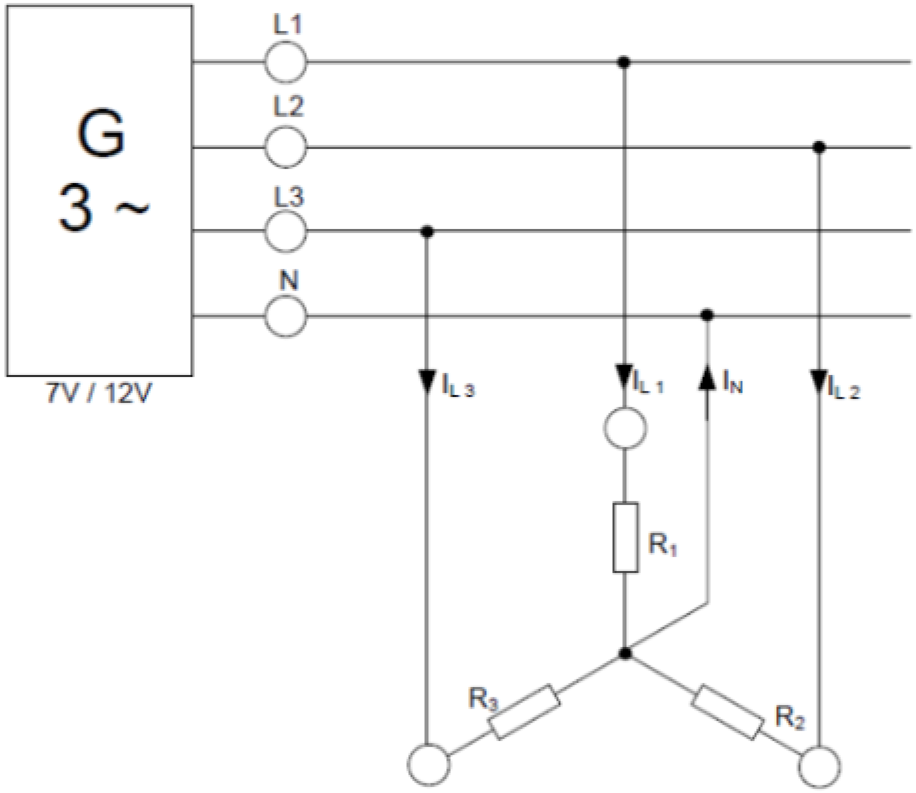

Figure 4 Y-Y system

- ***Part C: Star-Delta system***

In this part, we must connect the circuit in two ways. First, for a balanced load, this means the three resistances are equal, each being 1kΩ. Then, measure the line currents, phase currents, and line voltages which also equal the phase voltages. After that, we must connect the circuit in an unbalanced load, where the three resistances are not equal (1kΩ, 680Ω, 330Ω), and measure the same parameters, then record the results in Table 10.5

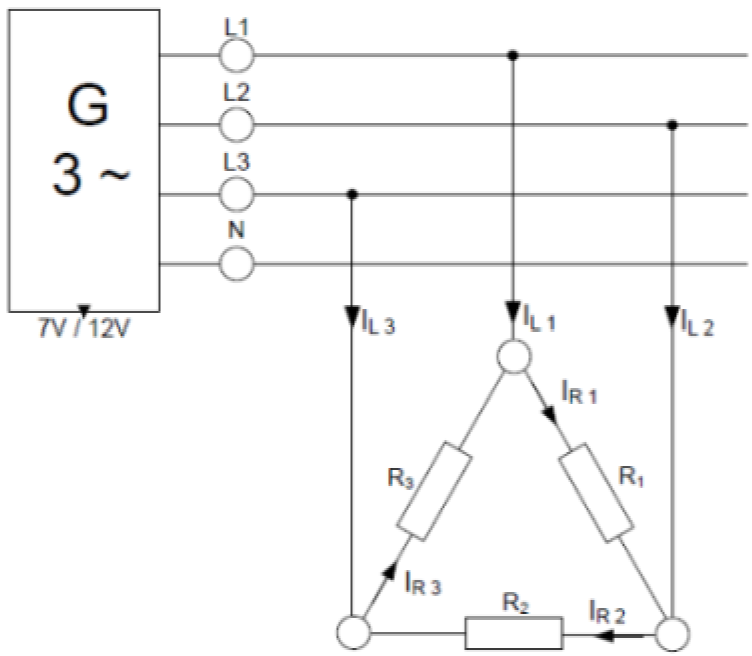

Figure 5 Y-Δ system

Data, calculations, and analysis of results:

- ***Part A: Source***

Measure T and Δt from the waveforms displayed on the oscilloscope,

Time-period T	20 ms
Time-shift between the two waveforms Δt	7 ms
Phase shifting angle	$\Delta\theta = 360*f*\Delta t = 126°$
Source frequency	F = 1\T = 50Hz

Table 2: 10.1 Table, three phase table

Here's the revised version of your sentence:

As mentioned before, the values of T and Δt were measured in the lab. After that, we calculated the phase shift, which represents the angle between the two waveforms and must equal 120°.

