Deniz Karakay - 2443307 Date: 29.10.2022

EE361- Homework 1

D1.

Since my school ID finishes with 7, I selected $R_L = 28\Omega$ and $L_L = 38mH$.

D2.

a. The graph of $V_{line-line}$ and V_{phase} of the wye-connected load can be seen in *Figure 1.*

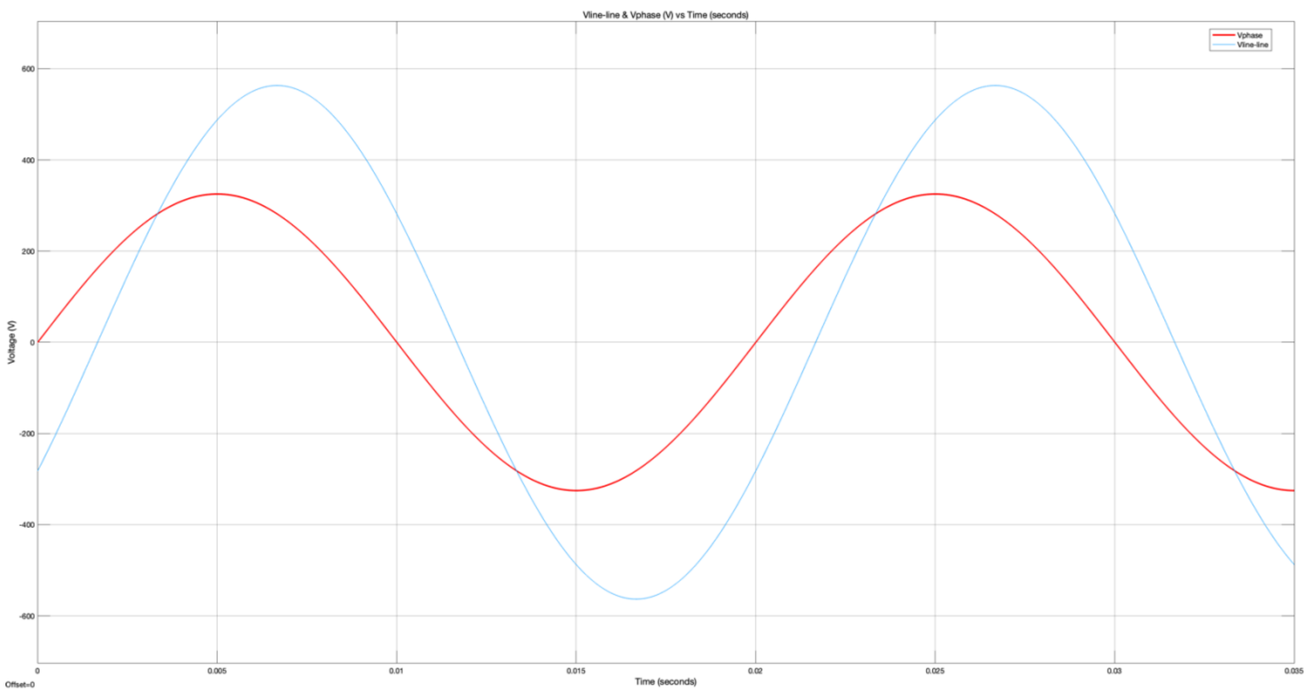
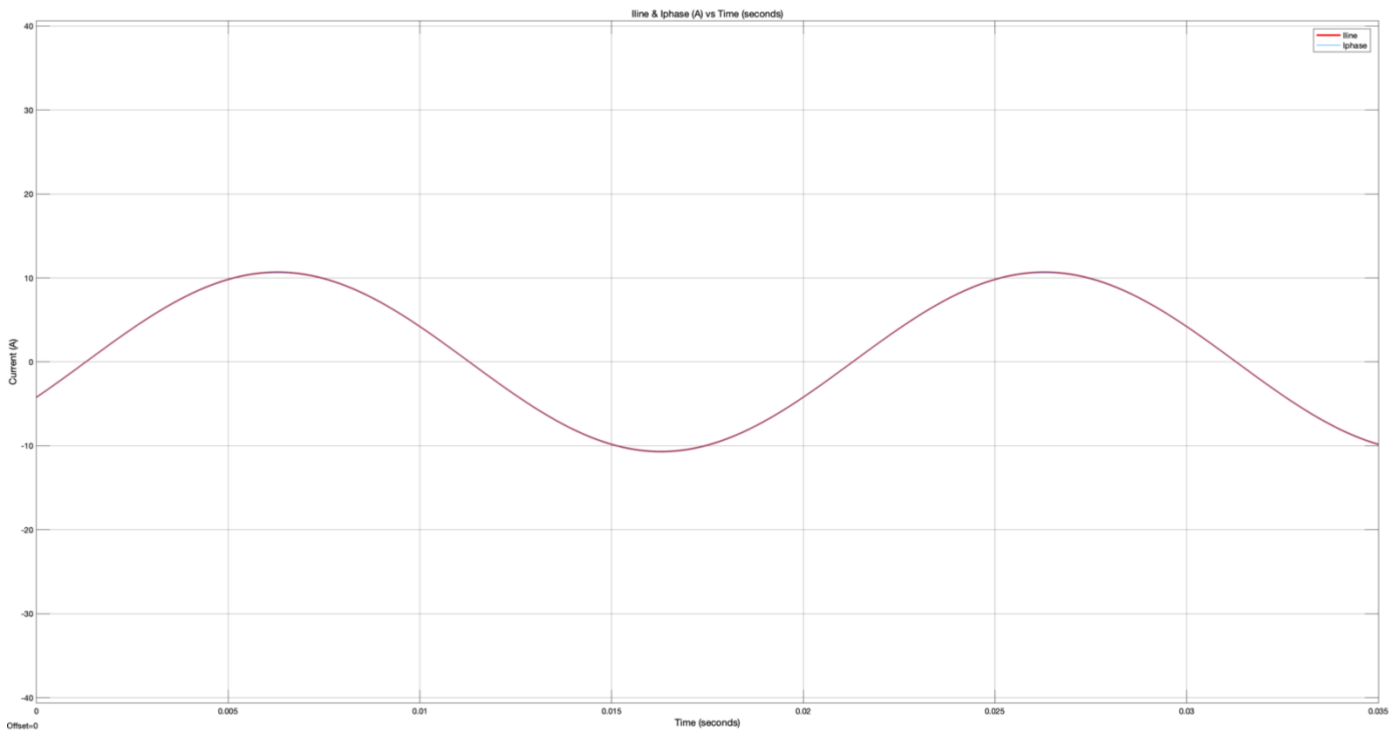


Figure 1. Vline-line and Vphase (V) vs Time (seconds) for wy-connected load.

b. The graph of I_{line} and I_{phase} of the wye-connected load can be seen in *Figure 2.* ($\mathrm{I_{line}} = \mathrm{I_{phase}}$)



c. You can inspect all three phase currents of load on a single graph more than two periods in *Figure 3*. The negative sequence is used in the naming.

