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EE160: Experiment 5

Objective: i) Model Ideal Transformer in SPICE. Subsequently, design and simulate the following circuits in SPICE:

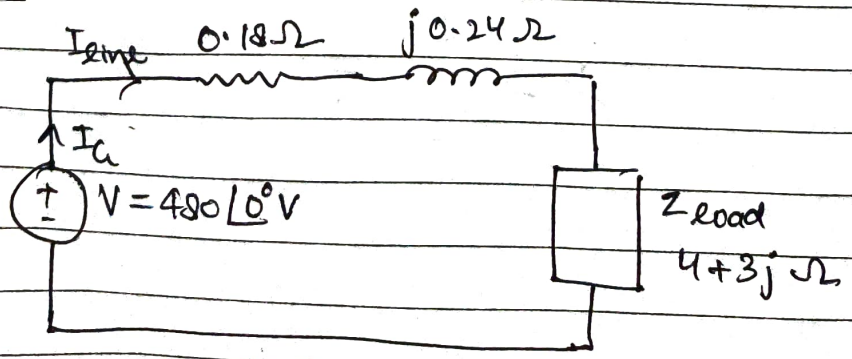
(a) Power transmission system without transformer
(b) Power transmission system with transformer at both ends of the transmission line.

(ii) Plot the voltages and currents for source, transmission line and load. Further, plot the power supplied by the source, power loss in the transmission line, and power delievered to the load.

(iii) Calculate these voltages, currents and powers theoretically. Also, calculate the efficiency of the power transmission system.

Mathematical Expressions and Theoretical Calculations

CIRCUIT 1:



From the circuit it is clear that,

$$\boxed{\bar{I}_{cct} = \bar{I}_{line} = \bar{I}_{load}}$$

$$\bar{I}_{line} = \frac{\bar{V}}{Z_{line} + Z_{load}}$$

$$= \frac{480\angle 0^\circ}{(0.18 + j0.24) + (4 + j3)}$$

$$= \frac{480\angle 0^\circ}{4.18 + j3.24}$$

$$\bar{I}_{line} = \frac{480\angle 0^\circ}{5.29\angle 37.8^\circ}$$

$$\boxed{\bar{I}_{line} = 90.8\angle -37.8^\circ \text{ A}}$$

∴ load voltage, $\bar{V}_{load} = \bar{I}_{line} \times \bar{Z}_{load}$

$$\bar{V}_{load} = 90.8\angle -37.8^\circ \times (5\angle 36.9^\circ)$$

$$\boxed{\bar{V}_{load} = 454\angle -0.9^\circ \text{ V}}$$

the losses due to line transmission line.

$$P_{loss} = (I_{line})^2 (R_{line})$$

$$= (90.8)^2 \times (0.18)$$

$$\boxed{P_{loss} = 1484 \text{ W}}$$

and, power supplied by generator

$$P_G = V_G \cdot I_G$$

$$= (480)(90.8)$$

$$\boxed{P_G = 43584 \text{ W}}$$

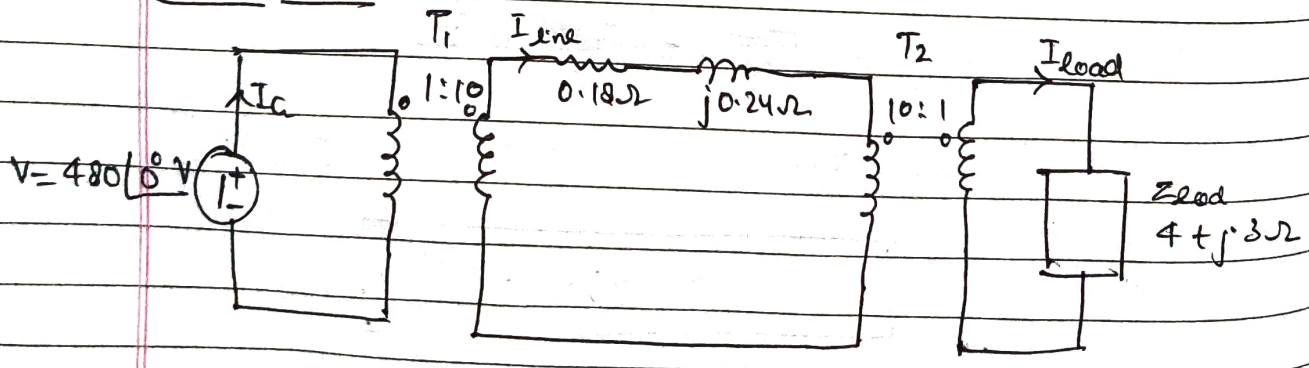
$$\therefore \text{Efficiency} = \frac{P_G - P_{loss}}{P_G} \times 100\%$$

$$= \frac{43584 - 1484}{43584} \times 100\%$$

$$\boxed{\therefore \text{Efficiency} = 96.59\%}$$

Hence, 96.59% of the power supplied by the source reaches the load.

