

PSDE 4001 Assignment 2

by Thomas Wood

FILE	15329_THOMAS_WOOD_PSDE_4001_ASSIGNMENT_2_145403_913596156.DOCX		
TIME SUBMITTED	06-MAY-2018 09:29AM (UTC+0100)	WORD COUNT	4832
SUBMISSION ID	88459864	CHARACTER COUNT	27512

PSDE 4001 Electrical and Electronic Principles

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WORD COUNT - 4826



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Introduction

Within this assignment an experiment shall be carried out in order to determine the effect of balanced and unbalanced loads on three phase systems. Within the experiment star and delta balanced loads will be analysed in order for a comparison to be made between the two. The practical results that is obtained will then be compared to calculated values and the differences will be analysed.

Extensive research will also be carried out into the reasoning behind three phase distribution within the UK, the importance of power factor and the three phase configurations of transformers.

*Too
brief.*

Task 1

In order to complete this task, the ELT171C unit (Figure 1) is needed; this unit allows both a star and delta three phase power supply. In this particular task the supply must be configured in star, this supply should then be connected to the ELT171A unit.

For this task the load needs to be balanced, in order to achieve this the variable resistors on the load unit must all be set to $70\ \Omega$, the L/C switches must all be switched to L (Inductor) and finally the variable inductors must all be set to 200mH. Once this configuration had been set up values were then recorded by utilising the NANOVIP. Values were obtained with the load set up in both star and delta.

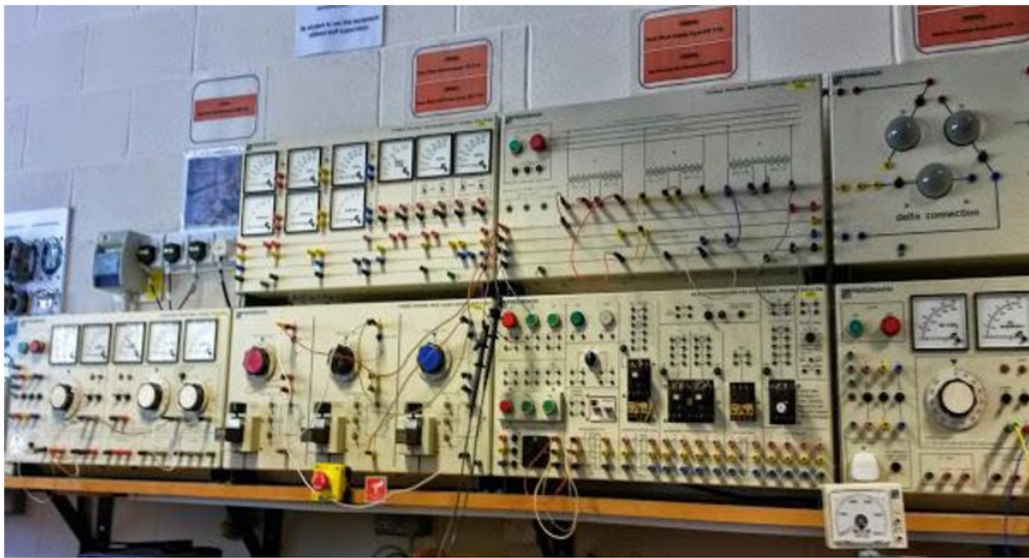


Figure 1 - ELT171C unit

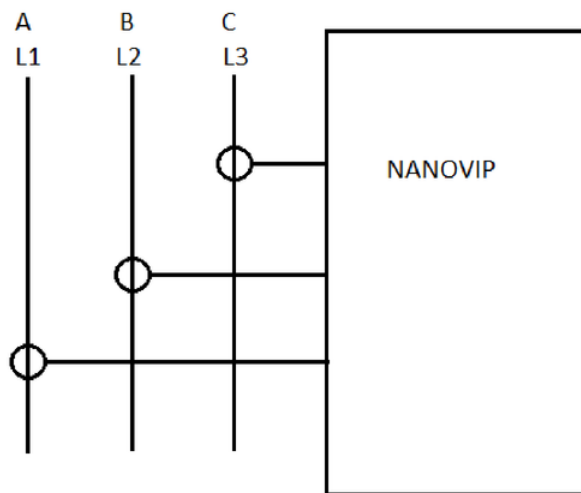


Figure 2 - Nanovip

Figure 2 illustrates how the NANOVIP will be connected in order to measure the phase currents. The NANOVIP will utilise CT's (Current Transformers) in order to determine the current within each phase.

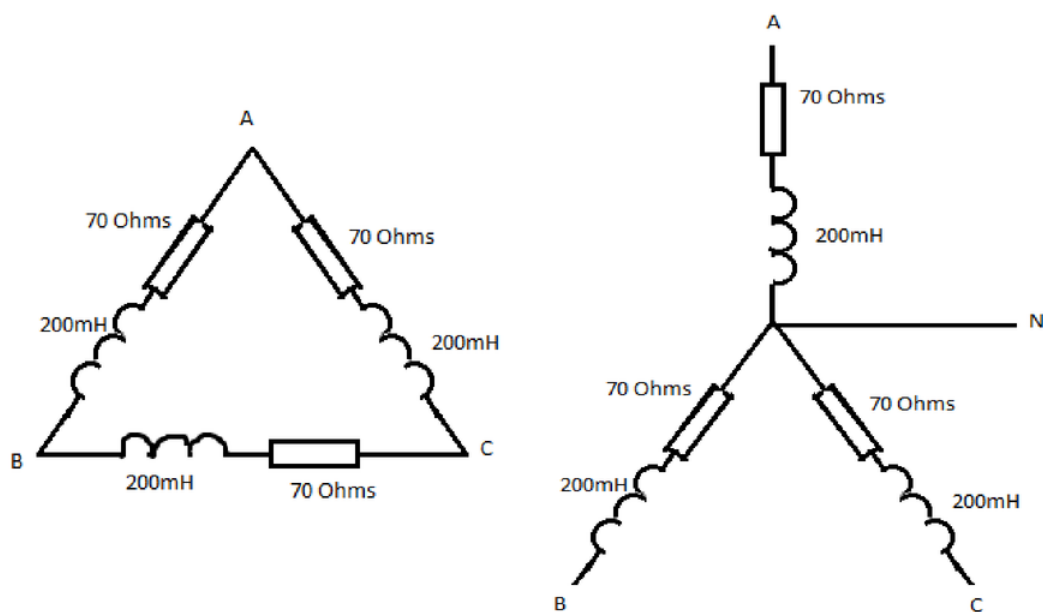


Figure 3 - Star and Delta configurations

Figure 3 illustrate a delta and star load. The figure on the left side is the diagram of a delta configuration, it is noticeable that there is no neutral point visible within this connection. Whereas the figure on the right illustrates a star configuration, differently to the delta connection there is a

neutral within this configuration which is taken from the point that each phase connects too (Star point). Within the diagrams the relevant values of resistance and inductance have been shown.

