

PSDE4001 Assignemnt 2 Adam Bedner

by Adam Bedner

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PSDE4001 Electrical and Electronic Principles

Assignment 2 Three-phase Circuits

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1. Star-Star and Star-Delta configurations

In this section, a practical activity and calculations will be undertaken about the three-phase balanced circuit in Star to Star and Star to Delta configurations. The practical task will be undertaken first, calculations will be done afterwards and to finish off the values measured from the practical and the calculated values will be compared.

1.1 Practical activity

For the practical activity, a three-phase power supply will be used together with *Feedback Three Phase Load Panel ELT171C* to put a resistive-inductive load on the phases as well as a *NANOVIP* meter to measure the voltage, current, power-factor, and the Real, apparent and reactive powers. The voltage of the three-phase is taken down to around 125VAC Phase-Neutral / 215VAC Phase-Phase to make the system safer to work on (240VAC Phase-Neutral / 415VAC Phase-Phase is considered too dangerous to work on even when supervised).

The ELT171C load unit is set to 70Ω of resistive load and 200mH of inductive load. Capacitive load is not present in the circuit.

The supply is connected in Star configuration and the load will be first connected in star configuration and in delta configuration afterwards. The *NANOVIP* meter used has two leads to measure voltage and a third lead ended on a current measuring clamp. To obtain the correct measurements, the voltage leads are first connected to 1st and 2nd phase and the clamp is clamped to the 3rd phase. Then the voltage lead is moved to the 1st and 3rd phase and the clamp clamped on the 2nd phase. After that the voltage leads are moved to the 2nd and 3rd phase and the clamp clamped to the 1st phase, that give the measurement for the line voltage between each of the phases, current on each of the phases, the power-factor and the real, apparent and reactive powers. That being done, the *NANOVIP* meter is used to measure the voltage between each phase and neutral. That procedure is done for both, star and delta configurations. The Table 1 shows the measurements of both, star-star and star-delta configurations.

supply	load	Line Voltages			Phase Voltages			Currents			PF	Powers		
		V _{AB}	V _{BC}	V _{CA}	V _{RN}	V _{YN}	V _{BN}	I _A	I _B	I _C		Real (W)	Apparent (VA)	Reactive (VAR)
Star	Star	216	215	216	124	124	125	1.19	1.21	1.23	0.64	291	457	354
Star	Delta	210	209	209	209	209	209	3.56	3.48	3.52	0.65	826	1284	981

Table 1 Measurements from the practical activity

As in delta configuration there's no neutral, and all the three phases are interconnected between each other, each load can draw current from all the three phases at once where in star configuration, the load instead of being connected across the phases is connected across one phase only and neutral, which limits the current to be drawn from one phase only. That is the reason why the current and power is much higher in delta configuration than star configuration. The power is higher as, being the same voltage on the phases and a higher current, from the power formula ($P=IV$) it is known that increasing either the voltage or the current will increase the power as well.

A very good explanation of the tasks here and a good set of results.

1.2 Calculations

Now the calculations for both, Star to Star and Star to Delta will be performed.

Star to Star configuration

Starting off with Star to Star configuration, the only known values are, line voltage = 216V, resistive load = 70Ω, inductive load = 200mH.

$$\text{Phase voltage } V_{ph} = \frac{V_{line}}{\sqrt{3}} \rightarrow V_{ph} = \frac{216}{\sqrt{3}} = 124.71V$$

The phase current is calculated using the formula $I_{ph} = \frac{V_{ph}}{Z_{ph}}$, for which "Z_{ph}" has to be calculated. For that, the following formula is used

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

For which Xl has to be calculated

$$Xl = 2\pi fl \rightarrow Xl = 2 * \pi * 50Hz * 200mH = 62.832$$

$$\text{Having that calculated, } Z = \sqrt{70^2 + 62.83^2} = 94.06\Omega$$

$$\text{Following that, calculating the current } I_{ph} = \frac{V_{ph}}{Z_{ph}} \rightarrow I_{ph} = \frac{124.71}{94.06} = 1.308mA$$

In star configuration, the phase and line currents are the same as the load is connected to only one of the phases and neutral. Therefore $I_{line}=1.308A$

To calculate the power factor, the phase angle has to be calculated.