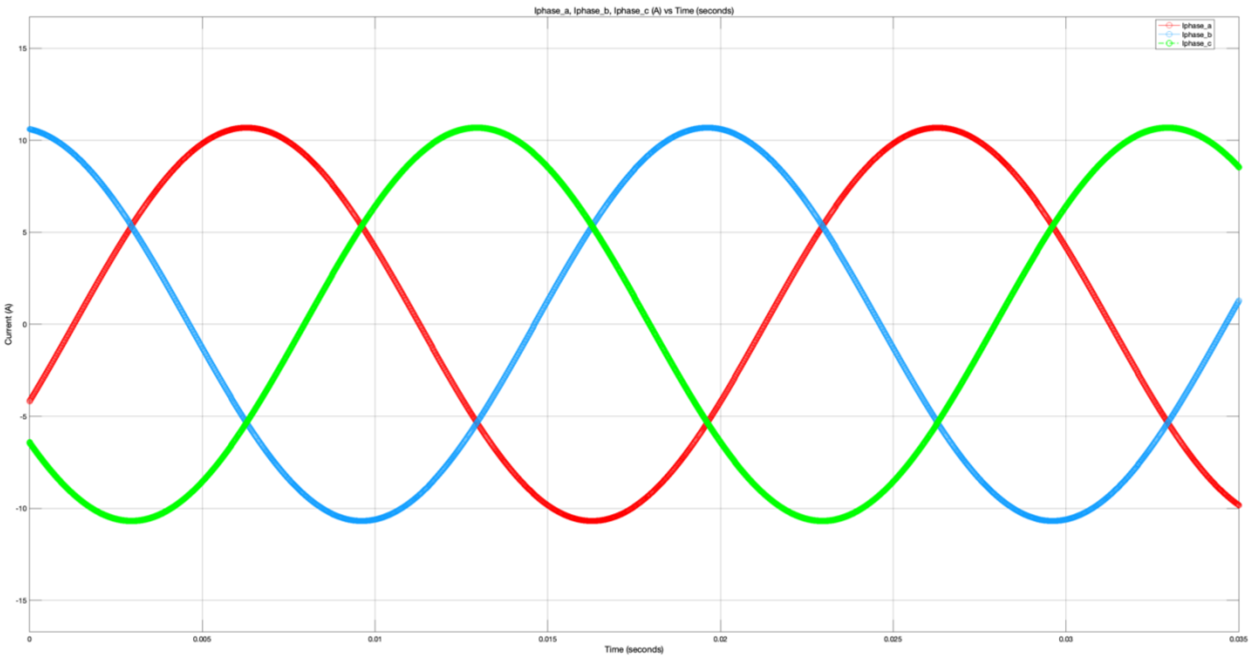
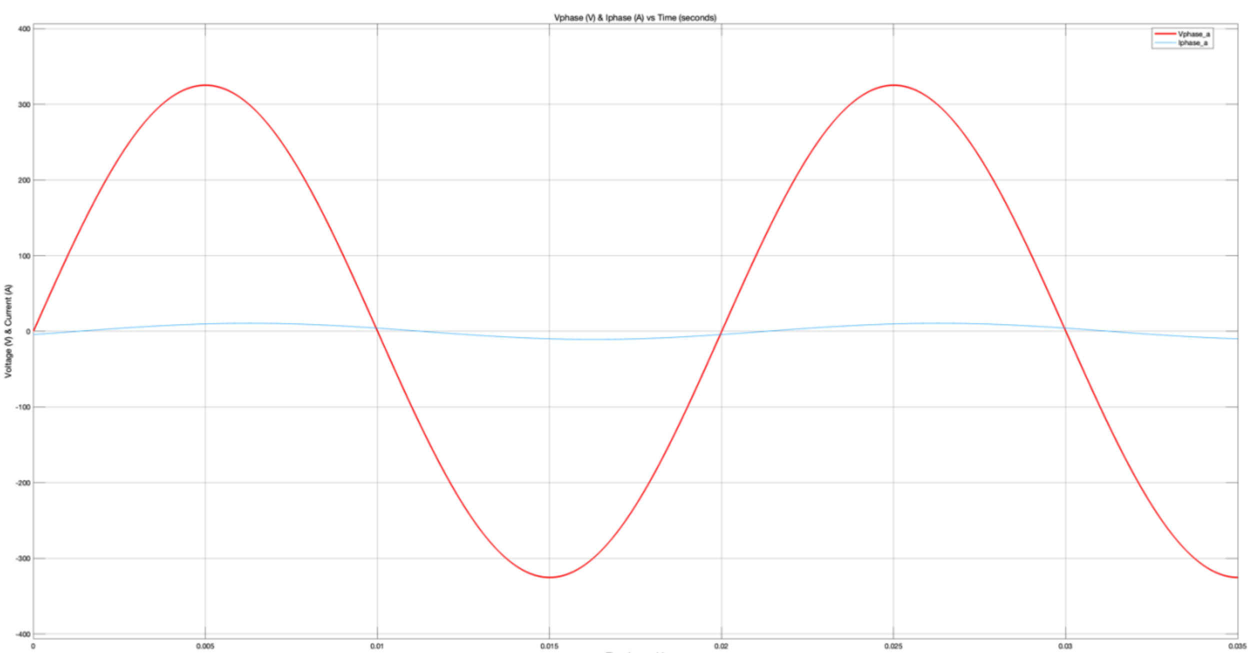


Figure 3. Three phase currents of load vs Time.

d. The graphs I_{phase} and V_{phase} of the wye-connected system can be seen in *Figure 4.*



D3.

I computed instantaneous power per phase by $p(t) = i(t) \times v(t)$ then added all of them to reach final result. The result can be inspected in *Figure 5*. The result can be found as 4796.0507 W.

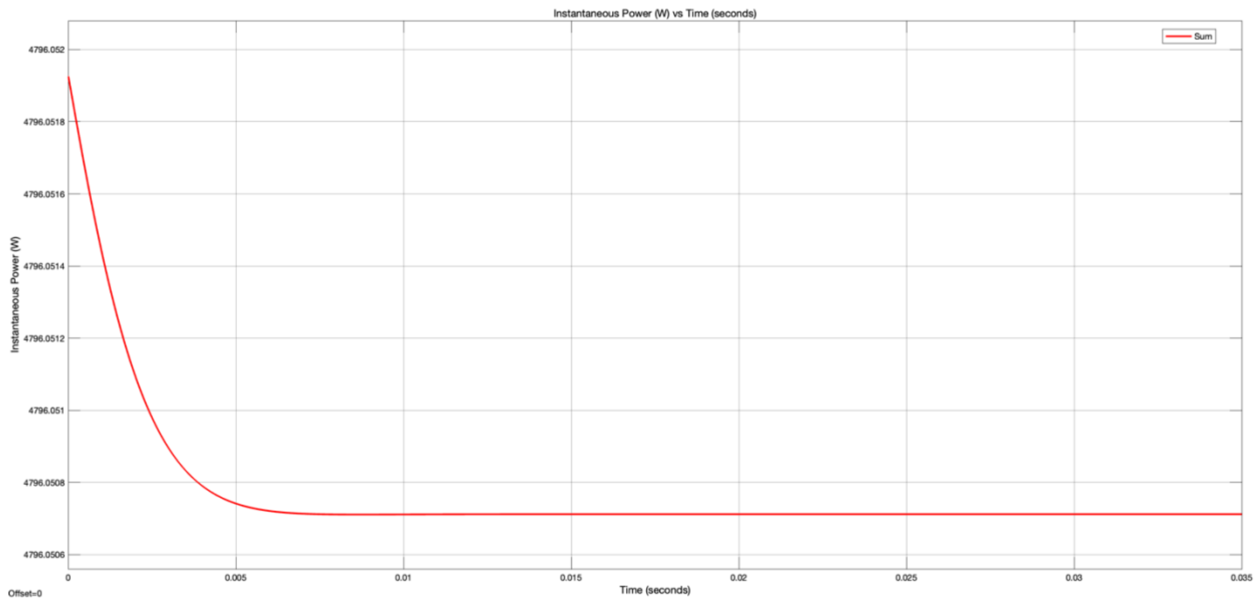


Figure 5. Instantaneous power of 3-phase (W) vs Time (seconds)

D4.

a. The connections of the current and voltage measurement blocks of my model can be seen in Figure 6. I used Two-Wattmeter method to compute the power of the 3-phase wye-connected load.

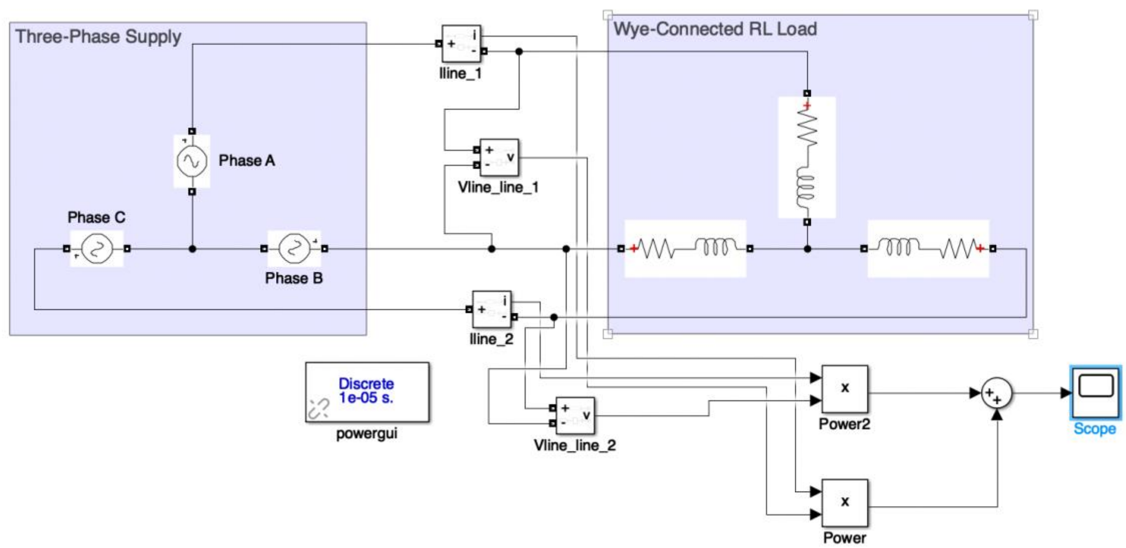


Figure 6. My model screenshot from Simulink to calculate 3-phase load power using Two-Wattmeter method.

b. $Total\ Instantaneous\ Load\ Power\ (W)\ vs\ Time(seconds)$ graph can be examined in *Figure 7*. And as it is expected, the calculated power value converges the previous value like in *Figure 5.*