The results obtained from the experiment can be seen within Table 1;

Good results

Supply	Load	Line Voltages			Phase Voltage			I _A	I _B	I _C	PF	Real Power (W)	Apparent Power (VA)	Reactive Power (VAR)
		V _{AB}	V _{BC}	V _{CA}	V _{RN}	V _{YN}	V _{BN}							
Star	Star	212	212	213	122	123	122	1.134	1.16	1.18	0.65	280	432	329
Star	Delta	206	205	206	206	205	206	3.45	3.4	3.48	0.65	806	1.24k	946

Table 1 - Practical Results balanced loads

After obtaining all relevant values the circuit was switched off and isolated. Within the results it is apparent that the line voltages for both loads were relatively similar with the highest difference between a particular line was 7v. However, the phase voltage for the star-star configuration was around 80v lower of the phase voltage of the star-delta configuration. This indicates that the star load requires less power to work. We also know that the line and phase voltages within delta loads are the same due to; $V_L = V_{PH}$.

One of the most significant differences between the values of the two different loads is the current flowing through each phase. From the results it can be seen that the current within each phase of the star load is around 1.15A; however, the delta load has values of around 3.44 A which is almost exactly treble the star load currents. The reason for this is because within delta loads the line voltage = phase voltage which therefore means that the voltage is higher, also the delta load acts as if it is in parallel and therefore current is being pulled from each phase. This consequently means that the power that can be produced from a delta load is 3 times that of a star load.

Interestingly the power factor of both connected loads is the same, at 0.65, this means that although the power dissipated from the star load is lower it is still as efficient as the delta load. Due to $P = IV$, the real power, apparent power and reactive power of the delta load is once again 3 times that of the star load.

*Good
expla
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of
result
s*

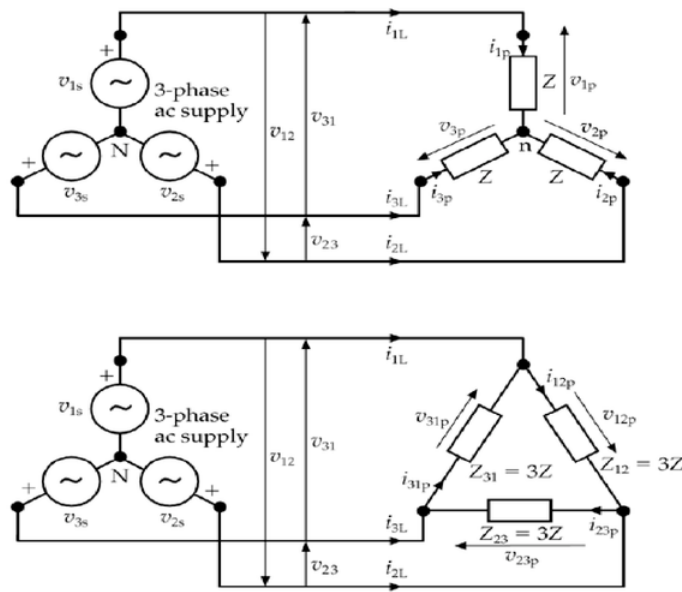


Figure 4 - Star Delta and Star Star Configurations

Figure 4 illustrates how both tests were setup, the top diagram is the star load and the bottom one the delta load.

Task 2

In order to ensure that the values obtained within the practical side are correct calculations are going to be carried out for both the star and delta configured loads. By carrying out the calculations it also allows for comparisons between measured values and calculated values to be made.

Star Load

Line voltage = 212v

$$\text{Phase voltage } V_{ph} = \frac{V_{line}}{\sqrt{3}}$$

$$\text{Phase voltage} = \frac{212}{\sqrt{3}} = 122.4V$$

Phase current $I_{ph} = \frac{V_{ph}}{Z_{ph}}$ the phase current cannot be found until Z is found, in order to find the value of Z the below formula shall be utilised;

$$Z = \sqrt{R^2 + X_L^2}$$

Once again another unknown must be found before Z can be found this is inductive reactance or X_L , in order to determine this the formula below shall be utilised;

$$X_L = 2\pi f l$$

$$X_L = 2 \times \pi \times 50 \times 200\text{mH}$$

$$X_L = 62.832$$

Therefore, Z can now be calculated utilising the value that was just calculated for Z ;

$$Z = \sqrt{70^2 + 62.832^2}$$

$$Z = 94.06\Omega$$

This therefore allows for the phase current to be calculated;

$$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{122.4}{94.06} = 1.301A$$

Within star loads the phase current is equal to the line current which therefore means that the line voltage also equals 1.301A.

