

1909750

by Ethan Joel

FILE	11105_ETHAN_JOEL_1909750_177819_1126870645.PDF (863.23K)		
TIME SUBMITTED	17-MAY-2020 04:51PM (UTC+0100)	WORD COUNT	2822
SUBMISSION ID	127953366	CHARACTER COUNT	19077

Course: HNC Electrical And Electronic Engineering
Module: SGEE4000 – Electrical and Electronic Principles
Assignment Title: Three Phase Systems
Name: Ethan Joel
University Number: 1909750
Date Submitted: 17/05/2020
Word Count: 2292

Contents

Table Of Figures.....	3
1. Introduction and Background Theory.....	4
2. Research	5
Task 3	5
Task 4	6
Task 5	8
Star – star	9
Star-Delta	9
Delta – Delta	10
Delta – Star	10
3. Experimental Procedure's and Results	11
Task 1 - Star	11
Task 1 – Delta	13
Task 2 – Star Unbalanced Circuit.....	14
Calculations.....	14
4. Discussion of Results	15
Task 1	15
Comparison Table	15
Task 2	15
Comparison Table	15
Task 3	15
Comparison Table	15
5. Conclusions.....	16
6. Reference List and Bibliography	17
Bibliography.....	17

Table Of Figures

Figure 1 - Three Phase Wave	5
Figure 2 - Motor Torque	6
Figure 3 - Power Factor	7
Figure 4 - Transformer	8
Figure 5 - STAR-STAR	9
Figure 6 STAR-DELTA	9
Figure 7 - DELTA-DELTA	10
Figure 8 - DELTA-STAR	10
Figure 9 – Task 1 - Star	11
Figure 10 - Power Triangle.....	12
Figure 11 - Task 1 Delta	13
Figure 12 - Task 2.....	14
Table 1 - Task 1	15
Table 2 - Task 2	15
Table 3 - Task 3	15

1. Introduction and Background Theory

Within this report, research and practical activities will be carried out with regards to different types of three phase systems. Three phase systems consist of three different voltages with a phase difference of 120° . These days, three phase systems within Europe are coloured Brown, Black and Grey whereas, in the United States, these colours are Red, Yellow and Blue.

Research will be carried out on three phase systems and why throughout the world, electricity is transmitted this way. Linked with this, the term 'Power Factor' will be explained and it's use within Electrical systems.

The report will also contain circuits representing both Star and Delta loads both balanced and unbalanced. Calculations will be calculated to work out various different values such as Impedances, phase angles and both Line and Phase Currents. To back up these calculations, a computer-based simulation package; 'NI Multisim' will be used to simulate the circuit to give accurate answers to the formulae. By having two sets of answers, this allows a full analysis of the results.

2. Research

Task 3

Three phase electrical systems are used around the world for various different applications. One of the main differences and why it's used is it has 3 Live wires compared to just the one within a single phase system. This meaning, three phase systems supply a more constant and reliable current. This is one reason why electricity is transmitted in this form, if one phase was disturbed, the other two phases would still deliver the power. (Nisbets, n.d.)

The total sum of the current within two phases equal to the magnitude within the other phase. With three phase systems, the phases are separated by 120° as shown in the image below.

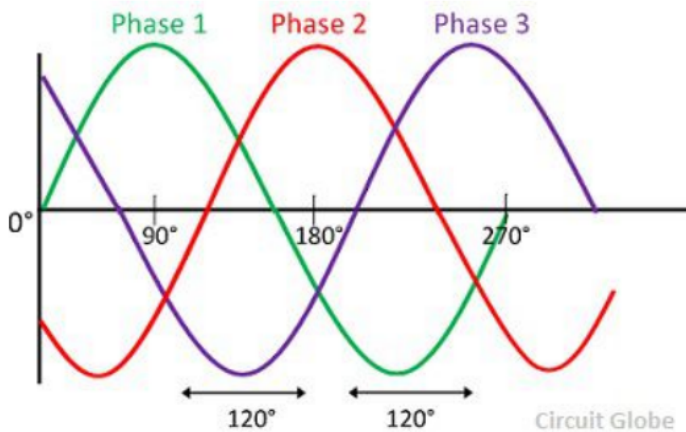


Figure 1 - Three Phase Wave

<https://circuitglobe.com/wp-content/uploads/2017/03/wave-shape-three-phase-systems.jpg>

Three phases tend to have 4/5 cables with the other cores tending to be a neutral and sometimes an earth depending on the application.

With regards to the neutral, the wire is equal to the total sum of the line currents of the three phases. Therefore, equal to the $\sqrt{3}$ multiplied by the zero phase sequence components of current.