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

Following the calculation of the power factor (PF)

$$PF = \cos\phi \rightarrow PF = \cos(41.91^\circ) = 0.744$$

Having all those values, the true, reactive and apparent power can be calculated.

$$\text{True power} \rightarrow P = \sqrt{3} * V_{line} * I_{line} * \cos\phi$$

$$\text{Reactive power} \rightarrow Q = \sqrt{3} * V_{line} * I_{line} * \sin\phi$$

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

$$P = \sqrt{3} * 216 * 1.308 * 0.744 = 364.08W$$

$$Q = \sqrt{3} * 216 * 1.308 * 0.688 = 326.89VAR$$

$$S = \sqrt{364^2 + 326.89^2} = 489.3VA$$

Good
set of
calculat
ions.

Delta Load Configuration

Line voltage = 209V

the phase voltage and line voltage in delta configuration are the same due to lack of neutrals in delta configuration.

The "Z" value is the same as in star configuration, the value being: $Z=94.06\Omega$

The current can now be calculated.

$$I_{ph} = \frac{V_{ph}}{Z_{ph}} \rightarrow I_{ph} = \frac{209}{94.06} = 2.22A$$

As each load is connected across two phases instead of one phase and neutral as was the case of star connection, the line current differs from the phase current and is calculated as follows.

$$I_{line} = \sqrt{3} * I_{ph} \rightarrow I_{line} = \sqrt{3} * 2.22 = 3.81A$$

The load being the same as in star configuration, the power factor is not affected as the configuration does not affect the power factor. The true, reactive and apparent powers can now be calculated.

$$\text{True power} \rightarrow P = \sqrt{3} * V_{line} * I_{line} * \cos\phi$$

$$\text{Reactive power} \rightarrow Q = \sqrt{3} * V_{line} * I_{line} * \sin\phi$$

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

$$P = \sqrt{3} * 209 * 3.8 * 0.744 = 1018W \text{ or } 1.018kW \approx 1kW$$

$$Q = \sqrt{3} * 209 * 3.8 * 0.668 = 907.9VAR$$

Calculations are good.

$$S = \sqrt{1018^2 + 907.9^2} = 1363VA \text{ or } 1.363kVA \approx 1.4kVA$$

Power Triangles

Using the calculated power values, all the three powers can be represented as triangles called the power triangle, those are shown in Fig. 1, there is one for Star configuration and one for delta configuration.

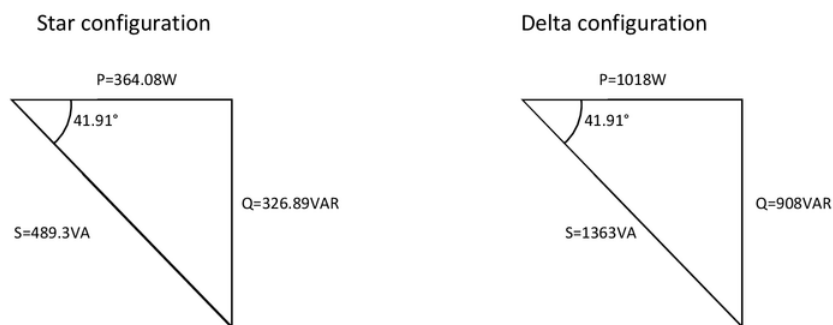


Fig. 1 Star and Delta configuration power triangles

A good set of derived vectors.

Comparison between calculated and measured values.

The two following tables show the values, the first table show the measured values and the second table shows the calculated ones.

Measured Values														
supply	load	Line Voltages			Phase Voltages			Currents			PF	Powers		
		V _{AB}	V _{BC}	V _{CA}	V _{RN}	V _{YN}	V _{BN}	I _A	I _B	I _C		Real (W)	Apparent (VA)	Reactive (VAR)
Star	Star	216	215	216	124	124	125	1.19	1.21	1.23	0.64	291	457	354
Star	Delta	210	209	209	209	209	209	3.56	3.48	3.52	0.65	826	1284	981

Calculated values														
supply	load	Line Voltages			Phase Voltages			Line Currents			PF	Powers		
		V _{AB}	V _{BC}	V _{CA}	V _{RN}	V _{YN}	V _{BN}	I _A	I _B	I _C		Real (W)	Apparent (VA)	Reactive (VAR)
Star	Star	216	216	216	124.7	124.7	124.7	1.308	1.308	1.308	0.744	364.08	326.89	489.3
Star	Delta	210	209	209	209	209	209	3.81	3.81	3.81	0.744	1018	907.9	1363

The both sets of values are similar and follow the same pattern, however there are small differences, mainly in the current values, phase factor and powers. The main reason for any differences might be due the inaccuracy of the meters, mainly the current clamp as those are know of their low accuracy. The measured values might as well be affected by the tolerance of the used components for the load, whose value usually is not dead on the chosen value.