CIRCUIT 2:



Let us convert this system to common voltage level using the following steps:

(i) Eliminate transformer T_2 by refering the load over to the transmission line's voltage level.

(ii) Eliminate transformer T_1 by refering the transmission line's element and equivalent load at the transmission line's over the source's side.

Load impedance on reflecting it to transmission system's voltage,

$$Z'_{load} = a^2 Z_{load}$$

$$= (10)^2 (4\Omega + j3\Omega)$$

$$Z'_{load} = (400 + j300)\ \Omega$$

The total impedance at transmission line level is now,

$$Z_{eq} = Z_{line} + Z'_{load}$$

$$= 400.18 + j(300.24)\ \Omega$$

$$\boxed{Z_{eq} = 500.3 \angle 36.88^\circ\ \Omega}$$

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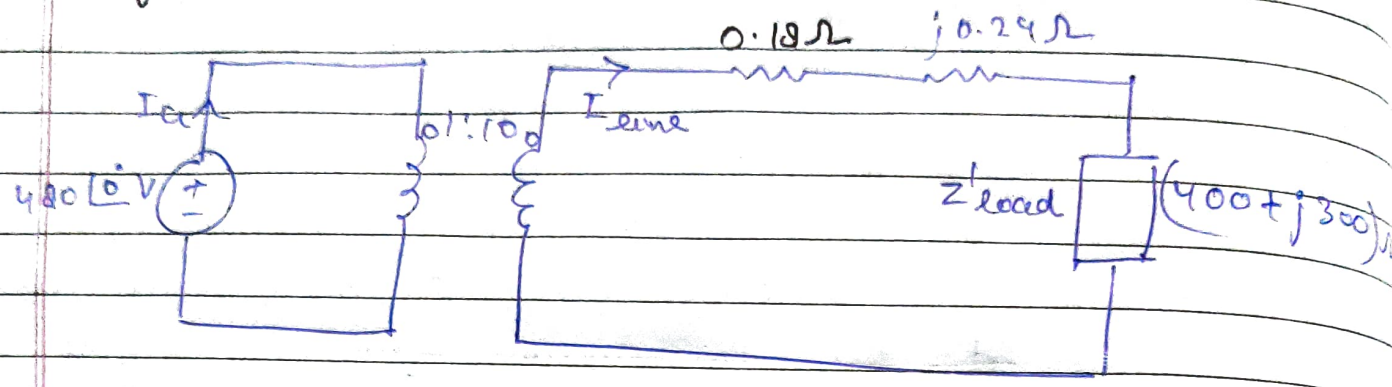
Equivalent Circuit



Now, the impedance at transmission line level ($Z_{line} + Z'_{load}$) is reflected across T_1 to the source voltage's level.

$$Z'_{eq} = a^2 Z_{eq}$$

$$= \frac{1}{100}\left(Z_{line} + Z'_{load}\right)$$

$$Z'_{eq} = \frac{1}{100}\left(400.18 + j\,300.24\right)\Omega$$

$$\boxed{Z'_{eq} = 5.003 \angle 36.88^\circ\ \Omega}$$

Now, we can say that

$$Z''_{load} = 4 + j3\ \Omega$$

$$Z'_{line} = 0.0018\ \Omega + j\ 0.0024\ \Omega$$

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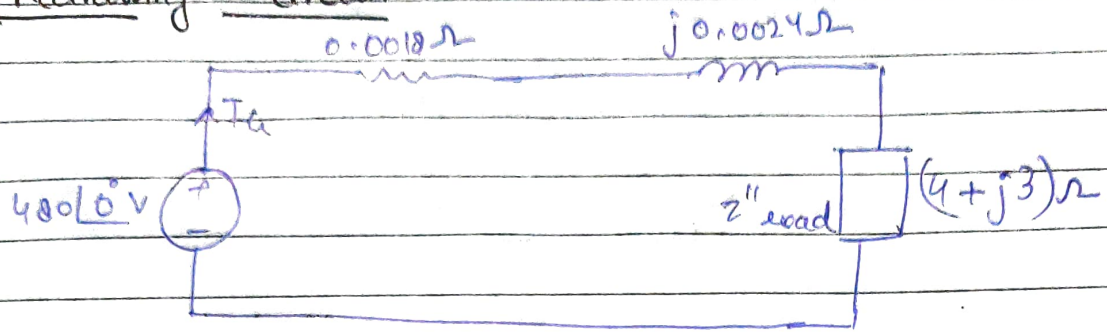
Redrawing circuit