(Anon., n.d.)

Another reason for the use of 3 phase systems is Motors. Induction motors are powered by three phase and Compared with a single-phase motor, a three-phase induction motor has higher power factor and efficiency. Also, Three-phase motors are self-starting due to the initial starting torque. This isn't the case with single phase motors and initially need an alternate starting method due to the lack of torque. This can be seen in the diagram below showing the initial torque that 3 phase systems have.

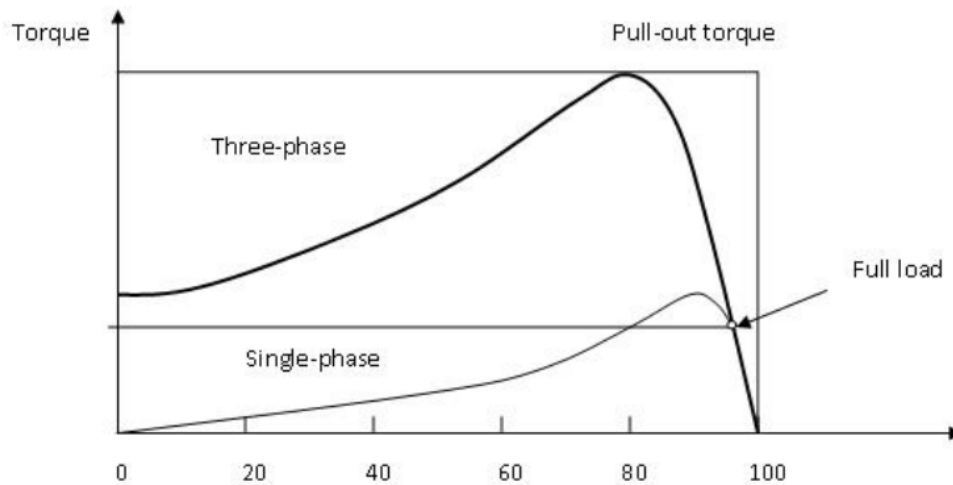


Figure 2 - Motor Torque

Another major benefit and reason why three phased are used with regards to motors is that the motor direction can be simply changed by swapping over two of the phases. This isn't possible with single phase motors as single phase has no rotation.

Some other major benefits of using three phases is that three phase distribution requires less conductors therefore less cost for the transferring the same amount of power.
(Transistor, 2016)

Task 4

Power factor is the ratio of working power to apparent power, which is shown as the following equation;

$$PF = kW/kVA$$



Power factor is a value which represents electrical utilisation. It's a representation of how effectively you are using the electricity. The higher the power factor the better in simpler terms. It's significant within electrical systems as it gives the user/company an idea of how effective their electricity usage is and gives them an induction of whether they can improve it to reduce costs.

By improving the power factor, it can improve the voltage to equipment, reduce power losses which results in cheaper costs aswell as maximising the capacity of current.

One way of improving the power factor is to introduce correction capacitors to the system. Correction capacitors can be installed anywhere within the circuit such as the distribution or at

the specified equipment. These capacitors work by offsetting the non-working power by inductive loads.

(Anon., n.d.)

Power factor has a maximum value of '1' otherwise known as unity which represents the most efficient loading of a system. A poor power factor can be classed as 0.9 or less. Machines and utilities such as induction motors and furnaces tend to bring the value of Power factor down.

Aswell as the financial benefits, power factor can also save energy. Due to it making your electrical system more efficient, greenhouse gas emissions will decrease which results in a reduced carbon footprint.

(Admin, 2019)

Within electrical systems, there are 3 different types of power factor being a leading, lagging and unity power factor.

A leading power factor represents that the circuits load is capacitive. This is because there is more capacitive reactance than inductive reactance in the circuit. This means the current will lead the voltage by 90° . Whereas a lagging power factor is the complete opposite. Unity as explained above is a purely resistive load.