In order to find the power factor, the phase angle must first be found, in order to find the phase angle the formula below is utilised;

$$\phi = \tan^{-1}\left[\frac{Xl}{R}\right] = \tan^{-1}\left[\frac{62.832}{70}\right] = 41.91^\circ$$

Now that the phase angle has been found the power factor can now be calculated;

$$\text{Power factor P.F.} = \cos(\phi) = \cos(41.91) = 0.744$$

$$\text{True power } P = (\sqrt{3})(Vl)(Il)(\cos \phi)$$

$$\text{True power } P = (\sqrt{3})(212)(1.301)(\cos 41.91)$$

$$\text{True power } P = 355.52 \text{ w}$$

$$\text{Reactive power } Q = (\sqrt{3})(Vl)(Il)(\sin \phi)$$

$$\text{Reactive power } Q = (\sqrt{3})(212)(1.301)(\sin 41.91)$$

$$\text{Reactive power } Q = 319.1 \text{ VAR}$$

$$\text{Apparent power } S = \sqrt{P^2 + Q^2}$$

$$\text{Apparent power } S = \sqrt{355.52^2 + 319.1^2}$$

$$\text{Apparent power } S = 477.72 \text{ VA}$$

Calc
s
look
corr
ect

Delta load

Line voltage = 206v

Within delta loads the line voltage equals the phase voltage, this therefore means that the phase voltage is also 206v.

As the load conditions have not changed the same Z value can be utilised within the phase current calculation for the delta load.

$$\text{Phase current } I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{206}{94.06} = 2.19A$$

In order to calculate the line current, the formula below is to be utilised;

$$I_{line} = \sqrt{3} \times I_{ph} = \sqrt{3} \times 2.19$$

$$I_{line} = 3.79 A$$

Due to the load not being changed when changing from star to delta loads, the power factor and phase angle do not change, therefore the P.F. of the delta load is 0.744 and the phase angle is 41.91° .

$$\text{True power } P = (\sqrt{3})(V_L)(I_L)(\cos \phi)$$

$$\text{True power } P = (\sqrt{3})(206)(3.79)(\cos 41.91)$$

$$\text{True power } P = 1006.4 \text{ w}$$

$$\text{Reactive power } Q = (\sqrt{3})(V_L)(I_L)(\sin \phi)$$

$$\text{Reactive power } Q = (\sqrt{3})(206)(3.79)(\sin 41.91)$$

$$\text{Reactive power } Q = 903.3 \text{ VAR}$$

$$\text{Apparent power } S = \sqrt{P^2 + Q^2}$$

$$\text{Apparent power } S = \sqrt{1006.4^2 + 903.3^2}$$

$$\text{Apparent power } S = 1352.33 \text{ VA}$$

*Calcs
are
good*

Power Triangles

Having completed the calculations for both star and delta loads power triangles can now be produced, the power triangles for both the star load and the delta load can be seen below;

Star

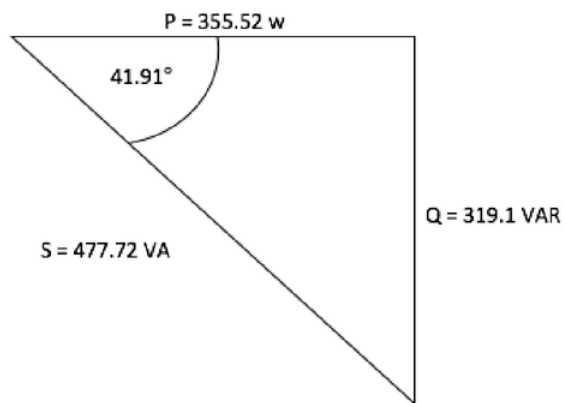


Figure 5 - Star Power Triangle

Delta

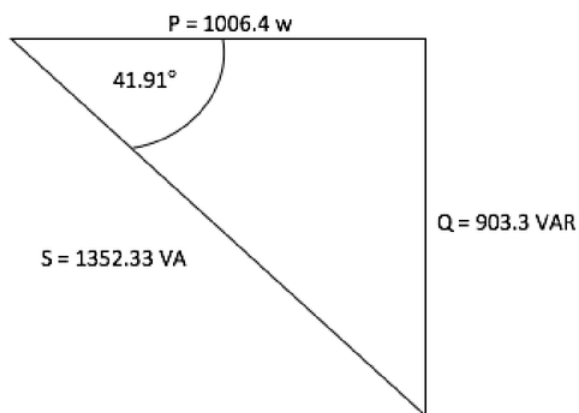


Figure 6 - Delta Power Triangle

*Good power triangles
derived from
measured values*

Having produced the power triangles, it was decided that the remaining calculated values would be put into a table in order allow for analysis of the results compared to measured values. The table can be seen below;

Load	Voltage (V)		Current (I)		PF	P (W)	Q (VA)	S (VAR)
	Line	Phase	Line	Phase				
Star	212	122.4	1.301	1.301	0.744	355.52	477.72	319.1
Delta	206	206	3.79	2.19	0.744	1006.4	1352.33	903.3

Table 2 – Calculated values

In order for a comparison to be made the measured values table will be shown below;

Supply	Load	Line Voltages			Phase Voltage			I _A	I _B	I _C	PF	Real Power (W)	Apparent Power (VA)	Reactive Power (VAR)
		V _{AB}	V _{BC}	V _{CA}	V _{RN}	V _{YN}	V _{BN}							
Star	Star	212	212	213	122	123	122	1.134	1.16	1.18	0.65	280	432	329
Star	Delta	206	205	206	206	205	206	3.45	3.4	3.48	0.65	806	1.24k	946

From analysing the two tables it can be seen although the values all follow the same kind of pattern there are some values that aren't quite the same. The voltages within both tables are very similar for example the line voltage for star is the same within both tables and then the phase voltage drops to 122.4 in the calculated values and is around 122 in the measured values. From the values it can be seen that the current physically measured is slightly lower than what was calculated. There can be many reasons for this, one particular theory would be that there is resistance within the leads utilised within the test that has caused for a slight dip in current, when calculating the resistance of the leads are not taken into account so this could cause the difference.

It is also evident that all the calculated power ratings are higher than that which was measured, however this is probably down to the discrepancies with the current, and therefore is not alarming as the values are following the same pattern as the measured values.

The line current for the delta load is almost 3 times the current of the star load, this is due to the current being constantly pulled from every phase.

The line current for the star load is relatively low due to the fact that the current being pulled is only from one phase at a particular time, this therefore means that the phase current is the same as the line current and makes it simple to calculate by using the phase voltage and phase impedance.

Line voltage is phase to phase voltage, this is the voltage that can be measured between phases, for a perfect 415v supply it would be expected that the line voltage would be 240v. Whereas phase voltage is the potential difference that is measured between any single phase and neutral. Therefore, because there is no neutral in delta connections the line voltage and the line voltage are deemed the same.