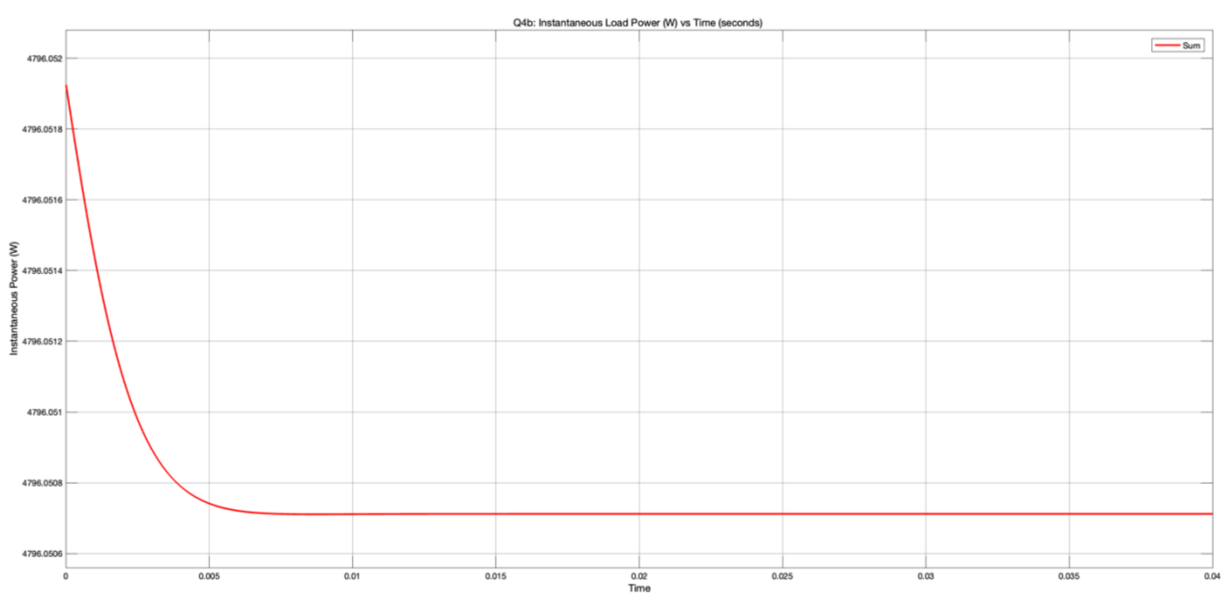


Figure 7. Total load instantaneous power vs Time.

D5.

The power factor (pf) of the load can be computed by using the phase difference between I_{phase} and V_{phase}. To find this phase difference, firstly I determined the time difference between the maximum peak points of two different waves as it can be seen in *Figure 8.* You can see that time difference is seen as 1.336 ms.

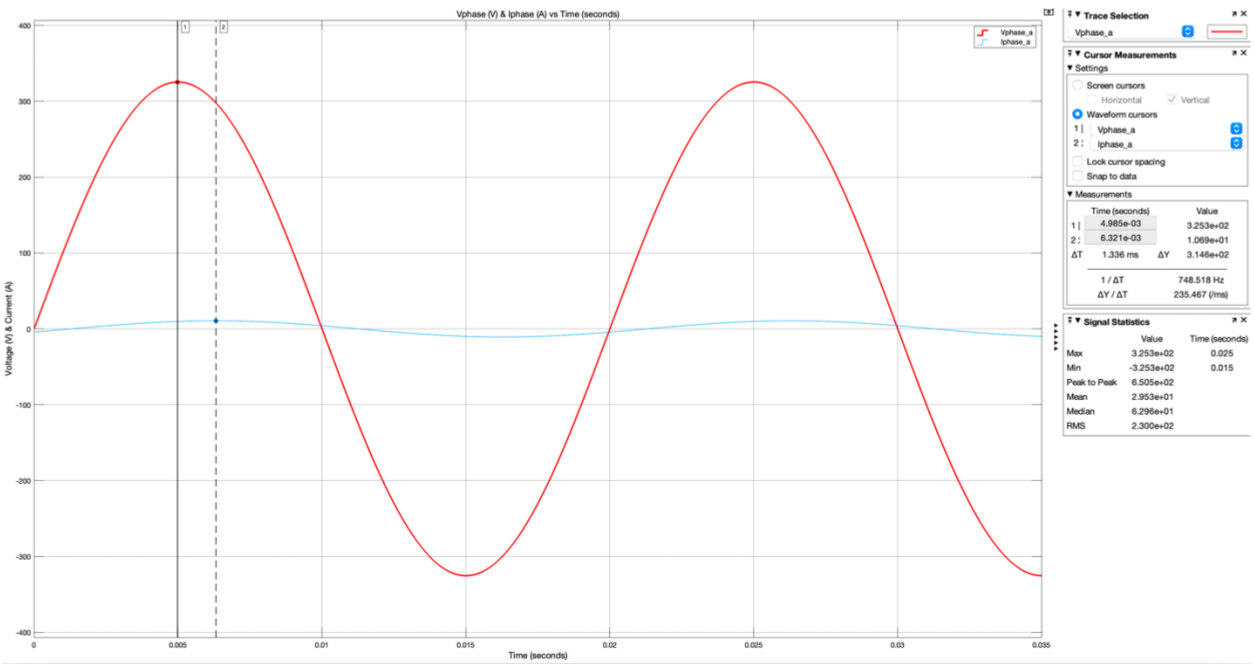


Figure 8. Vphase (V) vs Iphase (A) vs Time (seconds) for calculation of power factor.

Using a basic converter from time delay to phase angle, I calculated the phase angle difference like in *Figure 9.* In this case, the phase angle is 24.05°. The formula can be seen below:

$$Phase\ Shift\ (Degree)\ \phi = 360\ \times\ freq_{system}\ \times\ \Delta t$$
$$where\ \Delta t = 1.336ms\ and\ freq_{system} = 50\ Hz$$

This indicates that $power\ factor\ (pf) = \cos(24.05°)\ = 0.913$. After the calculation of power factor, we can retrieve the complex power of load and utilized power factor to determine the real and reactive powers in the system.

$$Real\ power\ (P) = \sqrt{3} \times S_{load}\ \times \cos(24.05°)\,,$$
$$Reactive\ power\ (Q) = \sqrt{3}\ \times S_{load}\ \times\ \sin\,(24.05°)$$

$$\text{Before contiuning, I utilized two}$$
$$-\ \text{wattmeter method to determine complex power. In our case:}$$

$$S_{load} = I_{line,rms}\ \times\ V_{line,rms}$$

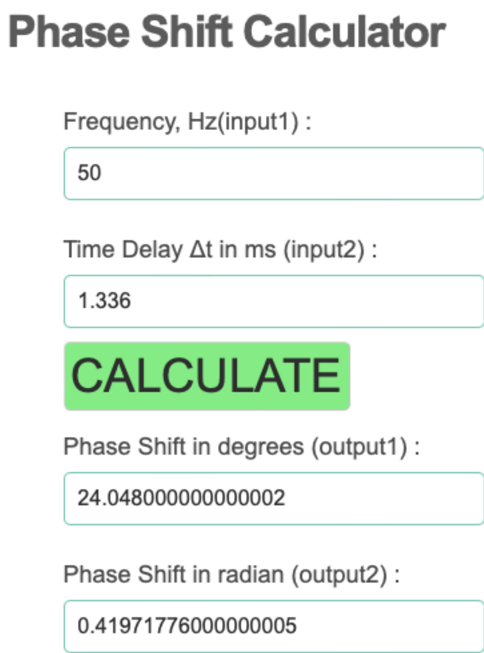


Figure 9. Conversion from time delay to phase angle difference.

I found the $V_{line,rms}$ and $I_{line,rms}$ values from the Simulink that can be seen in *Figure 10* and *Figure 11*, respectively.

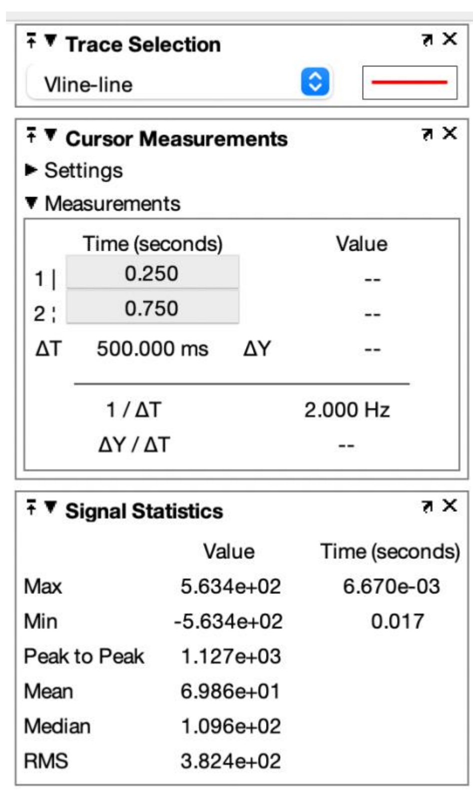


Figure 10. Vline-line from Simulink.