(Technology, 2019)

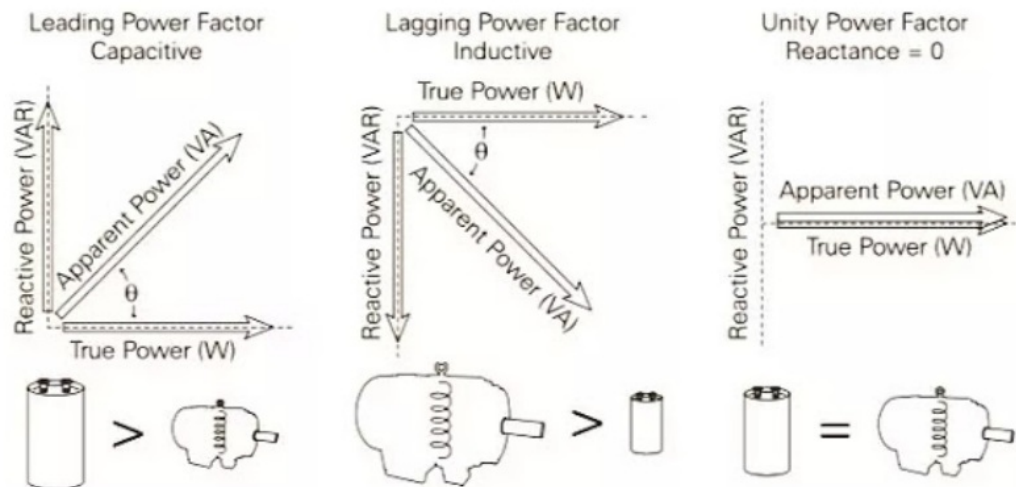


Figure 3 - Power Factor

<https://www.electrical-technology.com/2019/05/what-is-power-factor-and-why-is-it-important.html>

Task 5

Both the primary and secondary windings of a three-phase transformer can be wired in four different arrangements being;

- STAR – DELTA
- STAR – STAR
- DELTA – DELTA
- DELTA STAR

Whichever configuration is chosen depends on what voltage is required and what application the transformer is supplying. The primary windings on a transformer tend to be marked with upper-case letters where the secondary is the opposite. Similarly, each winding within the transformer is labelled '1' and '2' to show the start and end points of each winding.

Aswell as markings, symbols are also used to represent the winding arrangements and can be found on the transformer label. The symbol 'Y' represents star and 'D' represents delta. Therefore, a Star to Delta connected transformer would be identified as 'Yd'.
(Anon., n.d.)

Figure 4 below shows an example of a Star and Delta connected transformer from Primary to Secondary.

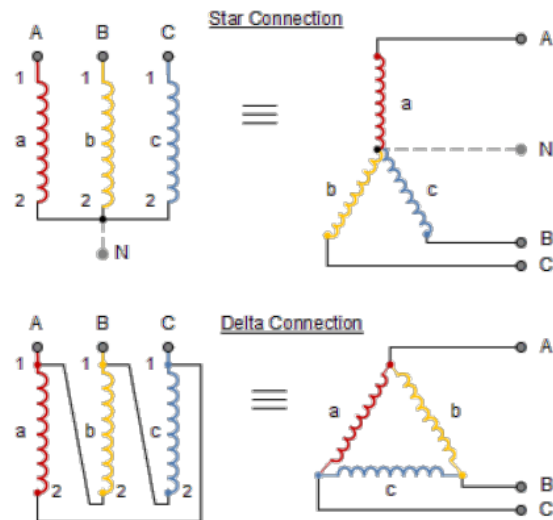


Figure 4 - Transformer

<https://www.electronics-tutorials.ws/wp-content/uploads/2018/05/transformer-trans36.gif>

Star – star

With a Star-Star connected transformer, VL (Line Voltage) is 3X the phase voltage. This connection type causes some problems however, if the load is unbalanced and a neutral is absent, the phase voltages become severely unbalanced. Although a benefit to this arrangement is that there's a Star point at both sides of the transformer which supplies a neutral point.

(Anon., n.d.)

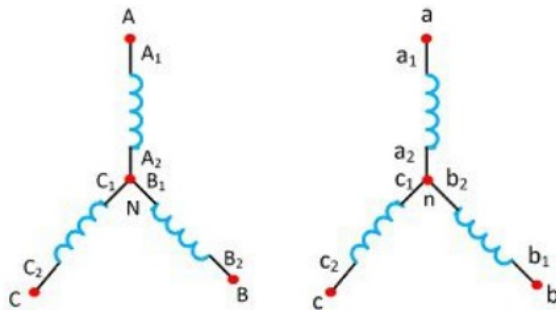


Figure 5 - STAR-STAR

This type of connection arrangement is hardly used these days due to the difficulties with the exciting current.

(Anon., n.d.)

Star-Delta

This type of transformer arrangement is used in step down processes. In this arrangement, the line voltage is $\sqrt{3}$ times the primary phase voltage. A benefit of this arrangement is due to the primary side being STAR connected, fewer turns are required which makes it more economical and efficient. Also, some unbalanced loads can be handled effectively.