Whilst conducting this experiment all load conditions were exactly the same for both loads.

Good arguments for differences.

Task 3

In order to complete this task, another experiment is to be carried out with a star un-balanced load, in order to do this the same star-star configuration will be utilised however the inductors will be removed to leave a purely resistive load and the values of the resistances will be different (Figure 7). The values of the resistors can be seen below;

- $R_a = 40\ \Omega$
- $R_b = 50\ \Omega$
- $R_c = 70\ \Omega$



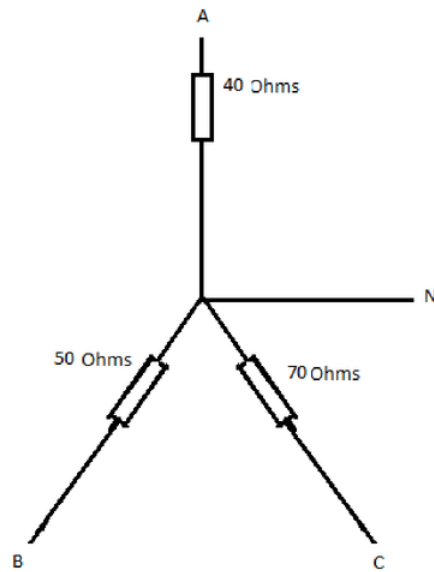
Figure 7 - Unbalanced Load set up

Load	VAB	VBC	VCA	V _{RN}	V _{YN}	V _{BN}	I _A	I _B	I _C	Pf
Star	206	208	210	118	118	122	3.77	2.72	1.93	1

Table 3 - Unbalanced Load Results

The measured results that were obtained from the unbalanced load can be seen within Table 3. In order to illustrate the unbalanced load a diagram has been produced below, it is also evident from the diagram that the inductor has been removed;

This should also include the power measurement results and explanation.



In order to analyse the measured values, the phase currents are going to be calculated,

$$I_{red} = \frac{V_{ph}}{R_{a_{ph}}} \rightarrow I_{red} = \frac{118}{40} = 2.95A$$

$$I_{yellow} = \frac{V_{ph}}{R_{b_{ph}}} \rightarrow I_{yellow} = \frac{118}{50} = 2.36A$$

$$I_{blue} = \frac{V_{ph}}{c} \rightarrow I_{blue} = \frac{122}{70} = 1.74A$$

Phase	Measured current (A)	Calculated current (A)
I_{red}	3.77	2.95
I_{yellow}	2.72	2.36
I_{blue}	1.93	1.74

Table 4 - Unbalanced measured and calculated values

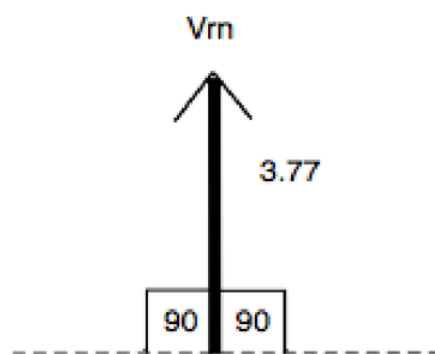
The table above illustrates the measured and calculated values for the phase currents, the calculated values are slightly lower than the measured currents, however the difference is not alarming as the difference is not extremely large. The differences could be caused by many things for example the resistance of the lead utilised, another reason could be that the supply unit is not calibrated properly which could lead to the resistances being different to what they are set at. The current clamp is also not the most accurate way of measuring current but is predominantly used to prevent the breaking of the circuit in order to measure current.

A phasor diagram is going to be produced of the line currents, this allows for the angles and magnitudes to be represented in a graphical way.

Within this particular circuit the line current is in phase with the voltages, because it is a purely resistive load. If inductors or capacitors were added, then the current would be out of phase with the voltage (lagging). In order to produce the phasor, diagram the horizontal and vertical values of each phase must first of all be found;

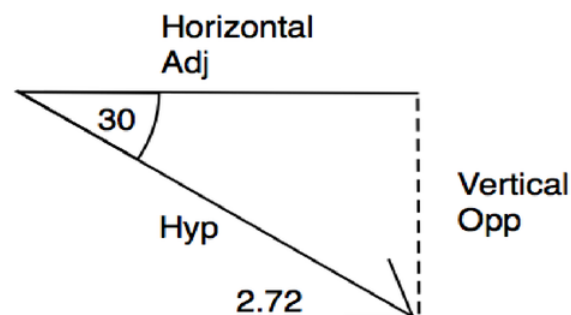
Red phase

Due to the red phase being at 90 degrees the horizontal will have no angle and therefore will have no value. The first part of the diagram with the red phase drawn can be seen below, as the red phase is vertical all current is shown.



Yellow phase

Due to the angle on the yellow phase trigonometry must be utilised in order to find the vertical and horizontal values of phase. In order to calculate the required values, the triangle below is utilised. The hypotenuse illustrates the yellow phase at 2.72A.



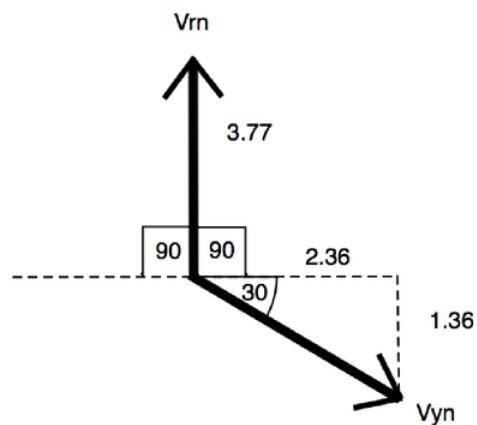
In order to calculate the vertical (Opposite) trigonometry is utilised, by utilising the phase angle and the phase voltage the value can be found;

$$Vertical = \sin(\theta) \times V_{ph} = \sin 30 \times 2.72 = 1.36$$

In order to calculate the horizontal, the adjacent is utilised;

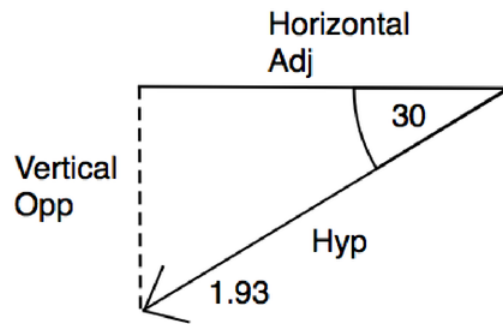
$$Horizontal = \cos(\theta) \times V_{ph} = \cos 30 \times 2.72 = 2.36$$

By utilising the calculation above the yellow phase can now be added to the diagram, this can be seen below;



Blue phase

Once again in order to find the horizontal and verticals of the blue the same trigonometry calculations as utilised to find the yellow phases values is utilised.