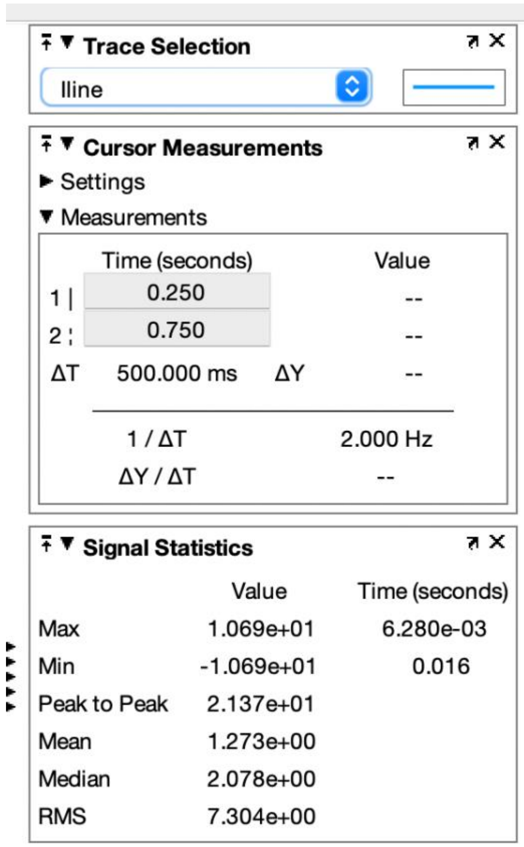


Figure 11. Iline from Simulink.

$$\frac{10.69}{\sqrt{2}} \cdot \frac{563.4}{\sqrt{2}} \cdot \sqrt{3} \cdot \cos(24.05) = 4763.063869$$

$$\frac{10.69}{\sqrt{2}} \cdot \frac{563.4}{\sqrt{2}} \cdot \sqrt{3} \cdot \sin(24.05) = 2125.635108$$

$$\cos(24.05) = 0.9131901652$$

Figure 12. The load power calculation using Vline-line (rms), Iline (rms) and power factor.

Afterward, I determined the Real and Reactive power of the load using an online calculator. According to Figure 12, the power of loads are:

$$Real\ power\ (P) = 4763.06\ W$$
$$Reactive\ power\ (Q) = 2125.63\ VAR$$

D6.

According to my student ID, I doubled the load resistance and inductance only on phase A, while keeping the values of other ones same. You can see the results of currents in Figure 13. The results for voltages can be seen in Figure 14. As you can see from the results, we have unbalanced three phase systems. The magnitudes of voltages for three different phases are not same and the current values are differed from each other. This not only breaks the balanced circuit but also can hurt the system itself. The $I_{phase,a}$ is decreased when we compare with previous case. On the other hand, $V_{phase,a}$ is increased in magnitude.

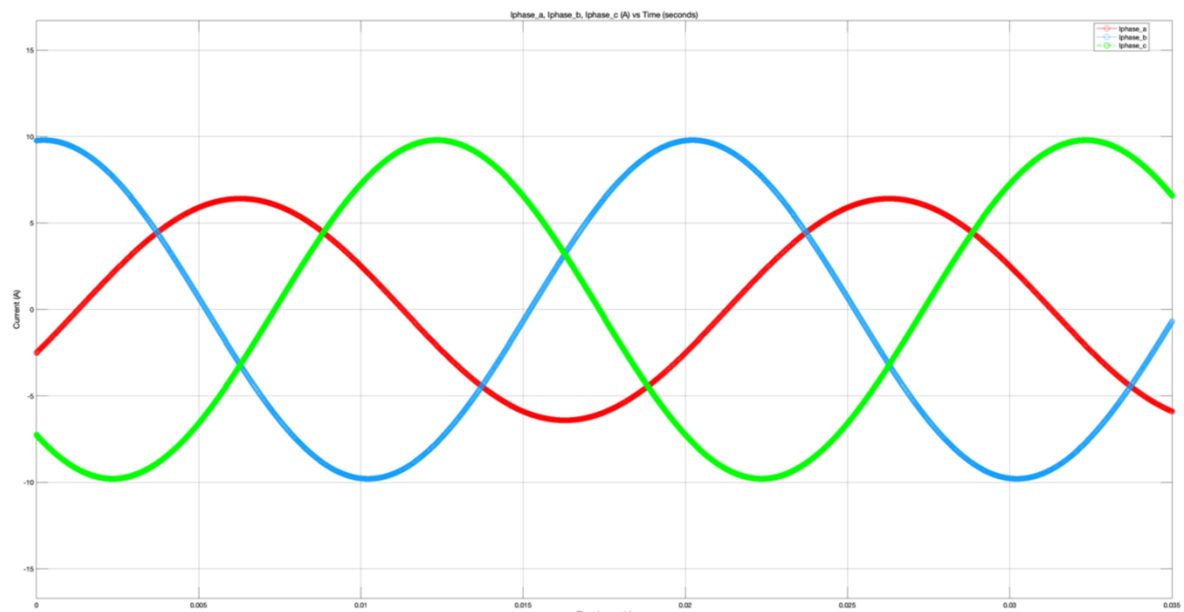


Figure 13. Three phase currents (load of A is modified) vs Time (seconds)

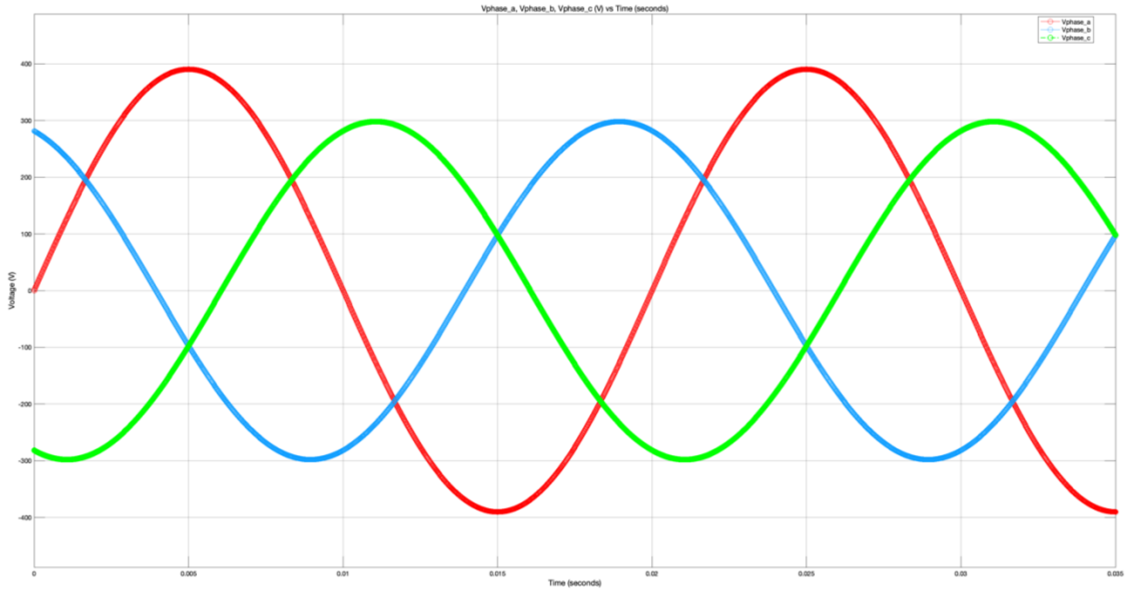


Figure 14. Three phase voltages (load of A is modified) vs Time (seconds)

D7.