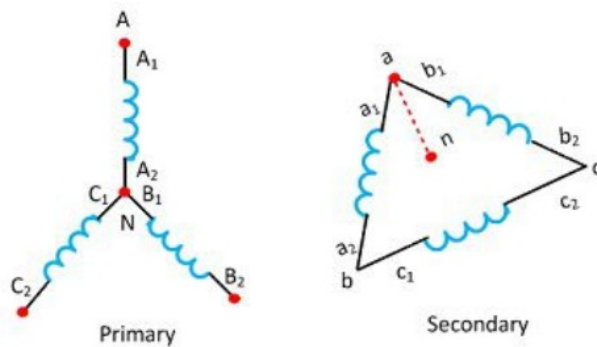


Figure 6 STAR-DELTA

One type of application for this arrangement is for power supply transformers. Its commonly installed within substations where the voltage needs to be stepped down. E.g from 6.6kV to 415V.

(jiguparmar, 2020)

Delta – Delta

With the Delta – Delta arrangement, both the Line and Phase Voltages don't change from the Primary to Secondary side which also means there isn't any phase shift between the voltages. Also, due to it being a closed Delta circuit, there are no harmonic voltages.

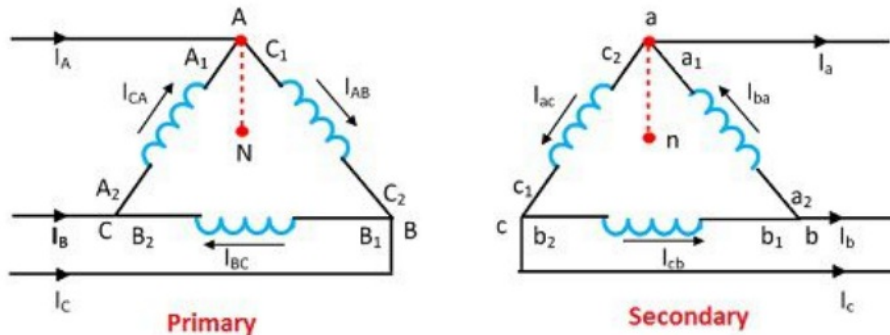


Figure 7 - DELTA-DELTA

This type of arrangement is used in systems where it needs to carry a large current on low voltages.

Delta – Star

This connection arrangement serves the purpose of stepping up the voltage. Unlike the Delta to Delta system, there is a phase shift of 30° . Also, the line voltage on the primary side of the transformer is equal to the phase voltage on the primary side. Another similarity with the Dd system is that large loads can be handled effectively.

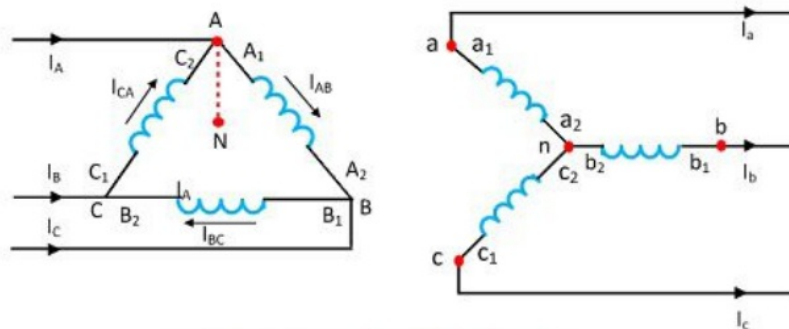


Figure 8 - DELTA-STAR

Opposingly to the Star-Delta arrangement, an application for this type is that its commonly used as a step-up transformer, where the voltage needs to be stepped up. This helps due to the

secondary side leading the primary by 30°. It's a popular arrangement used within the distribution sector as the Star secondary includes both 3 and 4 wire systems.

3. Experimental Procedure's and Results

Task 1 - Star

Figure 9 below shows a balanced R-L series circuit connected in STAR. As you can see it contains a 200mH inductor, a resistor of a chosen value of 75Ω, aswell as a Line voltage of 210V.