Good work.

2. Unbalanced load

In this task a resistive unbalanced load will be set up on three-phase star configuration. A practical task will be undertaken taking measurements and calculations will be done and afterwards the measured and calculated values will be compared.

The three resistors used will be 40Ω, 50Ω and 70Ω. Those will be connected in star configuration, where the 40Ω resistor will be connected to the phase A, the 50Ω resistor connected to the phase B and the 70Ω resistor to the phase C.

2.1 The practical

The equipment and voltages used in this practical will be the same as the ones used in the balanced load practical (See page 3). The load is purely resistive of values R_A=40Ω, R_B=50Ω and R_C=70Ω. The table below show the measured values.

Load	V _{AB}	V _{BC}	V _{CA}	V _{AN}	V _{BN}	V _{CN}	I _A	I _B	I _C	PF
Star	119	120	123	207	208	209	3.4	2.69	1.86	1.0

2.2 The calculations

In this section now, the currents for the phase A, B and C will be calculated and compared with the measured values.

Knowing that the line voltage is 208VAC, the phase voltage and currents can be calculated as follows:

$$V_{ph} = \frac{V_{ph}}{\sqrt{3}} \rightarrow V_{ph} = \frac{208}{\sqrt{3}} = 120.08V$$

$$I_A = \frac{V_{ph}}{R_{Aph}} \rightarrow I_A = \frac{120.08}{40} = 3A$$

$$I_B = \frac{V_{ph}}{R_{Bph}} \rightarrow I_B = \frac{120.08}{50} = 2.4A$$

$$I_C = \frac{V_{ph}}{R_{Cph}} \rightarrow I_C = \frac{120.08}{70} = 1.7A$$

Phase	Measured current (A)	Calculated current (A)
Phase A -> I_A	3.35	3.0
Phase B -> I_B	2.63	2.4
Phase C -> I_C	1.9	1.7

The differences between the measured and calculated values are due the poor accuracy of the current clamps. The tolerances of the resistances together with the internal resistance of the cables influences the total load resistance which affects the current.

Now the neutral current is to be calculated. For that, all the three currents will have to be transposed into verticals and horizontals. One of the currents is already vertical and the other two currents are angled 120° from the vertical one.

Phase A

The current vector for phase A is angled 90° from the horizontal which makes it a vertical, it is looking up which means it is between 1st and 2nd quadrant. Therefore this current has a vertical with a value of 3.35A and a horizontal with a value of 0A.

Phase B

The current vector for phase B is angled -30° meaning that the vector for this current is situated in the fourth quadrant. To calculate vertical and horizontal the sin and cos will have to be used respectfully. The calculations are as follows:

$$Vertical = \sin 30 \times 2.63 = 1.315A$$

$$Horizontal = \cos 30 \times 2.63 = 2.278A$$

The vector being in the 4th quadrant means that the vertical value is in int negative section of the Y-axis (going downwards) and the horizontal in the positive section of the X-axis (going right). This makes the vertical value negative and the horizontal value positive.

Phase C

The current vector for phase C is situated in the 3rd quadrant, angled 30° from the horizontal. The same calculations will be used as for the phase B. The calculations are as follows:

$$\text{Vertical} = \sin 30^\circ * 1.9 = 0.95A$$

$$\text{Horizontal} = \cos 30^\circ * 1.9 = 1.65A$$

The vector being in the 3rd quadrant means that the vertical value is in the negative section of the Y-axis (going downwards) and the horizontal value being on the negative section of the X-axis (going left). This makes both, vertical and horizontal values negative.

Summing all the horizontals and vertical gives a table of horizontal and vertical values of the vectors for each phase and those being added up will give the vertical and horizontal values of the neutral current.