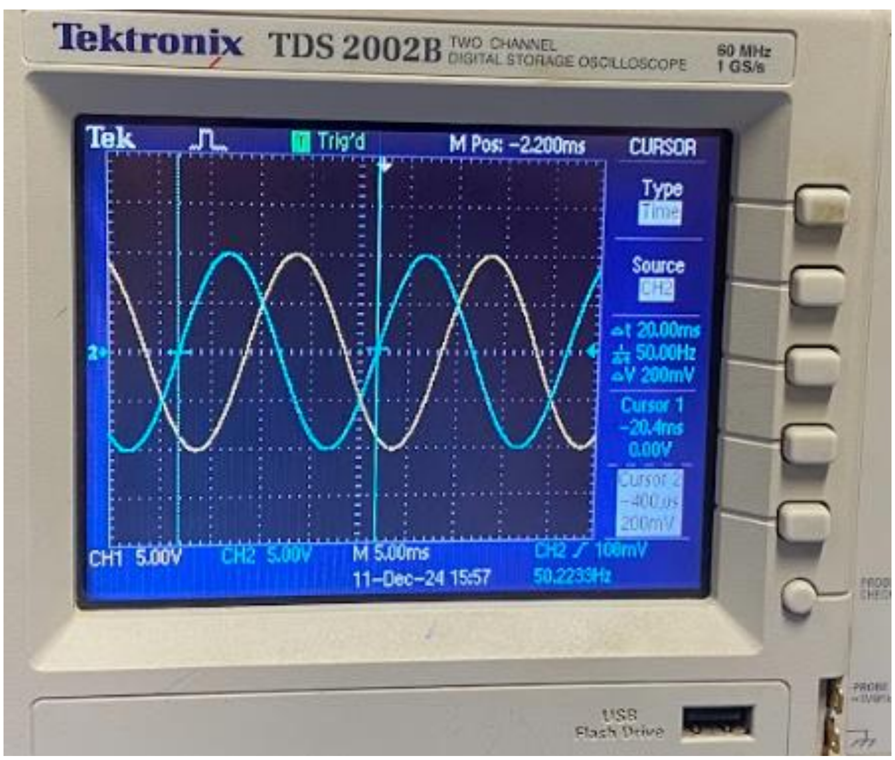

Figure 6 : waveform L1.L2

Sequence abc or acb?	abc

Table 3 : Sequence

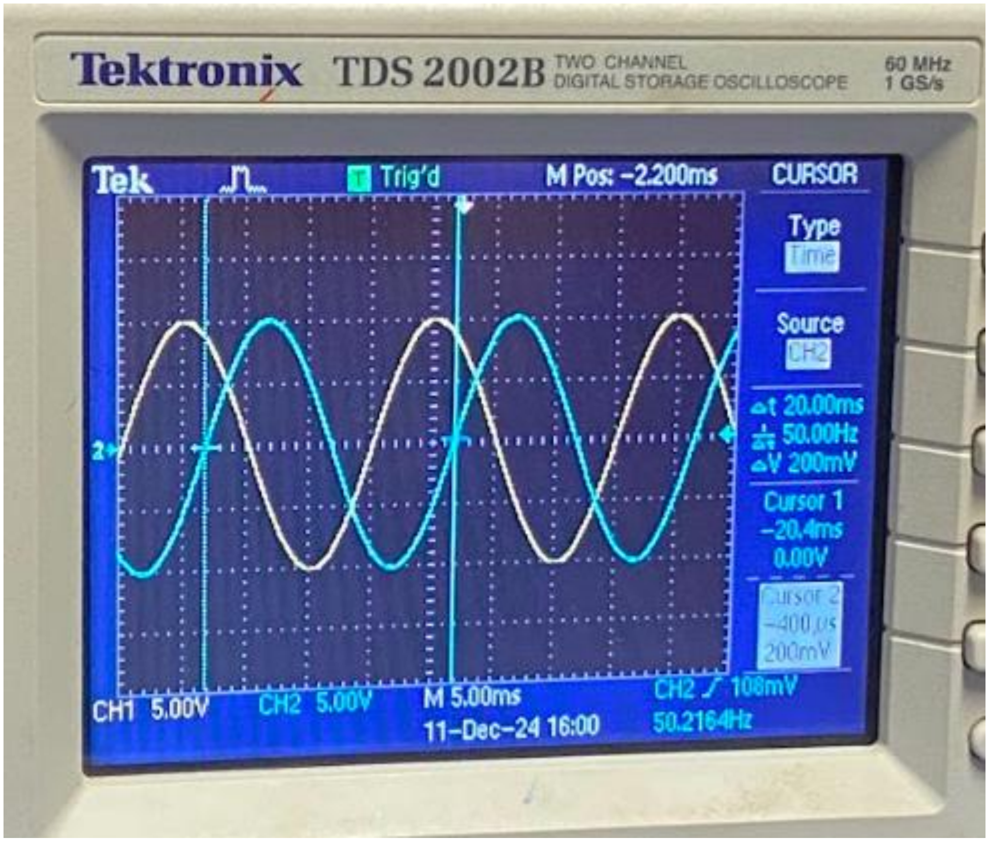

Figure 7 Waveform L2.L3

In the first picture, the yellow wave represents L1, while the blue wave represents L2. As we can observe, the L1 wave comes first, followed by L2. However, when we swape the phase between L2 and L3, we see that L3, represented by the blue wave, comes first, and L2, represented by the yellow wave, follows. Therefore, **the sequence is {abc},** knowing that L1 is (a), L2 is (b) and L3 is (c).

$V_{L1,N} = 6.97$	$V_{L1,L2} = 12.08$
$V_{L2,N} = 7.05$	$V_{L2,L3} = 12.20$
$V_{L3,N} = 7.00$	$V_{L3,L1} = 12.14$
Calculate the linkage factor defined as $\boldsymbol{V_{L,L}/V_{L,N}}$	1.734
Calculate the peak value $\boldsymbol{V_{L,N}}$	9.89
Calculate the peak value $\boldsymbol{V_{L,L}}$	17.168