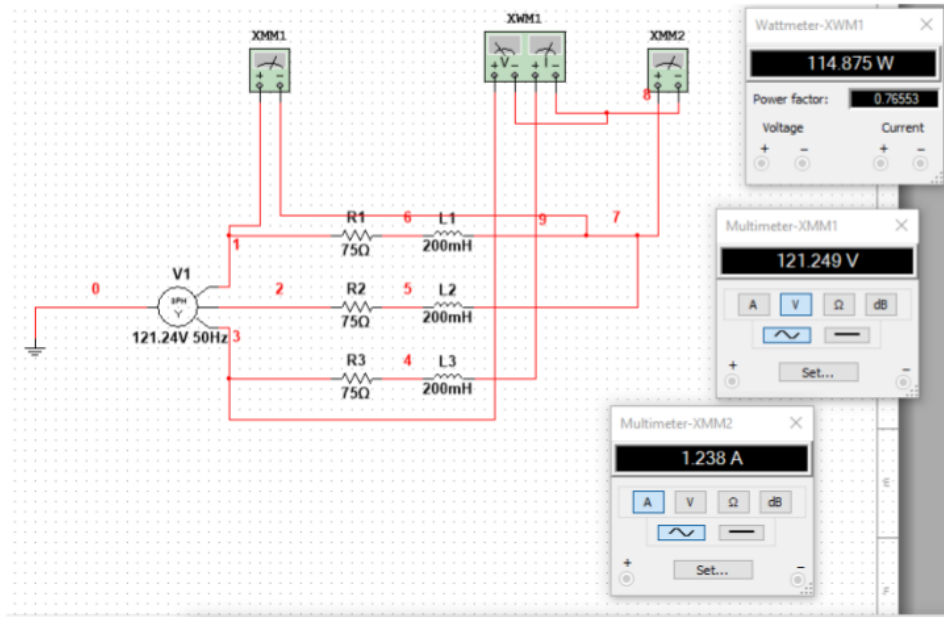


Figure 9 – Task 1 - Star

Below are the calculations for the circuit;

Calculations

$$\text{Inductive Reactance } (X_L) = 2\pi FL = 2\pi(50)(200 \times 10^{-3}) = 62.83\Omega$$

$$\text{Phase Impedance } (Z_P) = \sqrt{R^2 + X_L^2} = \sqrt{75^2 + 62.83^2} = 97.84\Omega$$

$$\text{Phase Voltage } (V_P) = \frac{V_L}{\sqrt{3}} = \frac{210}{\sqrt{3}} = 121.24V$$

$$\text{Phase/Line Current } (I_L/I_P) = \frac{V_P}{Z_P} = \frac{121.24}{97.84} = 1.24A$$

$$\text{CARTESIAN} = 1.24 \times \cos(39.96) = 0.95 \quad 1.24 \times \sin(39.96) = j0.79 \quad = 0.95j0.79$$

$$\text{Phase Angle } (\phi) = \tan^{-1} \frac{X_L}{R} = \frac{62.83}{75} = 39.96^\circ$$

$$\text{Power Factor} = \cos(\phi) = \cos(39.96) = 0.77$$

$$\text{True Power (P)} = I^2 R = 1.24^2 \times 75 = 115.32 \text{ W}$$

$$\text{Reactive Power (Q)} = I^2 X_L = 1.24^2 \times 62.83 = 96.6 \text{ W}$$

$$\text{Apparent Power (S)} = I^2 Z = 1.24^2 \times 97.84 = 150.44 \text{ W}$$



Power Triangle

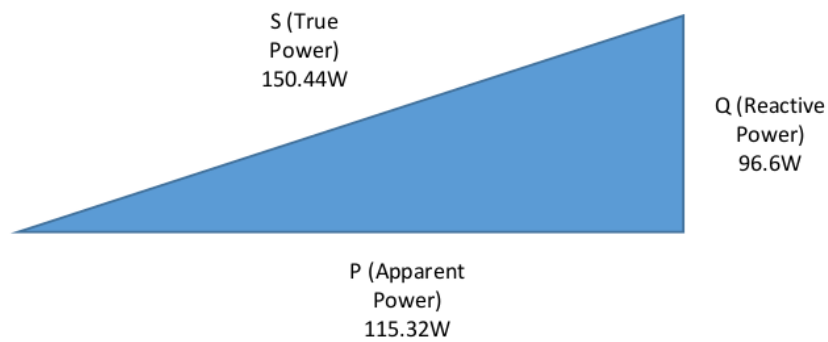


Figure 10 - Power Triangle

Please see comparison and evaluation in [Section 4.](#)

Task 1 – Delta

Figure 11 below shows Delta connected 3 phase circuit created on a simulation software package called NI Multisim. The circuit has the same values in terms of frequency, line voltage