Phase	Horizontal	Vertical
A	0	3.35
B	2.28	-1.1315
C	-1.65	-0.95

In order to find the neutral current the following formulae has to be used

Good results from calculations here.

$$I_N = \sqrt{(\text{sum of verticals})^2 + (\text{sum of horizontals})^2} \rightarrow$$
$$I_N = \sqrt{(3.35 - 1.1315 - 0.95)^2 + (0 + 2.28 - 1.65)^2} = \sqrt{1.265^2 + 0.63^2} = 1.41A$$
$$\phi = \tan^{-1} \left[\frac{\text{sum of verticals}}{\text{sum of horizontals}} \right] \rightarrow \phi = \tan^{-1} \left[\frac{1.265}{0.63} \right] = 63.526^\circ$$

The current going through the neutral cable is 1.41A at an phase angle of 63.526°.

The load being purely resistive, meaning the absence of any inductive or capacitive loads, means that the power factor is 1.0, the current is not lagging nor leading.

Should have a diagram.

3. Research on three-phase

The three-phase format is the main way of distributing electricity. That is mainly due to make the distribution of electricity cheaper and more effective.

In three-phase format, all three of the phases are AC with a frequency of 50 or 60Hz (50Hz for UK and Europe), the phases are on a offset of 120° between each other, therefore the voltage peaks three times more often than in a single phase format. Due to that, it is possible to achieve more power with the same current in three phase compared to single phase. That is mainly seen in electrical motors where three-phase motors are much more effective than single phase motors, those achieve more power and torque drawing the same current as the single phase motors, that is why three phase motors are widely used in industry, making equipment more efficient and powerful.

So industries uses mainly three-phases for their equipment, but there is only one phase in the socket that industries uses for smaller equipment like lighting, computers and as well houses uses single phases. That is easily achieved by using only one of the phases and the neutral. As well known from previous sections, the three-phase can be set up in either delta configuration, where there is no neutrals and the loads are connected between phases, and star configuration where each load is connected to only one of the phases and the neutral. Mainly the star configuration is used in distribution as that allows to supply houses in a neighbourhood (or better said, the houses connected to the same distribution transformer) with different phases to make the load on each phase approximately the same. That means that $\frac{1}{3}$ of the houses will be supplied by phase A, another $\frac{1}{3}$ of houses will be supplied by the phase B and the last $\frac{1}{3}$ of the houses will be supplied by the phase C, this way, the load is distributed more or less equally on all the three phases, making it balanced and the current drawn from each phase will be approximately the same.

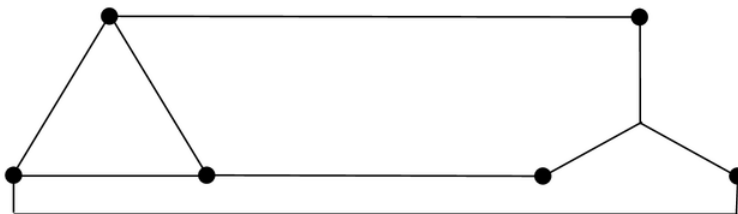
As well, when using three phases for distribution there is three times amount of wires required as compared to single phase and the step up and step down transformers require three separated cores for each of the phases. But using three phases, and therefore three wires for each of the phases have it advantage, having three wires means that the current is distributed between those three wires, which can be much thinner than in case of having single phase and one single wire which would have to withstand three times the current making the cable many times thicker and therefore much heavier and more expensive to produce. Another advantage of having three thinner over one, much thicker and heavier wire is the need off less supporting towers, the wires being thinner and lighter makes possible to hang them over greater distances without them breaking. As well, coming back to the step up and step down transformers for the distribution, the current and load being distributed over three cores allows to use thinner wires for the windings of the transformers, making them smaller, lighter and more cost-effective.

4. The Power Factor

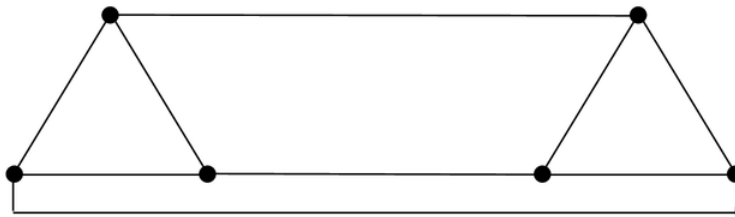
The power factor represents the relation between the real work and the apparent work. Whenever there are inductors or capacitors in a AC circuit, the current will lead or lag against the voltage, which will significantly reduce the efficiency. That is mainly due to the inductive loads like transformers or electrical motors or any other magnetic or electromagnetic equipment; those require to generate a magnetic flux to do the work that those are designed to do, the current taken to generate that magnetic flux does not contribute in any way to the work done by the equipment, that power is called the reactive power. The best power factor value is 1.0, which means that the current and voltage are perfectly in synchronisation, whenever the value of the power factor goes below 1.0 means that the voltage and current are not perfectly in sync and losses are generated.