Table 4: Line and Phase voltages

$$\boldsymbol{V_{L,N} = \frac{6.97 + 7.05 + 7}{3} = 12.14}$$

$$\boldsymbol{V_{L,L} = \frac{12.08 + 12.05 + 12.14}{3} = 7}$$

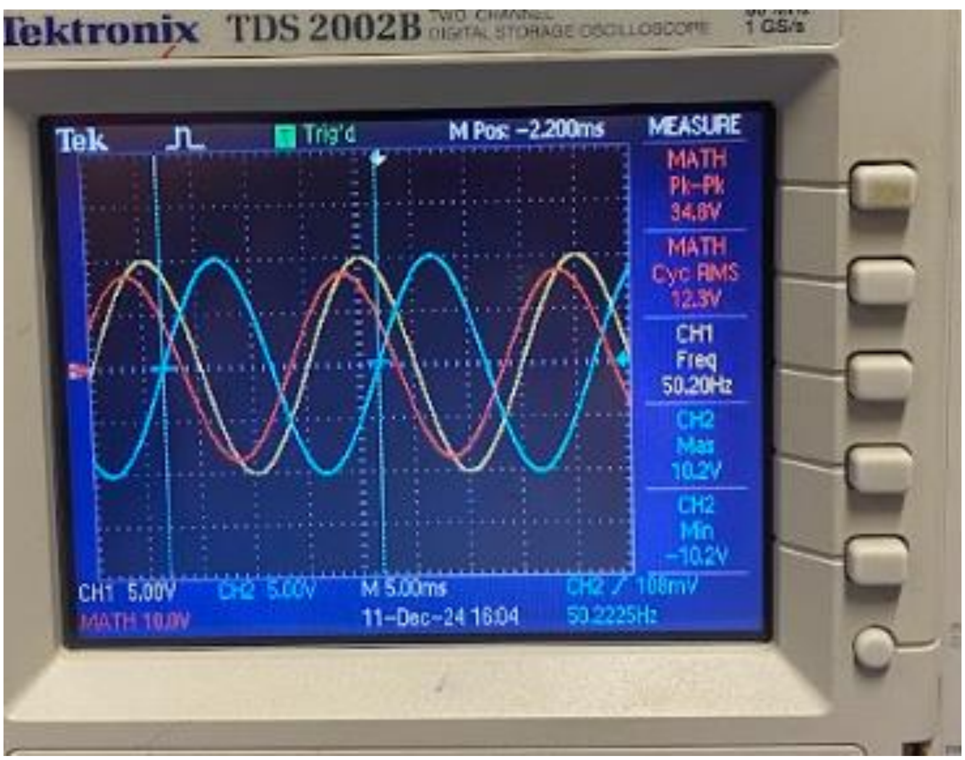

Figure 8: Math function figure

After applying the math function in the oscilloscope we can see the red wave is ($\boldsymbol{V_{L1.L2} = V_{L1,N} - V_{L2.N}}$) so this function will show to us the relation between line-to-line voltages and phase and line voltages.

- ***Part B: Star-Star system***

Y-Y connection		Balanced Load	Unbalanced Load
Resistor	R1	1KΩ	1KΩ
	R2	1KΩ	680Ω
	R3	1KΩ	330Ω
Phase Currents	$\boldsymbol{I_{L1}}$	7.01	9.96
	$\boldsymbol{I_{L2}}$	7.06	10.45
	$\boldsymbol{I_{L3}}$	7.01	21.00
	$\boldsymbol{I_{N}}$	0.11	12.3
Line Voltages	$\boldsymbol{V_{L1,L2}}$	12.01	12.00
	$\boldsymbol{V_{L2,L3}}$	12.16	12.10
	$\boldsymbol{V_{L3,L1}}$	12.07	12.02
Phase Voltages	$\boldsymbol{V_{L1,N}}$	6.91	6.92
	$\boldsymbol{V_{L2,N}}$	7.02	7.00
	$\boldsymbol{V_{L3,N}}$	6.98	6.91
Phase Power	$\boldsymbol{P_{R1}}$	48.44mW	48.16mW
	$\boldsymbol{P_{R2}}$	49.56mW	73.15mW
	$\boldsymbol{P_{R3}}$	48.92mW	145.11mW
Total Power	$\boldsymbol{P_{3ph}}$	146.92mW	266.42mW

Table 5: Balance and Unbalanced loads for Y-Y connection

First, we connected the balanced loads in a Y configuration, as shown in Figure 4 Using a multimeter, we measured the phase voltages and currents. The results indicated that in balanced loads, both the currents and voltages were equal across all phases, However, when we connected unbalanced loads, the phase currents varied across the loads, although the voltages remained consistent.