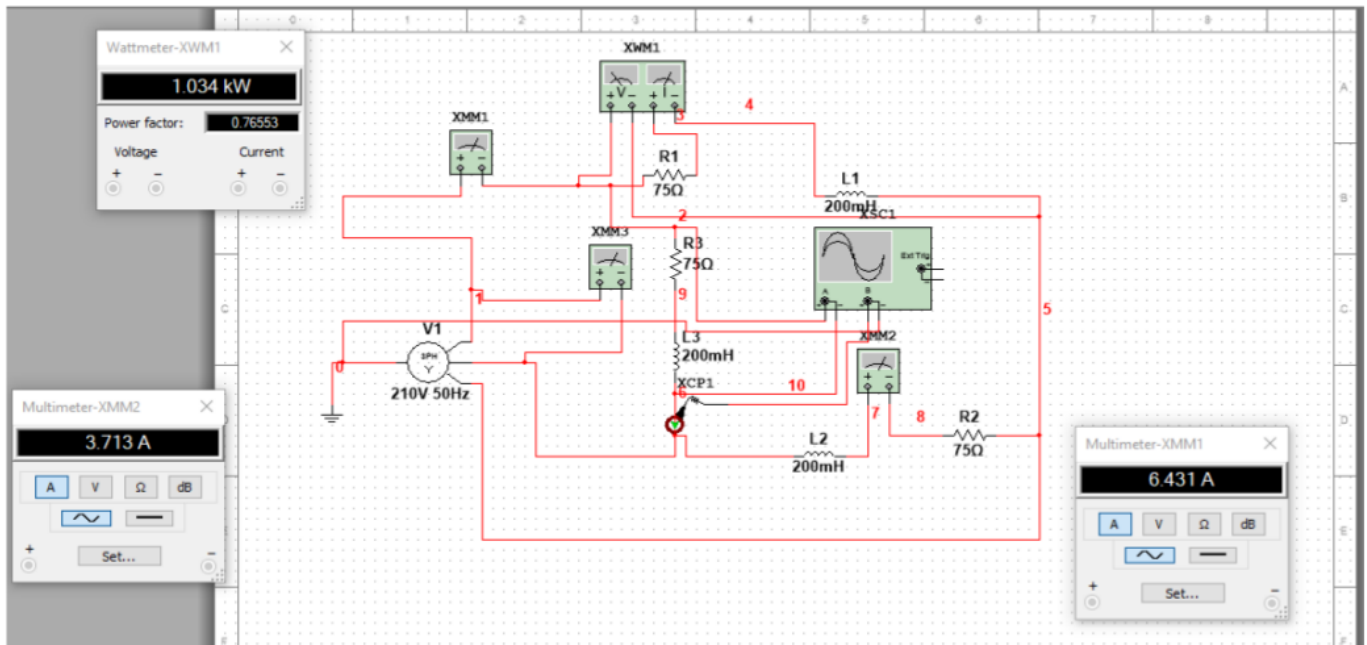


Figure 11 - Task 1 Delta

and inductor values as the previous star circuits, but the fact the circuits connected in delta, means that some calculations are different as shown below.

Line Current = 3.713A
Power Factor = 0.77

Phase Current = 6.431A

Power = 1.034kW

Calculations

$$\text{Inductive Reactance } (X_L) = 2\pi FL = 2\pi(50)(200 \times 10^{-3}) = 62.83\Omega$$

$$\text{Phase Impedance } (Z_P) = \sqrt{R^2 + X_L^2} = \sqrt{75^2 + 62.83^2} = 97.84\Omega$$

$$\text{Phase Current } (I_P) = \frac{V_L}{Z_P} \times \sqrt{3} = \frac{210}{97.83} \times \sqrt{3} = 2.14 \times \sqrt{3} = 3.71A$$

$$\text{Line Current } (I_L) = \sqrt{3} \times I_{ph} = \sqrt{3} \times 3.71 = 6.43A$$

$$\text{Phase Angle } (\phi) = \tan^{-1} \frac{X_L}{R} = \frac{62.83}{75} = 39.96^\circ$$

$$\text{Power Factor} = \cos(\phi) = \cos(39.96) = 0.77$$

$$\text{True Power } (P) = 3 \times V_{ph} \times I_{ph} \times \cos\phi = 3 \times 210 \times 2.14 \times 0.77 = 1033W$$

Please see comparison and evaluation in [Section 4](#).