Delta version of load can be seen in *Figure 15.*

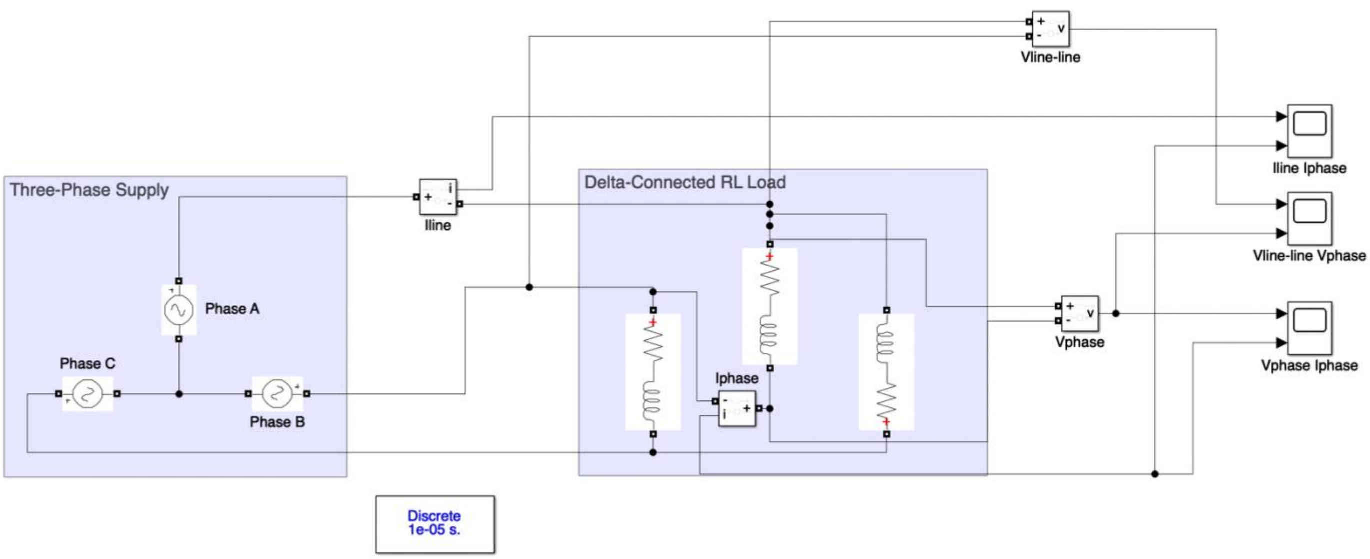


Figure 15. Delta version of Load.

a. The graph $V_{line-line}$ and V_{phase} (V) vs $Time$ $(seconds)$ of the delta-connected load can be seen in *Figure 16.* $V_{line-line} = V_{load}$
b. The graph I_{line} and I_{phase} (A) vs $Time$ $(seconds)$ of the delta-connected load can be seen in *Figure 17.*
c. The graph I_{phase} $(A) and$ V_{phase} (V) vs $Time$ $(seconds)$ of the delta-connected system can be examined in *Figure 18.*

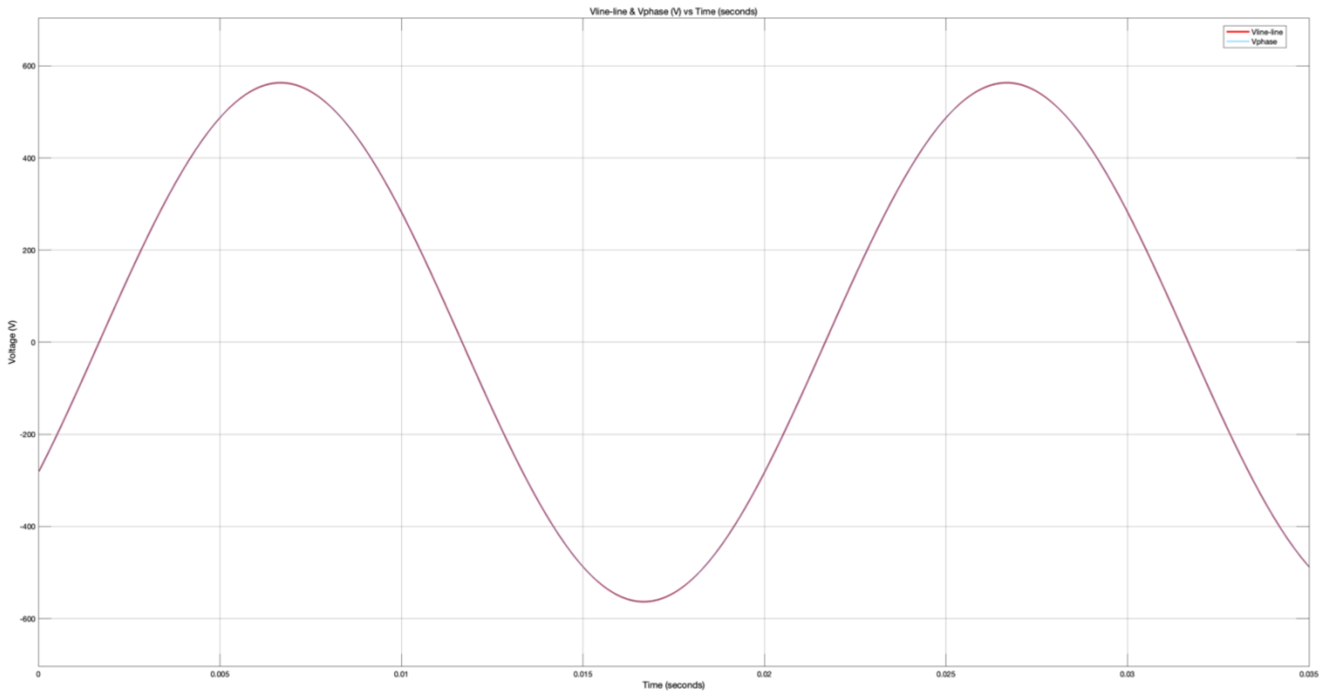


Figure 16. Vline-line and Vphase (V) vs Time (seconds) for delta connected load.

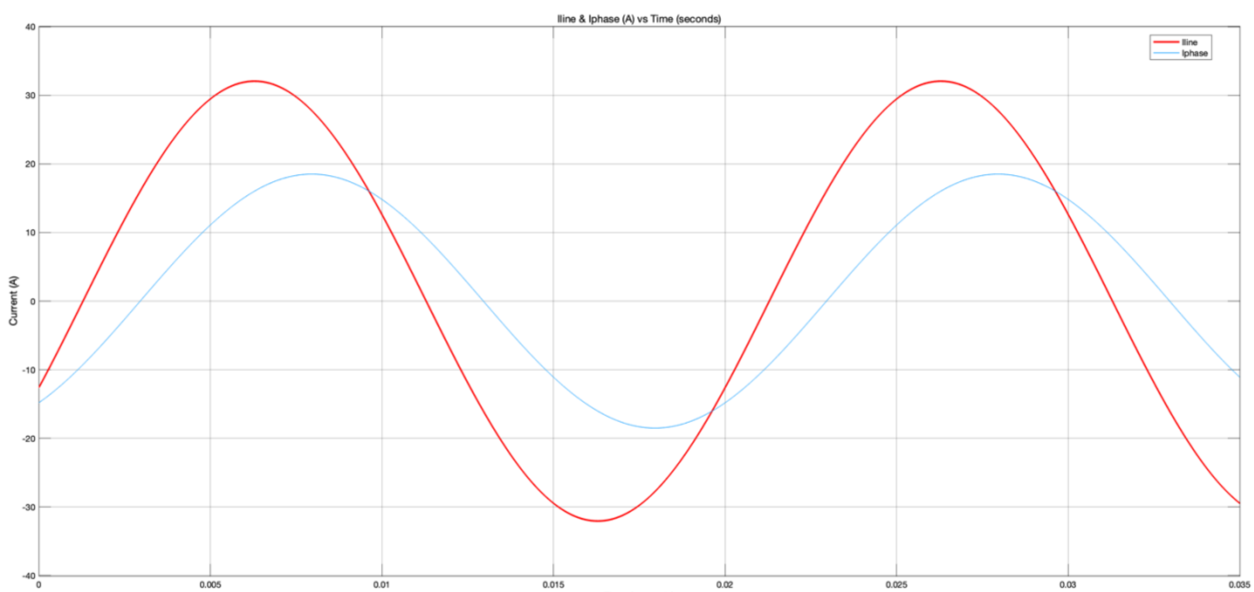


Figure 17. Iline and Iphase (A) vs Time (seconds) for delta connected load.

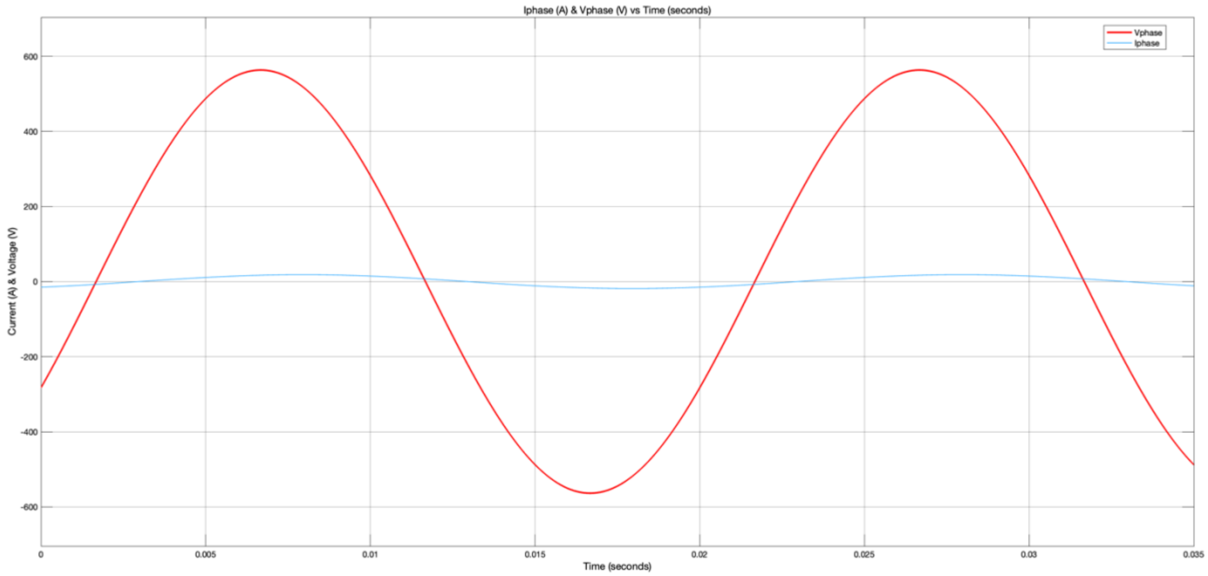


Figure 18. Iphase (A) and Vphase (V) vs Time (seconds) for delta-connected system.