We then calculated the phase power using the formula:

$$P = V_{L,N}\, I_L$$

where $V_{L,N}$ is the line-to-neutral voltage and I_L is the line current

Additionally, the total power was found to be higher in the unbalanced load configuration. This is because the unbalanced loads had lower resistance compared to the balanced loads, resulting in higher currents according to Ohm's Law.

- ***Part C: Star-Delta system***

Y-Y connection		Balanced Load	Unbalanced Load
Resistor	R1	1KΩ	1KΩ
	R2	1KΩ	680Ω
	R3	1KΩ	330Ω
Line Currents	$\boldsymbol{I_{L1}}$	20.8	42.2
	$\boldsymbol{I_{L2}}$	20.8	25.9
	$\boldsymbol{I_{L3}}$	20.6	46.5
Phase currents	$\boldsymbol{I_{R1}}$	11.95	11.8
	$\boldsymbol{I_{R2}}$	12.00	17.6
	$\boldsymbol{I_{R3}}$	12.00	35.2

Line Voltages =Phase Voltages	$V_{L1,L2}$	12.01	11.8
	$V_{L2.L3}$	11.91	11.85
	$V_{L3,L1}$	12.01	11.62
Phase Power	P_{R1}	143.5mW	139.24mW
	P_{R2}	142.92mW	208.56mW
	P_{R3}	144.12mW	409.00mW
Total Power	P_{3ph}	430.54mW	756.8mW

Table 6: Balance and Unbalanced loads for Y-Δ connection

First, we connected the balanced loads in a delta configuration, as shown in Figure 5 Using a multimeter, we measured the currents and voltages. The results showed that, for balanced loads, both the currents and voltages were nearly identical across all loads. When unbalanced loads were connected, the phase currents varied between the loads, while the voltages remained constant. We then calculated the power, which was found to be higher for the unbalanced loads compared to the balanced ones.