That does not apply to the households, but companies and factories have to watch their power factors as, if it gets too low, those can be fined. There is a way correcting the power factor and that is done by installing a control unit together with banks of capacitors in parallel with the power lines. The control unit monitors the power factor of the plant or building and connects or disconnects the banks of capacitors when it is required to do so in order to keep the power factor as close to 1.0 as possible. That is used because the capacitors contrast the effects of the inductors, and as in the plant or building the inductive load can be changing constantly, the control unit is required to control it, whenever more inductive load is connected and the power factor goes down, the control unit connects the bank of capacitors and when the inductive load is disconnected, the bank of capacitors are automatically disconnected to prevent the over leading of current caused by the capacitors, which would effectively drop the power factor. In house hold, any equipment that uses any electrical motors, (like washing machines, fans) have the power-factor correcting capacitors directly attached to the motor or any other inductive equipment.

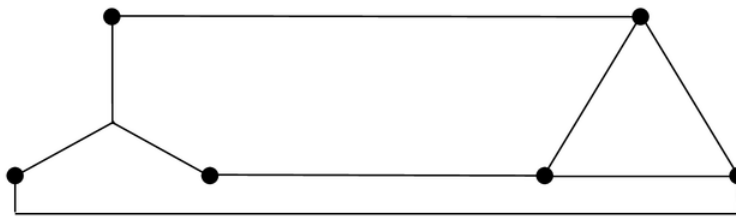
5. Star and Delta arrangement



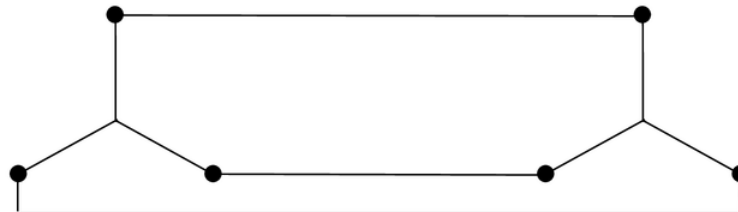
A delta to star arrangement is usually used in transformer applications and the star load can be used for a start up of a electrical motor, it can be a substitution for a softstart.



The delta to delta configuration is mainly used for a smooth drive of motors but as the delta configuration does not limit the current as good as star load configuration, it is not good for motor start-ups.



The star to delta arrangement is usually used for large step up applications as the star configuration requires of less windings than the delta.



The star to star arrangement is widely used in electrical distribution as that allows for both single and three phase circuits connections as well as it allows to the neutral to be earthed whenever It is necessary.

*Research
is good but
there are
no
references.*

PSDE4001 Assignemnt 2 Adam Bedner

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

62/100

PAGE 1

PAGE 2

PAGE 3

Text Comment. A very good explanation of the tasks here and a good set of results.

PAGE 4

Text Comment. Good set of calculations.

PAGE 5

Text Comment. Calculations are good.

Text Comment. A good set of derived vectors.

PAGE 6

Text Comment. Good work.

PAGE 7

PAGE 8

Text Comment. Good results from calculations here.

Text Comment. Should have a diagram.

PAGE 9

PAGE 10

PAGE 11

Text Comment. Research is good but there are no references.

ADAM BEDNER

0

RESEARCH-INFORMED LITERATURE



There is obvious evidence of research. 3/5 No references used. 0/5

3/10

KNOWLEDGE AND UNDERSTANDING



There is an introduction to the assignment and what it entails. 3/5 Description of procedures is good. 3/5 A good discussion of the results even though the instrument has not been discussed. 6/10

12/20

ANALYSIS



This area is good in the report. 24/30. There is no section for conclusion, but there are conclusive discussions included. 4/10

28/40

PRACTICAL APPLICATION AND DEP.



Procedures have been detailed and explained apart from the instrument. There should have been a diagram of the setup included. 3/5 Discussion of results should have included the instrument. The practical was carried out very competently. 3/5

12/20

Quality of work is good. 6/10

SKILLS FOR PROFESSIONAL PRAC.



Report is good even though some diagrams and explanations were left out. 3/5 Practical was carried out very well. 4/5

7/10