D8.

The power factor (pf) of the load can be computed by using the phase difference between I_{phase} and V_{phase}. To find this phase difference, firstly I determined the time difference between the maximum peak points of two different waves as it can be seen in *Figure 19.* You can see that time difference is seen as 1.332 ms. If we compare the value with power factor in D5. We can see that they are almost same. In fact, they are identical it is because of selecting peak values manually.

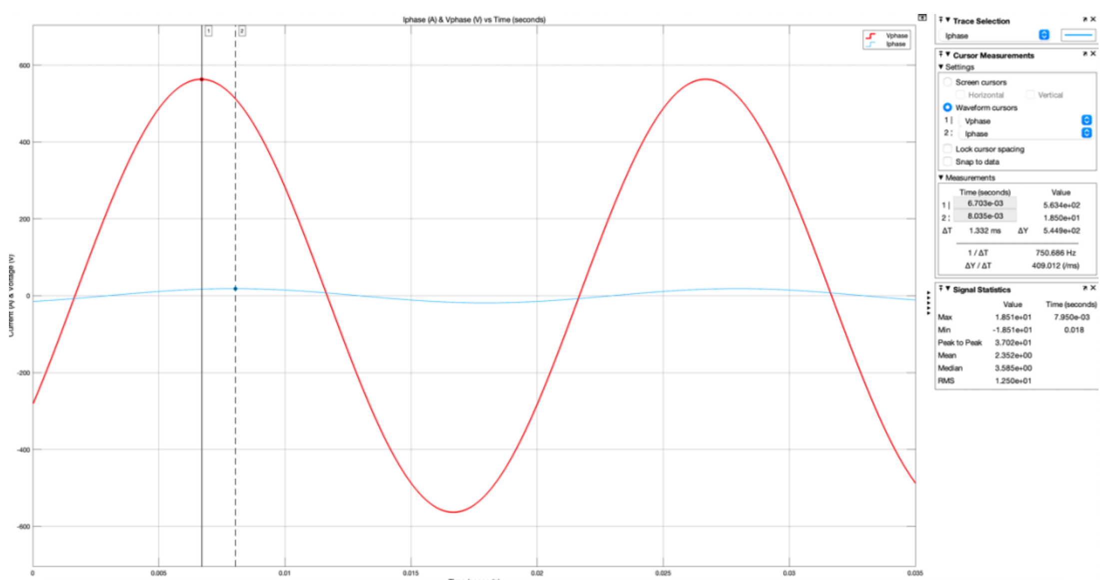


Figure 19. Vphase vs Iphase for calculation of power factor.

Using a basic converter from time delay to phase angle, I calculated the phase angle difference like in *Figure 20.* In this case, the phase angle is 24°. The formula can be seen below:

$$Phase\ Shift\ (Degree)\ \phi = 360\ \times\ freq_{system}\ \times\ \Delta t$$
$$where\ \Delta t = 1.332ms\ and\ freq_{system} = 50\ Hz$$

This indicates that $power\ factor\ (pf) = \cos(24°)\ = 0.914$. After the calculation of power factor, we can retrieve the complex power of load and utilized power factor to determine the real and reactive powers in the system.

$$Real\ power\ (P) = \sqrt{3} \times S_{load}\ \times \cos(24°)\,,$$
$$Reactive\ power\ (Q) = \sqrt{3}\ \times S_{load}\ \times\ \sin\,(24°)$$

$$\text{Before contiuning, I utilized two}$$
$$-\text{wattmeter method to determine complex power. In our case:}$$

$$S_{load} = I_{line,rms}\ \times\ V_{line,rms}$$

I got the $V_{line,rms}\ and\ I_{line,rms}$ values from the Simulink given in *Figure 21* and *Figure 22*.

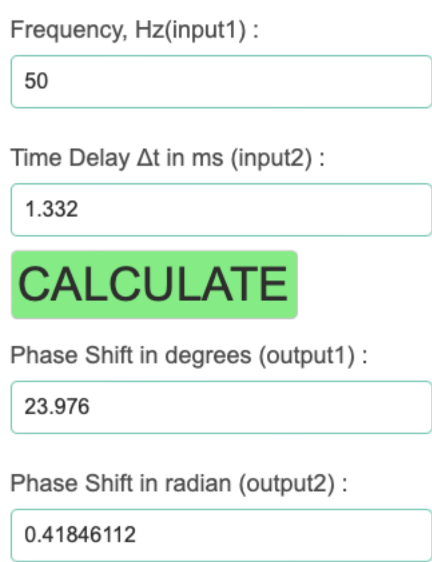


Figure 20. Conversion from time delay to get phase angle difference.

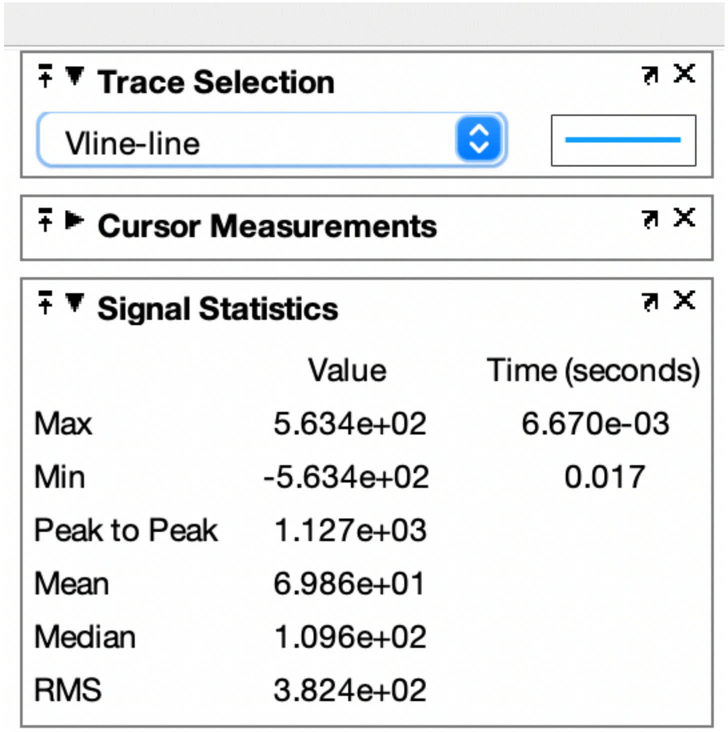


Figure 21. Vline-line rms value from Simulink

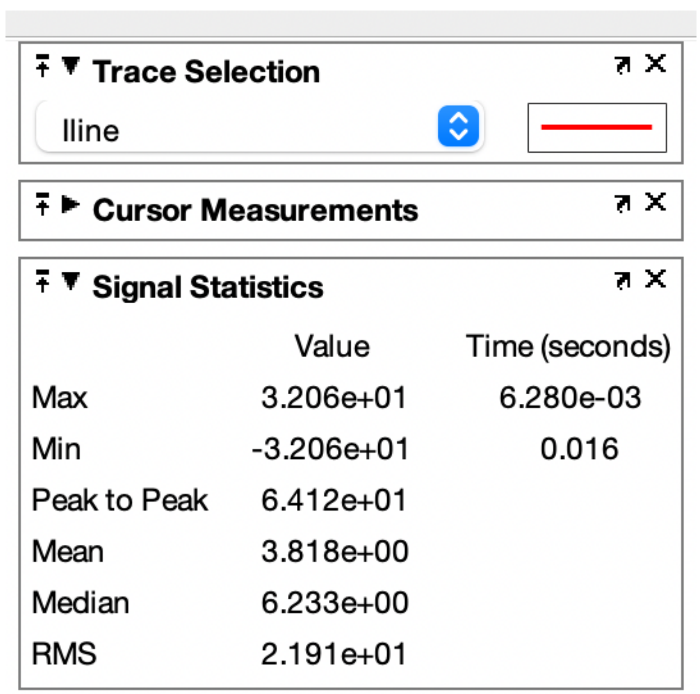


Figure 22. Iline rms value from Simulink

Then, I calculated the Real and Reactive power of the load using calculator. According to *Figure 23*, the power of load is:

$$Real\ power\ (P) = 14290.3\ W$$
$$Reactive\ power\ (Q) = 6362.45\ VAR$$

$\frac{32.06}{\sqrt{2}} \cdot \frac{563.4}{\sqrt{2}} \cdot \sqrt{3} \cdot \cos(24)$	$= 14290.29371$
$\frac{32.06}{\sqrt{2}} \cdot \frac{563.4}{\sqrt{2}} \cdot \sqrt{3} \cdot \sin(24)$	$= 6362.44868$
$\cos(24)$	$= 0.9135454576$

Figure 23. The load power calculation using Iline,rms, Vline,rms and power factor

E1.