In order to calculate the vertical (Opposite) trigonometry is utilised, by utilising the phase angle and the phase voltage the value can be found;

$$Vertical = \sin(\theta) \times V_{ph} = \sin 30 \times 1.93 = 0.97$$

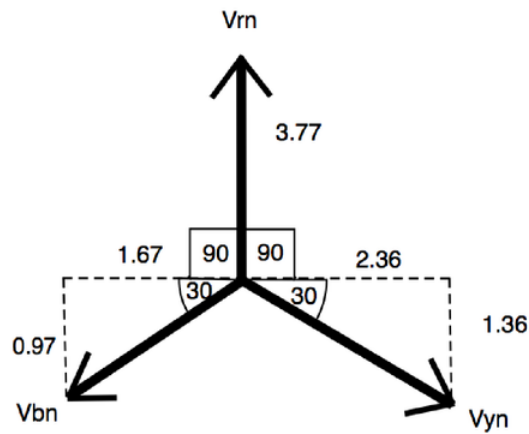
In order to calculate the horizontal, the adjacent is utilised;

$$Horizontal = \cos(\theta) \times V_{ph} = \cos 30 \times 1.93 = 1.67$$

<u>Phase</u>	<u>H</u>	<u>V</u>
Red	0	3.77
Yellow	2.36	1.36
Blue	1.67	0.97

Table 5 - Horizontal and Vertical values

The table above represents all the horizontals and verticals of the phases, the final horizontal and vertical plot can also be seen below;



In order to produce the phasor, diagram the vertical and horizontal points must be found, these are found as shown below;

To find the vertical: $3.77 - 1.36 - 0.97 = 1.44$

To find the horizontal: $2.36 - 1.67 = 0.69$

The final value needed in order to produce the phasor diagram is the neutral current, this is found by utilising the formula below;

$$I_n = \sqrt{(\text{sum of verticals})^2 + (\text{sum of horizontals})^2}$$

$$I_n = \sqrt{(1.44)^2 + (0.69)^2} = 1.597A$$

Now that the three plots have been found the phasor diagram can now be drawn;

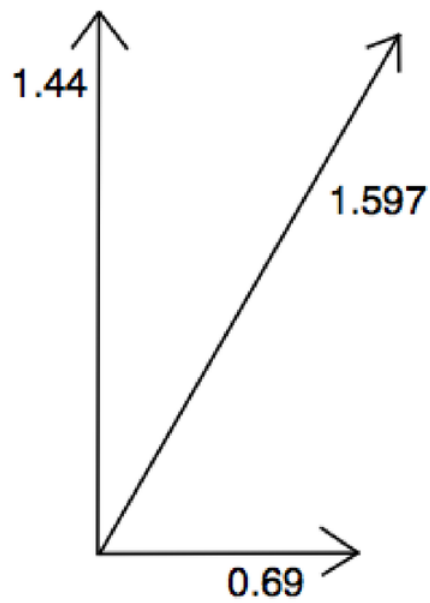


Figure 8 - Phasor Diagram

The phasor diagram above has been drawn using a scale where every 4cm is equal to 1 amp (1Amp:4cm). The power factor that was found within this experiment was measured to be 1.0. this is because the inductors and capacitors that would distort the power factor where removed and therefore the load was purely resistive that means it will be in phase and not leading or lagging. When something is deemed to be in phase it means that the power factor will be 1.

*Good use of trig to
find the vectors.*

Task 4

Distributing electricity is not as simple as it may seem, there are many different concerns that must be understood to ensure that the most efficient way of distributing electricity is utilised. Within the UK electricity is distributed by utilising 3 phase, there are many reasons for this, these are further explained below.

Theoretically the amount of phases that could be utilised in transmission is endless, and “experimental studies have considered up to 36 phases systems” (electrowsky, 2011). The reason that these studies have been carried out is due to the increasing demand for electricity. However, although this research the UK currently uses three phase transmission; when electrical transmission first began within the UK single phase transmission was utilised however this was quickly changed to 3 phase due to the substantial amount of power three phase could transmit at a lower voltage compared to single phase.

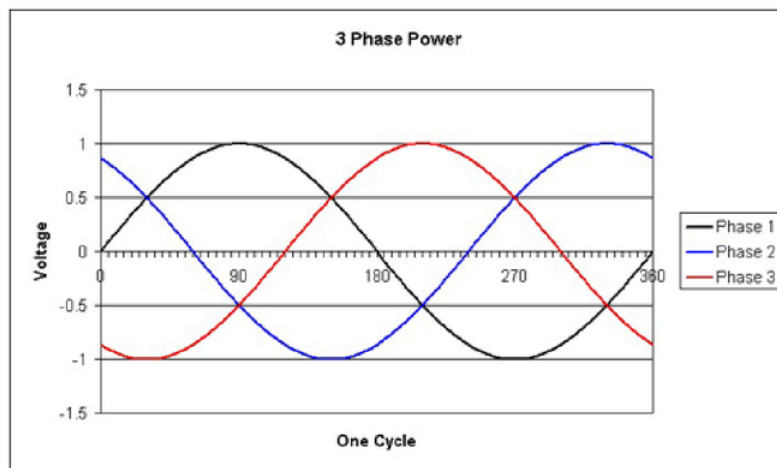


Figure 9 - 3 Phase waveform (Mindy, 2011)

Figure 9 represents the waveform of 3 phase transmission. If only of the phases is analysed it can be seen that within the time that one phase takes to reach its peak within three phase the peak has been reached three times, this is where the greater power comes from within 3 phase systems and therefore shows why 3 phase is more efficient.