Task 2 – Star Unbalanced Circuit

In figure 12 below, we have the same STAR connected circuit as in task 1 with the exception that its unbalanced. The inductor's have been removed and the 3 resistor values chosen are 50Ω, 70Ω and 100Ω

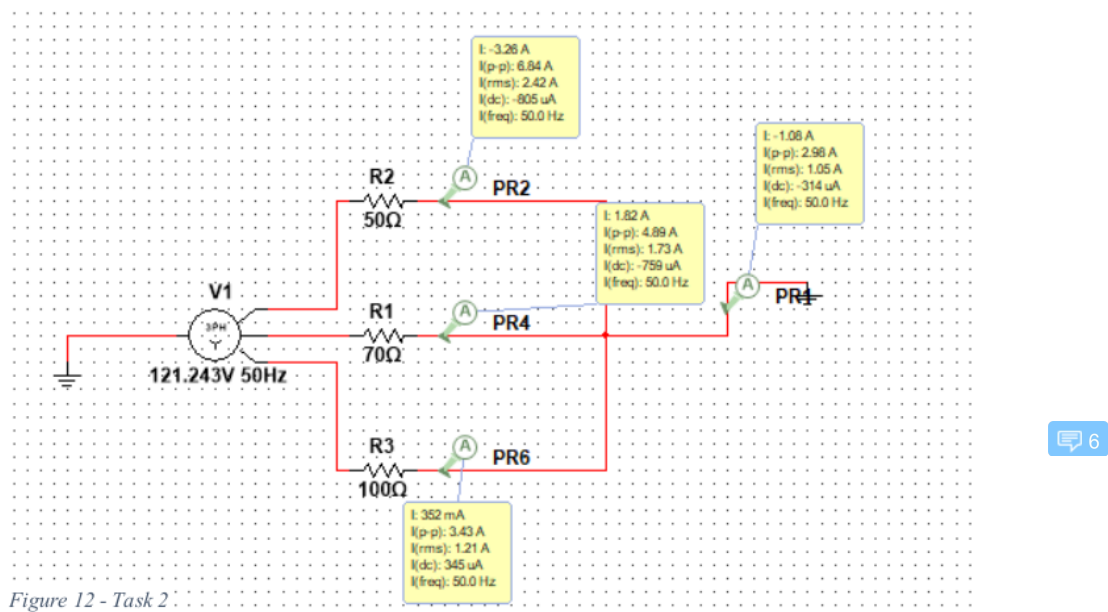


Figure 12 - Task 2

$I_1 = 2.42 \text{ A}$

$I_2 = 1.73 \text{ A}$

$I_3 = 1.21 \text{ A}$

Neutral Current – 1.05A

Calculations

$$I_1 = \frac{V}{R} = \frac{121.24}{50} = 2.42 \text{ A}$$

$$I_2 = \frac{V}{R} = \frac{121.24}{70} = 1.73 \text{ A}$$

$$I_3 = \frac{V}{R} = \frac{121.24}{100} = 1.21 \text{ A}$$

$$\begin{aligned} \text{Neutral Current} &= \sqrt{I_1^2 + I_2^2 + I_3^2 - (I_1 \times I_2) - (I_1 \times I_3) - I_2 \times I_3} \\ &= \sqrt{2.42^2 + 1.73^2 + 1.21^2 - (2.42 \times 1.73) - (2.42 \times 1.21) - 1.73 \times 1.21} \\ &= 1.03 \text{ A} \end{aligned}$$

Please see evaluation and Comparison in [Section 4](#)

4. Discussion of Results

Task 1

Comparison Table

<u>Circuit Characteristic</u>	<u>Simulation Value</u>	<u>Calculated Value</u>
Phase Voltage	121.249V	121.24V
Line/Phase Current	1.238	1.24A
True Power	114.875W	115.32W
Power Factor	0.765	0.77

Table 1 - Task 1

As seen from table 1 above, the simulated values are very similar to the calculated values. This verifies that the calculations were calculated correctly. Some very slight differences in the values could have been resulted in rounding up the decimal places different. However, as seen they make hardly any difference at all.

Task 2

Comparison Table

<u>Circuit Characteristic</u>	<u>Simulation Value</u>	<u>Calculated Value</u>
Power	1.034kW	1.034kW
Line Current	3.71A	3.713A
Phase Current	6.43A	6.431A
Power Factor	0.77	0.77

Table 2 - Task 2



As seen from table 2 above, both the simulation and calculated results are exactly the same. Again, this verifies that my calculated results were calculated correctly.

Task 3

Comparison Table

<u>Current</u>	<u>Simulation Value</u>	<u>Calculated Value</u>
I1	2.42A	2.42A
I2	1.73A	1.73A
I3	1.21A	1.21A
Neutral Current	1.05A	1.03A

Table 3 - Task 3

Table 3 above, the calculated and simulated values for the unbalanced STAR circuit and as shown, the results are exactly the same except the neutral current. This again verifies that my calculations are indeed correct. The neutral current error is very small indicating that it may be due to a human error within the calculation such as a rounding error but again the error is very minimal.