There are oscillations in the waveforms of current and voltage in single-phase systems since they consist of an AC source and a load. In other words, due to having an AC source, the load's voltage and current are sinusoidal signals. Since multiplying these waves yields the instantaneous power, each time a new sinusoidal signal appears, the instantaneous power changes. It shows that the instantaneous power for a single-phase system cannot be constant.

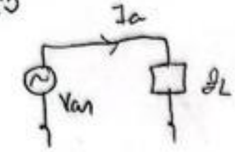
E2.

We are utilizing three-phase systems connected into delta or wye instead of having three single systems due to several reasons. Firstly, the instantaneous power is constant in three-phase systems because of summation of vectors. Secondly, we can decrease the number of wires required to build such system and reduce the complexity of the circuit.

E3.

The drawing and all calculation for E3 can be seen in *Figures 24.*

E3



$V_{an} = 230\,V_{rms}$ $R_L = 28\Omega$ $L = 38\,mH$

$Z_L = 28 + j\omega L = 28 + j2\pi f L = (28 + j11.938)\,\Omega$

1φ per phase cct

$V_{an} = 325.27\angle 0^\circ$ V $\qquad I_a = \dfrac{V_{an}}{Z_L} = \dfrac{325.27}{28 + j11.938} = \dfrac{325.27\angle 0}{30.44\angle 23.09}$

$= 10.69\angle -23.09$ A

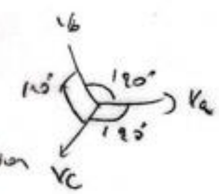
$V_{an} = 325.27\angle 0^\circ$ V $\longrightarrow \sqrt{2}.230\cos(\omega t + \phi v)$

$I_a = 10.69\angle -23.09$ A $\longrightarrow \sqrt{2}.7.56\cos(\omega t + \phi v - 23.09)$

Phase voltages

$V_{an}(t) = \sqrt{2}.230\cos(\omega t + \phi v)$
$V_{bn}(t) = \sqrt{2}.230\cos(\omega t + \phi v + 120^\circ)$
$V_{cn}(t) = \sqrt{2}.230\cos(\omega t + \phi v - 120^\circ)$

Negative sequence is used.



Line voltages.

$|V_{line}| = \sqrt{3}\,|V_{phase}|$
$I_{line} = I_{phase}$
Y connection

$V_{ab}(t) = \sqrt{6}\;230\cos(\omega t + \phi v - 30^\circ)$
$V_{bc}(t) = \sqrt{6}\;230\cos(\omega t + \phi v + 90^\circ)$
$V_{ca}(t) = \sqrt{6}\;230\cos(\omega t + \phi v - 150^\circ)$

$\omega t = 100\pi$

Line currents = Phase Currents

$I_a(t) = \sqrt{2}.7.56\cos(\omega t + \phi v - 23.09)$ A
$I_b(t) = \sqrt{2}.7.56\cos(\omega t + \phi v + 96.91)$ A
$I_c(t) = \sqrt{2}.7.56\cos(\omega t + \phi v - 143.09)$ A

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Figure 24. Calculation for E3.

E4.

My calculated results (E3) for line-to-line voltage and current values are same for Simulink results in D5.

$$I_{line-simulink} = 10.69\ A$$
$$I_{line-calculated} = 10.69\ A$$

E5.

The phasor diagrams for E5 can be seen in *Figure 25*.

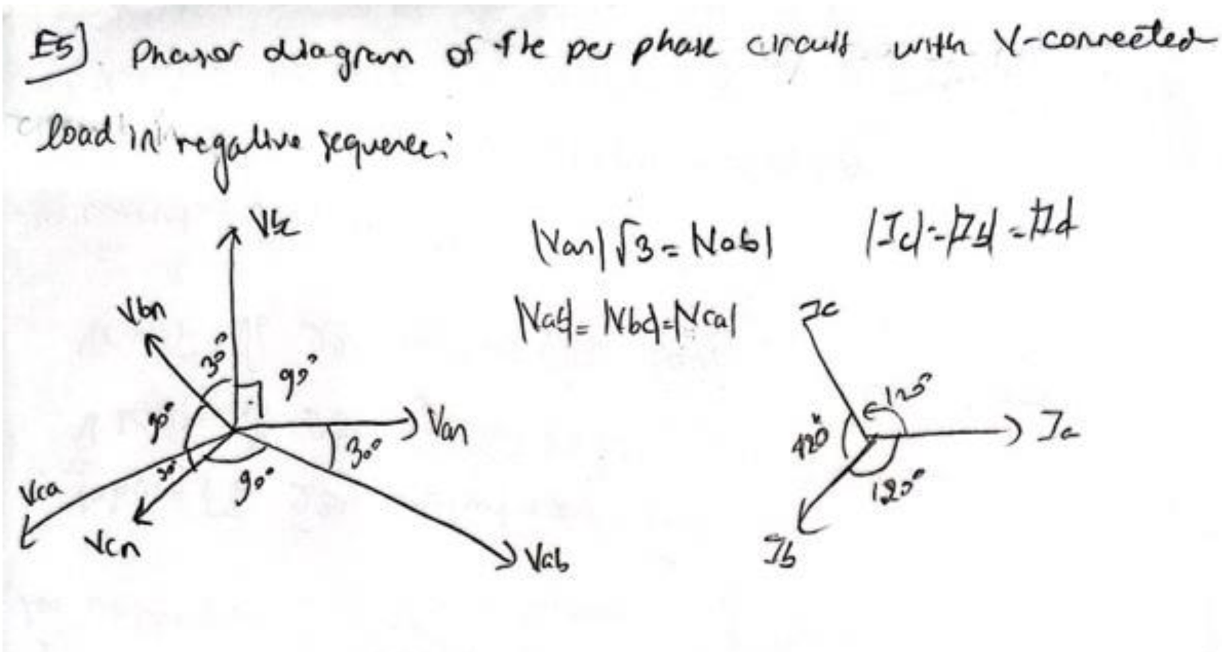


Figure 25. Phasor diagrams for E5.

E6.

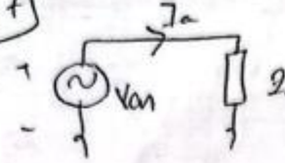
The power calculations for part D3 & D5 return almost the same result. Though the way I approach and solve the problem differs, the result for load power is almost same for both of these cases. The difference happened due to manual rounding operations, significant values etc.

$$P_{D3} = 4796.50\ A$$
$$P_{D5} = 4763.06\ A$$

E7.

The calculations can be seen as in *Figure 26*.

E7)



↑ per phase cct

$V_{an} = 325.27\angle 0^\circ$

$Z_{L\Delta} = 28 + j11.938\ \Omega$

$Z_L' = Z_{LY} = \frac{Z_{L\Delta}}{3} = 9.33 + j3.98\ \Omega$

$wt = 100\pi$

$V_{an} = 230 \cdot \sqrt{2} \cdot \cos(wt + \phi_V)$ ← from E3

↑ (V_{rms})

$I_a = \frac{V_{an}}{Z_L'} = \frac{325.27}{9.33 + j3.98} = \frac{325.27\angle 0}{10.15\angle 23.09} = 32.05\angle -23.09\ A$

$I_a = 22.66\sqrt{2}\cos(wt + \phi_V - 23.09)\ A$

For Δ connected load → $V_{line} = V_{phase}$

For Δ-connected load
$|I_{line}| = |I_{phase}|\sqrt{3}$

line voltages:

$V_{ab,l} = \sqrt{2}\,230\cos(wt + \phi_V)\ V$

$V_{bl} = \sqrt{2} \cdot 230\cos(wt + \phi_V + 120^\circ)\ V$

$V_{cl} = \sqrt{2} \cdot 230\cos(wt + \phi_V - 120^\circ)\ V$

$I_{an}(t) = \sqrt{2} \cdot 22.66\cos(wt + \phi_V - 23.09)\ A$

$I_{bn}(t) = \sqrt{2} \cdot 22.66\cos(wt + \phi_V + 96.91)\ A$

$I_{cn}(t) = \sqrt{2}\ 22.66\cos(wt + \phi_V - 143.09)\ A$

↑ line currents

Phase currents:

$I_{ab} = \frac{1}{\sqrt{3}}\sqrt{2}\ 22.66\cos(wt + \phi_V - 53.09)\ A$

$I_{bc} = \frac{1}{\sqrt{3}}\sqrt{2} \cdot 22.66\cos(wt + \phi_V + 66.91)\ A$

$I_{ca} = \frac{1}{\sqrt{3}}\sqrt{2} \cdot 22.66\cos(wt + \phi_V - 173.09)\ A$

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Figure 26. Calculation for E7.