Conclusion:

In the three-phase experiment, we observed the behavior of both balanced and unbalanced loads in Y and Δ configurations. For balanced loads, the currents and voltages were equal across all phases, showing the symmetry of the system. On the other hand, unbalanced loads caused differences in the phase currents, while the phase voltages stayed the same. In conclusion, we learned how to connect three-phase circuits in both delta and Y configurations for balanced and unbalanced loads.

References:

-ENEE2101-Manual

-Data taken in the laboratory

Data sheet:

Experiment 10 - Data Tables:

Table 10.1: Three Phase Data

Time-period T	20 ms
Time shift between the two waveforms Δt	$\Delta t = 7$ ms
Phase shifting angle $\xrightarrow{50\ Hz}$ $360 * f * \Delta t = 120$	$360 \times 50 \times 7\times10^{-3}$ $\Delta\theta = 126$
Source frequency $\frac{1}{T} = 50$	$= \frac{1}{20\times10^{-3}} = 50$ Hz

Table 10.2: Sequence

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Sequence abc or acb?	abc

Table 10.3: Line and Phase Voltages

$V_{L1,N} =$ 6.97	$V_{L1,L2} =$ 12.08
$V_{L2,N} =$ 7.05	$V_{L2,L3} =$ 12.20
$V_{L3,N} =$ 7.00	$V_{L3,L1} =$ 12.14
Calculate the linkage factor defined as $V_{L,L}/V_{L,N} =$ $V_{L,N} = 12.14$, $V_{L,L} = 7 \Rightarrow \frac{V_{L,L}}{V_{L,N}} = \frac{12.14}{7} = 1.734$	
Calculate the peak value of $V_{L,N} =$ $V_P = \sqrt{2}\, V_{L,N} = \sqrt{2}\,(7) = 9.89$	
Calculate the peak value of $V_{L,L} =$ $V_P = \sqrt{2}\, V_{L,L} = \sqrt{2}\,(12.14) = 17.168$	

Table 10.4: Balance and Unbalanced loads for Y-Y Connection

Y-Y connection		Balanced Load	Unbalanced Load
Resistor	R_1	1 kΩ	1 kΩ
	R_2	1 kΩ	680 Ω
	R_3	1 kΩ	330 Ω
Phase Currents	I_{L1}	7.01	6.96
	I_{L2}	7.06	10.45
	I_{L3}	7.01	21.0
	I_N	0.11	12.3
Line Voltages	$V_{L1,L2}$	12.01	12.00
	$V_{L2,L3}$	12.16	12.10
	$V_{L3,L1}$	12.07	12.02
Phase Voltages	$V_{L1,N}$	6.91	6.92
	$V_{L2,N}$	7.02	7.00
	$V_{L3,N}$	6.98	6.91
Phase Power	P_{R1}	$V_{L1,N} \times I_{L1} = 48.44$ mW	$V_{L1,N} \times I_{L1} = 48.16$ mW
	P_{R2}	$V_{L2,N} \times I_{L2} = 49.56$ mW	$V_{L2,N} \times I_{L2} = 73.15$ mW
	P_{R3}	$V_{L3,N} \times I_{L3} = 48.92$ mW	$V_{L3,N} \times I_{L3} = 145.11$
Total Power	P_{3ph}	$= 146.92$ mW	$= 266.42$ mW

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Table 10.5: Balance and Unbalanced loads for Y-Δ Connection

Y-Δ Connection		Balanced Load	Unbalanced Load
Resistor	R_1	1 kΩ	1 kΩ
	R_2	1 kΩ	680 Ω
	R_3	1 kΩ	330 Ω
Line Currents	I_{L1}	~~11.95~~ 20.8	42.2
	I_{L2}	20.8	25.9
	I_{L3}	20.6	46.5
Phase Currents	I_{R1}	11.95	11.8
	I_{R2}	12.0	17.6
	I_{R3}	12.0	35.2
Line Voltages =phase voltages	$V_{L1,L2}$	12.01	11.8
	$V_{L2,L3}$	11.91	11.88
	$V_{L3,L1}$	12.01	11.62
Phase Power	P_{R1}	$V_{L1,L2} \times I_{R1}$ = 143.5 mW	$V_{L1,L2} \times I_{R1}$ = 139.24 mW
	P_{R2}	$V_{L2,L3} \times I_{R2}$ = 142.92 mW	$V_{L2,L3} \times I_{R2}$ = 208.56 mW
	P_{R3}	$V_{L3,L1} \times I_{R3}$ = 144.12 mW	$V_{L3,L1} \times I_{R3}$ = 409.0 mW
Total Power	P_{3ph}	= 430.54 mW	= 756.8 mW

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