5. Conclusions

To conclude this report, the author has learned various different aspects of three phase systems including the basic concepts of three phase systems and why they are used. The different types of systems including STAR, DELTA and the differences between both. The use of Power Factor and how important it is to measure the user/companies use of their electricity to measure efficiency and reduce costs. Also, how three phase transformers are configured including the benefits and drawbacks of each of the four different arrangements.

Task 1 and 2 of the report included manual calculations included simulated circuits of both Star and Delta circuits both unbalanced and balanced. From completing these tasks, the author has learnt that the currents are different in unbalanced systems due to the difference in Resistances along the three phases. This is shown in [Task 2](#). Whereas Task 1 shows the current value as the same throughout the three phases due to the singular resistance value.

The report has also enhanced the authors ability in using NI Multisim. It's enabled him to enhance his knowledge by using various new tools such as Wattmeter's to measure the power. Using a simulation package was a good idea in terms of verifying the calculated results. If both the results matched, it helps verify the answers are indeed correct. If not, it helps identify that an error has been made either within the simulation or with a human error in the calculations.



[Section 4](#) of the report displays all values calculated and simulated in table format to present the results in an easy-to read format. It also includes an evaluation of the results and highlights any anomalies or slight errors.

6. Reference List and Bibliography

Bibliography

- Admin, 2019. *Equip Test*. [Online]
Available at: <https://www.equiptest.co.uk/what-is-power-factor-correction-and-why-is-it-important/>
[Accessed 15 5 2020].
- Anon., n.d. *Circuit Globe*. [Online]
Available at: <https://circuitglobe.com/three-phase-transformer-connections.html>
[Accessed 16 5 2020].
- Anon., n.d. *Circuitglobe*. [Online]
Available at: <https://circuitglobe.com/three-phase-system.html>
[Accessed 15 5 2020].
- Anon., n.d. *Edisto Electric*. [Online]
Available at: <http://edistoelectric.com/understanding-power-factor-and-why-its-important/>
[Accessed 15 5 2020].
- Anon., n.d. *Electronic Tutorials*. [Online]
Available at: <https://www.electronics-tutorials.ws/transformer/three-phase-transformer.html>
[Accessed 16 5 2020].
- Anon., n.d. *StudyElectrical*. [Online]
Available at: <https://studyelectrical.com/2014/11/star-star-connection-of-three-phase-transformer.html>
[Accessed 16 5 2020].
- jiguparmar, 2020. *Electrical-Engineering-Portal*. [Online]
Available at: <https://electrical-engineering-portal.com/star-delta-transformer-connection-overview>
[Accessed 16 5 2020].
- Nisbets, n.d. *Nisbets*. [Online]
Available at: <https://www.nisbets.co.uk/single-phase-vs-three-phase-electricity-explained>
[Accessed 15 5 2020].
- Technology, E., 2019. *Electrical-Technology*. [Online]
Available at: <https://www.electrical-technology.com/2019/05/what-is-power-factor-and-why-is-it-important.html>
[Accessed 15 5 2020].
- Transistor, 2016. *Electronic Stack Exchange*. [Online]
Available at: <https://electronics.stackexchange.com/questions/255536/why-3-phase-and-not-1-phase-power-transmission>
[Accessed 15 5 2020].



FINAL GRADE

GENERAL COMMENTS

Instructor

65/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5



Comment 1

equation

PAGE 6



Comment 2

power triangle?

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11



Comment 3

add a neutral return

PAGE 12



Comment 4

total ?

PAGE 13



Comment 5

wrong formula

PAGE 14



Comment 6

neutral return?

PAGE 15



Comment 7

Star and Delta P and I relationship

PAGE 16



Comment 8

not wholly relevant

PAGE 17



Comment 9

use harvard

GRADING FORM: NEW CSG-RUBRIC

ETHAN JOEL

65

1. ENGAGEMENT WITH LITERATURE



A range of websites inform the research which is sufficiently detailed and covers main points. It is however somewhat disjointed in places and not always clear. Use books/journals and a standard method such as Harvard.6/10

6

2. KNOWLEDGE AND UNDERSTANDING



Competent knowledge of the basic underlying principles is evident, there are a few small errors as marked and inconclusive results. 12/20

12

3. COGNITIVE AND INTELLECTUAL



Good evaluation overall, some minor errors, no direct comparison of the star and delta loads and some vague reasons given as explanations. No real recommendations included. 22/40

22

4. PRACTICAL APPLICATION



Methods adopted are logical and correctly applied for the most part, some errors in calculations are present leading to inconclusive results. 13/20

13

5. TRANSFERABLE SKILLS



Can communicate effectively and has done so, structure generally good, some more clarity in the research in some areas such as definition of terms etc would be an improvement.12/20

12