E8.

If we compare the line currents for wye and delta connected loads, we can state that line currents for wye connected loads is less than delta-connected ones. We can obtain this conclusion from the examining the *Figures 11* and *Figures 22*.

$$I_{line-delta} = 32.06\ A$$
$$I_{line-wye} = 10.69\ A$$

E9.

The real & reactive powers delivered to 3-phase load of the circuit are increased if the connection of RL load is changed from wye to delta type of connection. We can get the real power which is delivered to 3-phase load under wye connection from *Figure 12* as 4.763 kW, the reactive power as 2.126 kVAR. For 3-phase load with delta connection, real power can be found as 14.290 kW from *Figure 23,* the reactive power can be found as 6.362 kVAR.

E10.

The calculations in which I did to find capacitance of capacitor that sets power factor of load as 1 can be examined in *Figure 27*.

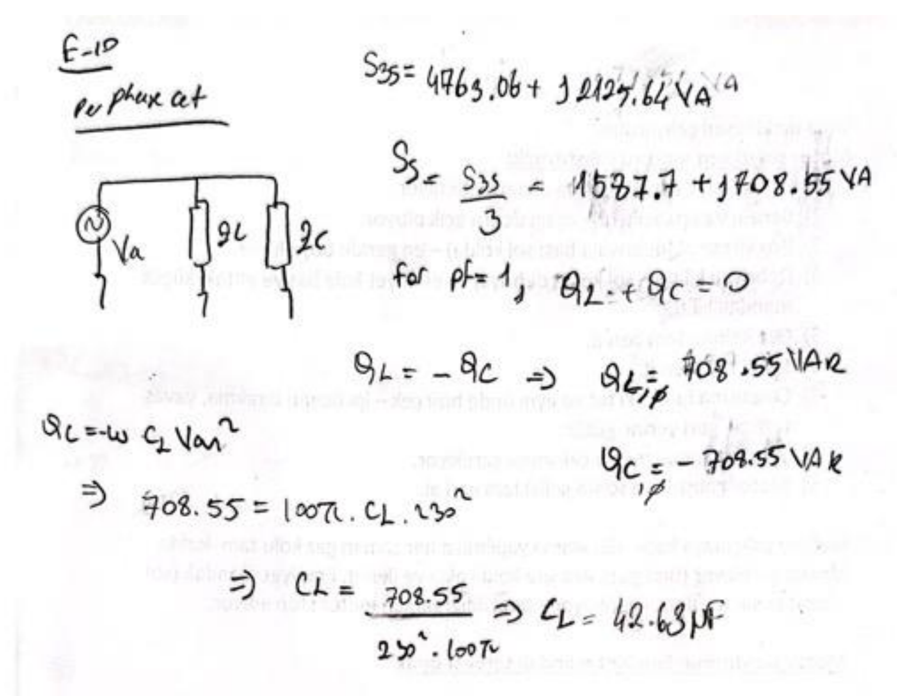
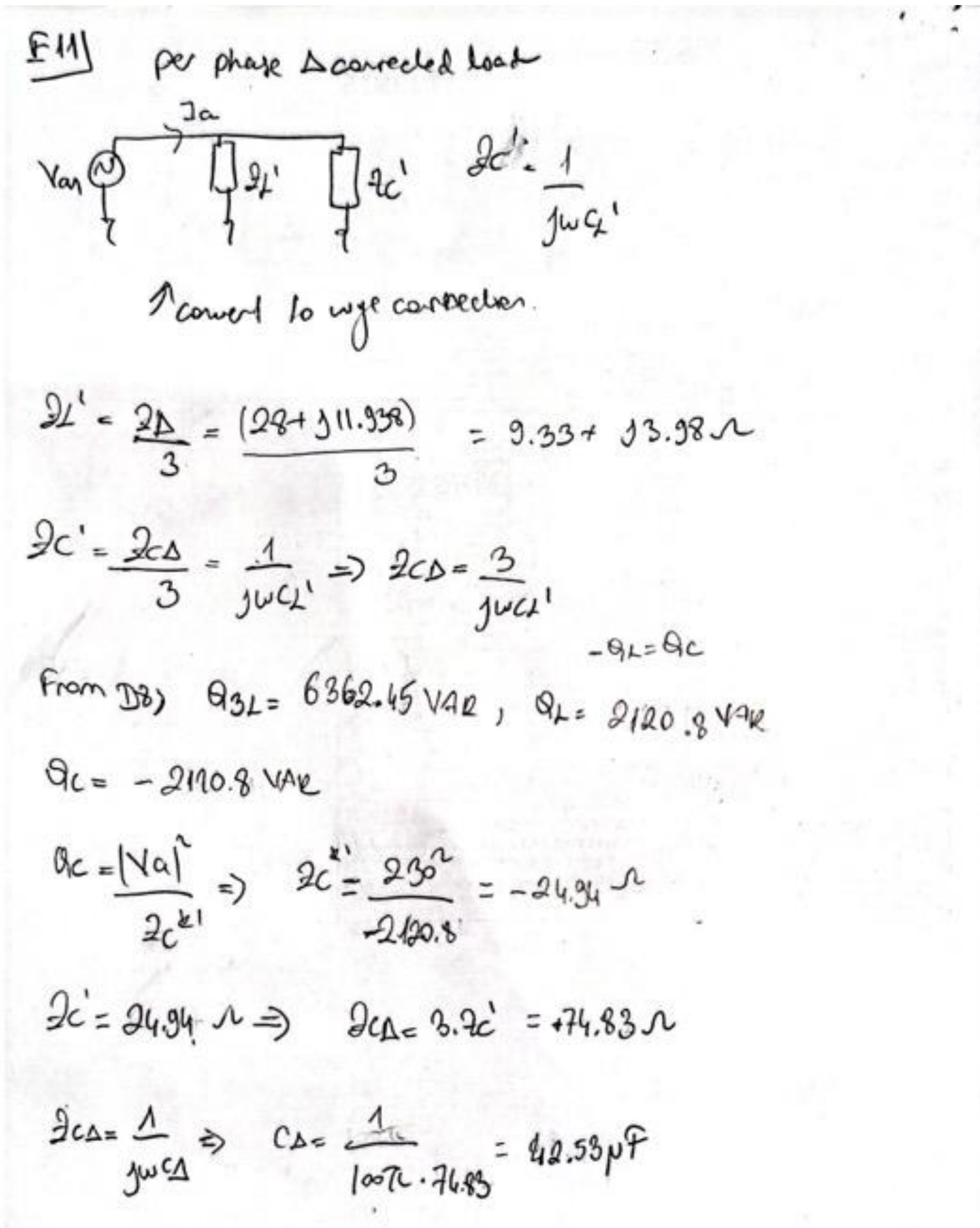


Figure 27. Calculations for finding capacitance to make pf = 1.

E11.

The calculations to determine capacitance of capacitor to set pf = 1 can be examined in *Figure 28*. You can see that capacitance values of capacitor from *Figure 27* and *Figure 28* are almost same. The negligible difference originates from the manual calculations.



E11) per phase Δ connected load

$Z_C' = \frac{1}{j\omega C_L'}$

↑ convert to wye connection.

$Z_L' = \frac{Z_\Delta}{3} = \frac{(28 + j11.938)}{3} = 9.33 + j3.98\,\Omega$

$Z_C' = \frac{Z_{C\Delta}}{3} = \frac{1}{j\omega C_L'} \Rightarrow Z_{C\Delta} = \frac{3}{j\omega C_L'}$

$-Q_L = Q_C$

From D8) $Q_{3L} = 6362.45$ VAR , $Q_L = 2120.8$ VAR

$Q_C = -2120.8$ VAR

$Q_C = \frac{|V_a|^2}{Z_C^{*'}} \Rightarrow Z_C^{*'} = \frac{230^2}{-2120.8} = -24.94\,\Omega$

$Z_C' = 24.94\,\Omega \Rightarrow Z_{C\Delta} = 3 \cdot Z_C' = 74.83\,\Omega$

$Z_{C\Delta} = \frac{1}{j\omega C_\Delta} \Rightarrow C_\Delta = \frac{1}{100\pi \cdot 74.83} = 42.53\mu F$

Figure 28. The calculations for capacitance value for capacitor for pf = 1.