Another advantage of three phase transmission compared to single phase is the physical size of cores. Three phase transmission cores can be significantly smaller than that of one phase as the cross sectional area of cores don't need to be as large when utilising 3 phase as the current is split between the phases in 3 phase. Whereas the current would only have one core to flow through in single phase and therefore lead to a great amount of current. This theory is illustrated within the two figure below;

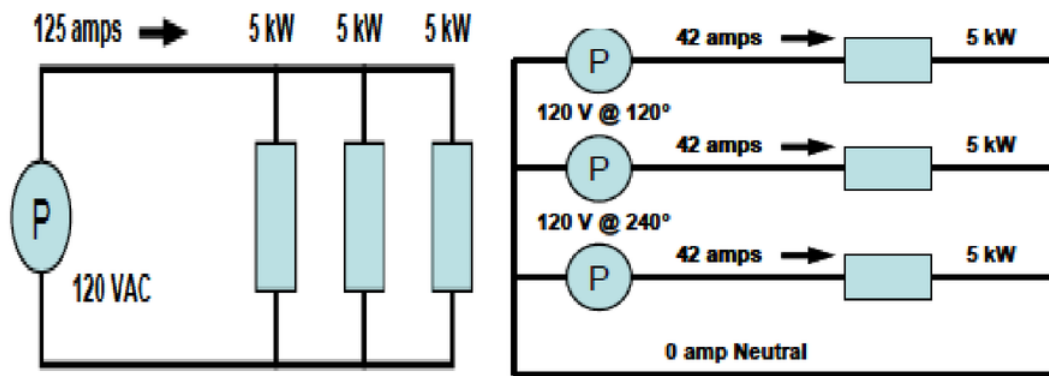


Figure 10 - 3 Phase and Single Phase Distribution (Geist, 2008)

Figure 10 illustrates the current that would be within cables for three phase and single phase transmission. The figure on the left illustrates that in order to power three 5 kW systems the amperage that would be drawn would be 125 A. On the other hand, in order to power the same systems with three phase the amperage being drawn on each phase would only be just under 42 A, this therefore shows that the size of the single phase core would have to be almost three times that of the three phase core.

When distributing to groups of homes a star configurations is utilised in order to supply the houses, the star configuration is utilised after utilising a residential transformer. Due to the use of a star configuration houses within the same area may not necessarily be supplied by the same phase. This is because unless a house requires three phase power supply, different houses will be supplied by different phases to balance the load on each phase. The three phase supply is 415v this therefore means that the voltage on each phase will be 240v; ($\frac{415}{\sqrt{3}} = 240V$) this is the UK household voltage.

Three phase transmission is also much more suitable for industrial purposes. This is evident as industries will most likely have an array of three phase motors, therefore if the supply from the grid was single phase then the industry would have to heavily invest in order to convert the single phase supply into 3 phase just to power their motors. Although this industry would still have to convert three phase into single phase however this would be much cheaper to achieve than the alternative.

Finally, three phase transmission is also beneficial as it can be rectified with much less ripple than single phase, this is therefore beneficial to DC applications. Figure 11 represents a rectified 3 phase waveform;

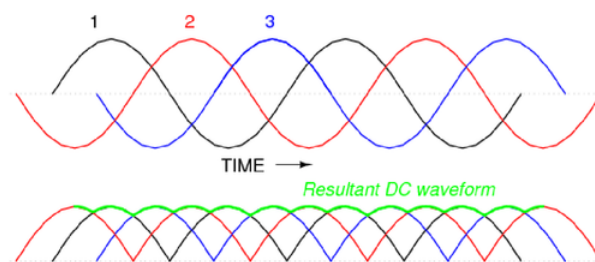


Figure 11 - Rectified 3 Phase waveform (Anon., n.d.)

[Good work here.](#)

Task 5

As a team it was discussed what the fundamentals of power factor is, through utilising everyone's opinions on power factor the flowing description of power factor was produced.

Power factor is the difference between the real power (kW) and the apparent power (kVA). In more broad terms this means power factor is a numerical representation of the efficiency of a circuit/system; this is therefore important as it depicts the amount of power that is being used to do 'work'.

The power factor represents the angular displacement between voltage and current; circuits that are in-phase will have no angular displacement and therefore would have a pf of 1, subsequently if the current was leading or lagging then angular displacement of the voltage and current would be present and therefore the pf would be smaller than 1 due to inefficiency of the circuit. The most common reason for a poor power factor is a highly inductive load, such as AC motors.

Through understanding power factor, a circuit can be deemed to be in phase, leading or lagging. This is evident because a circuit with a pf of 1 is deemed to be in-phase, a circuit that has a negative pf is deemed to be leading and a circuit with a positive pf that is under 1 is deemed to be lagging.

Vector diagrams are widely used to represent the relationship of the 3 powers found in a circuit. These powers are; reactive, apparent and real, by utilising these three powers a power triangle/vector diagram can be formed.

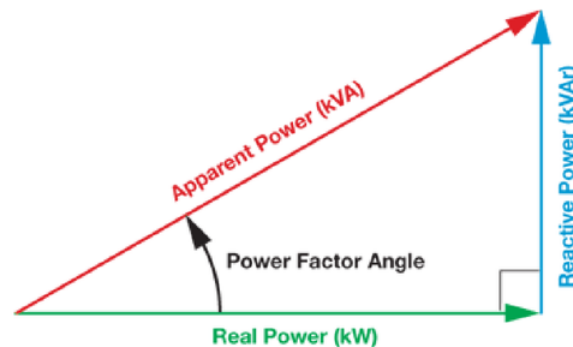


Figure 12 - Power Triangle (Seshadri, n.d.)

The diagram above depicts what a power triangle looks like. The equation that is utilised in order to determine the power factor of a system can be seen below;

$$\text{Power Factor } p.f = \cos \frac{\text{Useful Power (kW)}}{\text{Total Power (kVA)}}$$

Through analysing the formula, it can be seen that when the p.f is low then either the apparent or real power increases. If a system has a low p.f then this means that the power supply company would have to provide that particular system with more power. This would therefore lead to an

increase in line current, this subsequently would have a negative impact on the conductors and cables and could lead to faults occurring more frequently. Through the extra heat of the conductors because of the increased line current therefore the cost to supply the system would be much more than for a system with an acceptable p.f. This cost would also increase the consumer's bills.

It can therefore be deemed desirable to improve the p.f for both the consumer and the supplier; therefore, power factor correction is undergone. The most common way of improving the p.f is through the use of capacitor banks (Figure 13).

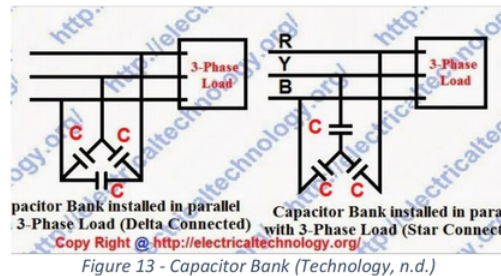


Figure 13 - Capacitor Bank (Technology, n.d.)

The purpose of power factor correction (PFC) is to bring the power factor of a system as close to 1 as possible. This is done by adding capacitor banks into the circuit, these capacitors are utilised in order to 'compensate for the reactive power demand of the inductive load and thus reduce the burden on the supply' (Ware, 2006).

The capacitors that are utilised in the circuit for PFC are wired in parallel to the load. The capacitors work by storing any non desirable power, by doing this not as much power is wasted and therefore the efficiency is increased. By doing this the angular dissipation is decreased which causes the p.f to increase; the typical corrected value of p.f is around 0.9 – 0.95.

Within large industries that have a substantial amount of induction motors, there tends to be a lagging power factor due to the windings of the induction motors acting as inductors to the power supply. Capacitors have the direct opposite effect on power supplies and can therefore be utilised in banks in order to compensate for the induction motors. Within certain industries it can also be desirable to have capacitors added to each individual motor due to the chance of overcorrection from capacitor banks that can lead to overvoltage which could cause trips to occur, therefore motors that are important to a process normally have individual capacitors added to its starter. By utilising these capacitor banks it saves the consumer and the supplier money, fines can also be waived for poor p.f from certain large companies that are dependable on a efficient power supply.

*Good explanation, but
the better way is by using
a calculation example.*

Task 6

There are 4 different types of star and delta transformer arrangements, these are;

- star star
- star delta
- delta delta
- delta star

Whilst carrying out the practical tasks within this assignment 2 of these arrangements were utilised, these were; star star and star delta.

Star - Star

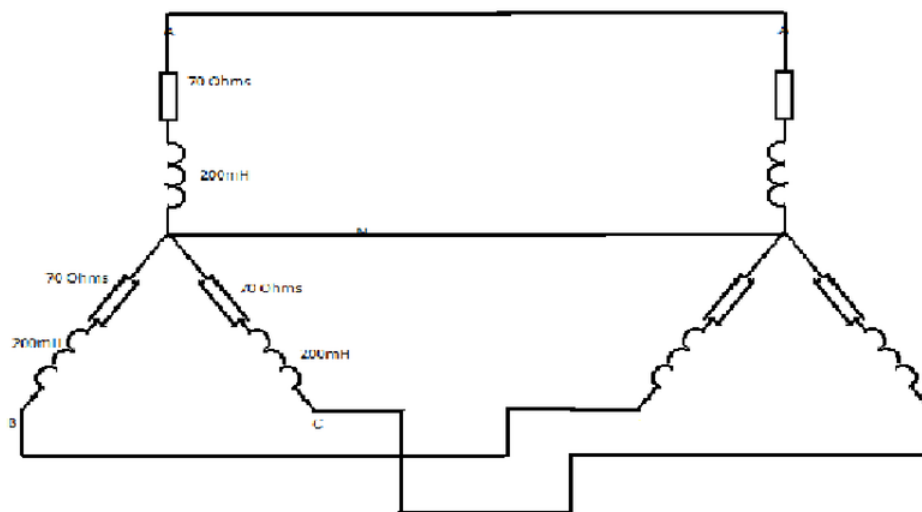


Figure 14 - Star Star Configuration

This figure above depicts a star load being supplied from a star supply. The benefit of using this particular connection within transformers is the reduced amount of windings needed compared to delta connections. A neutral point can also be connected within this configuration this neutral can be utilised commonly across each winding, a disadvantage of this configurations is the fact that if one of three transformers connected in this style were to become faulty the other two transformers would probably malfunction.

The benefits of using a star supply is the ability to branch each individual phase in order to supply single phase to banks of houses, this is much easier to do in star configuration compared to delta. This configuration also has a neutral which can allow for grounding. Star connected loads have low line currents and phase voltage, the power that is needed is also low.

Star – Delta

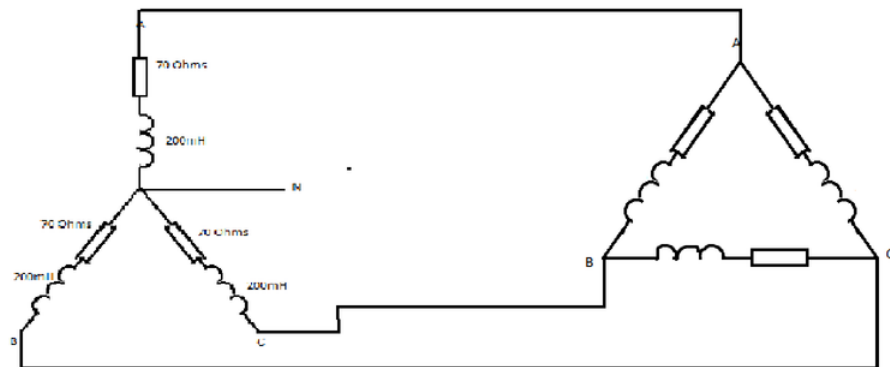


Figure 15 - Star Delta Configuration

The star delta configuration is most widely utilised for large step-up applications such as that within transformers. This is due to the small amount of coils that is needed on the star windings compared to that of the delta windings. This configuration also allows for three phase and single phase supply and also allows the loads to be balanced effectively.

Delta – Star

The delta star configuration for a transformer can allow for a 3 wire supply to be turned into a 4 wire load. When connecting transformers windings with different connections the ratio of windings is much more complex.

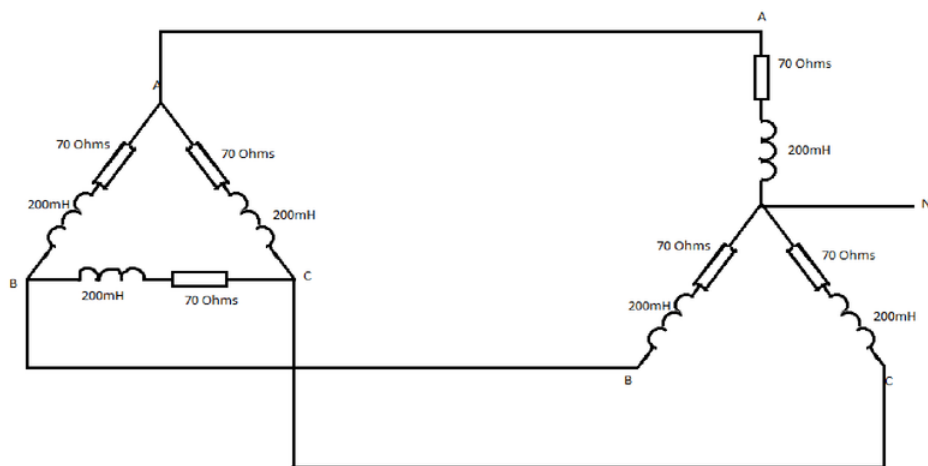


Figure 16 - Delta Star Configuration

The delta star configuration is not a very common configuration, this configuration would be desirable for motor start-up due to the low current and low voltage needed in order to start the

motor at high torque, however when running this configuration is not as efficient as a delta connected load and therefore normally switched over after start-up.

Delta – Delta

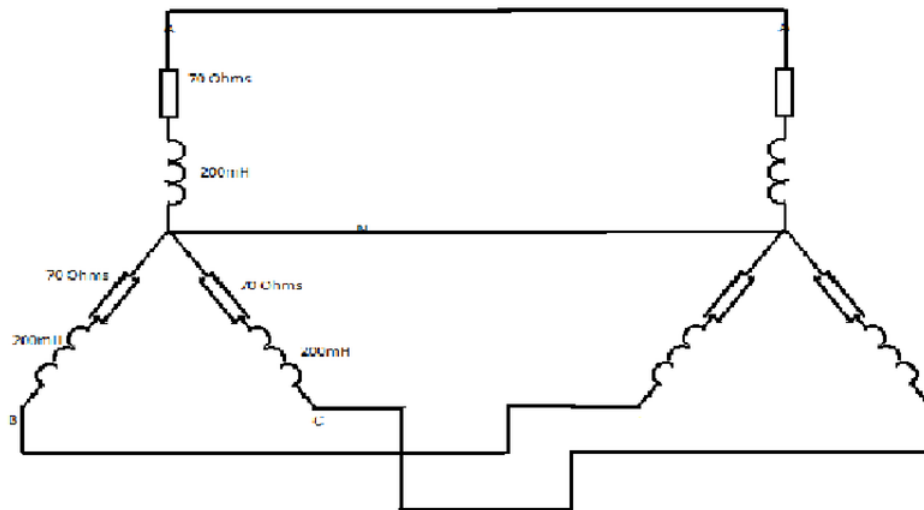


Figure 17 - Delta Delta Configuration

Delta delta wound transformers require a large amount of windings due to the full line voltage of the connection being constant, this therefore means that costs are increased when using this configuration. There is also no neutral present within this particular connection. An advantage of this connection is if there were three transformers connected in this way and one was to become faulty the other two transformers would produce enough power to continue the running of any loads.

Delta delta configurations are also utilised to run motors this is due to the ability to allow large motors to be supplied from relatively low supply voltages. However, on start up the excess current is not desirable therefore, star delta switchover systems are utilised so that the motor is started up in star and then switched over to delta whilst running.

*Good
explanations*

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Good refs used.

PSDE 4001 Assignment 2

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

63/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

Text Comment. Too brief.

PAGE 5

PAGE 6

Text Comment. Good explanation of procedure

PAGE 7

Text Comment. Good results

Text Comment. Good explanation of results

PAGE 8

PAGE 9

PAGE 10

Text Comment. Calcs look correct

PAGE 11

Text Comment. Calcs are good

PAGE 12

Text Comment. Good power triangles derived from measured values

Text Comment. Good arguments for differences.

Text Comment. This should also include the power measurements results and explanation.

Text Comment. Good use of trig to find the vectors.

Text Comment. Good work here.

Text Comment. Good explanation, but the better way is by using a calculation example.

Text Comment. Good explanations

Text Comment. Good refs used.

THOMAS WOOD**0****RESEARCH-INFORMED LITERATURE**

Research is very good. 4/5 Relevant sources are very good 4/5

8/10**KNOWLEDGE AND UNDERSTANDING**

Intro is too brief but the practical does have an intro in the section. 2.5/5 Description of procedures is good. 3.5/5 Discussion of results is good but the power measurements for the unbalanced and explanation is missing. 6/10

12/20**ANALYSIS**

Testing and results are good apart from power measurements and PF missing in task 3. 20/30 No conclusion section but some conclusive discussion in report. 3/10

23/40**PRACTICAL APPLICATION AND DEP.**

Description of practical procedures is good. 3/5 Discussion of prac results is good. 3.5/5 Quality of work is good. 6.5/10

13/20**SKILLS FOR PROFESSIONAL PRAC.**



Report is good 3.5/5 team work is good. 3.5/5

7/10