Now, generator's current I_G,

$$\bar{I}_G = \frac{\bar{V}}{\bar{Z}_{eq}}$$

$$\bar{I}_G = \frac{400\angle 0^\circ \text{ V}}{5.003\angle 36.88}$$

$$\boxed{\bar{I}_G = 95.94\angle -36.88^\circ \text{ A}}$$

working back through T_1, we get

$$N_{p_1} \bar{I}_G = N_{s_1} \bar{I}_{line}$$

$$\therefore \bar{I}_{line} = \frac{N_{p_1}}{N_{s_1}} \bar{I}_G$$

$$\bar{I}_{line} = \frac{1}{10}\left(95.94\angle -36.88^\circ\right)$$

$$\boxed{\therefore \bar{I}_{line} = 9.594\angle -36.88^\circ \text{ A}}$$

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Now, working back through I_2,

$$N_{P_2} I_{line} = N_{S_2} I_{load}$$

$$\bar{I}_{load} = \frac{10}{1} \times (9.594 \angle -36.88^\circ)$$

$$\boxed{\bar{I}_{load} = 95.94 \angle -36.88^\circ \text{ A}}$$

Now,

$$\bar{V}_{load} = \bar{I}_{load} \times \bar{Z}_{load}$$

$$= (95.94 \angle -36.88^\circ) \times (5 \angle 36.87^\circ)$$

$$\boxed{\bar{V}_{load} = 479.7 \angle -0.001^\circ \text{ V}}$$

Now, line losses P_{loss_L}

$$P_{loss_L} = (I_{line})^2 \times R_{line}$$

$$= (9.594)^2 \times (0.18)$$

$$\boxed{P_{loss_L} = 16.7 \text{ W}}$$

and, power supplied by generator

$$P_G = \bar{I}_G \bar{V}_G$$

$$= (480)(95.94 \text{ A})$$

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$$P_L = 46051.2\,W$$

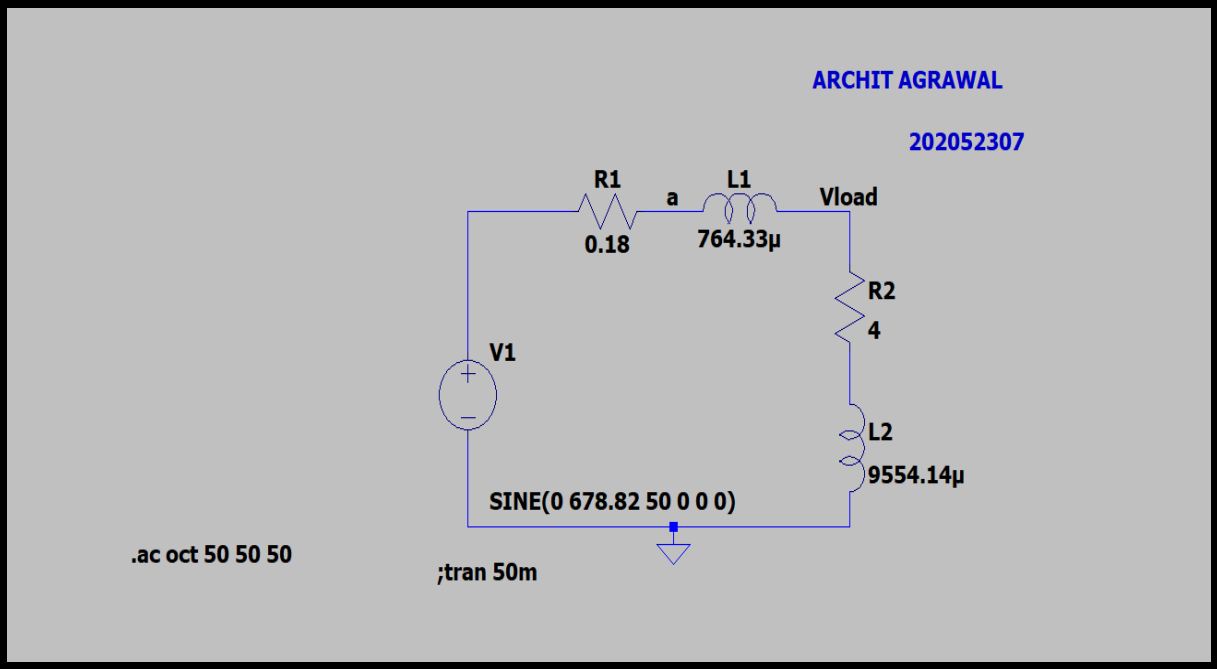
$$\therefore \text{Efficiency} = \frac{46051.2 - 167}{46051.2} \times 100\%$$

$$\text{Efficiency} = 99.964\%$$

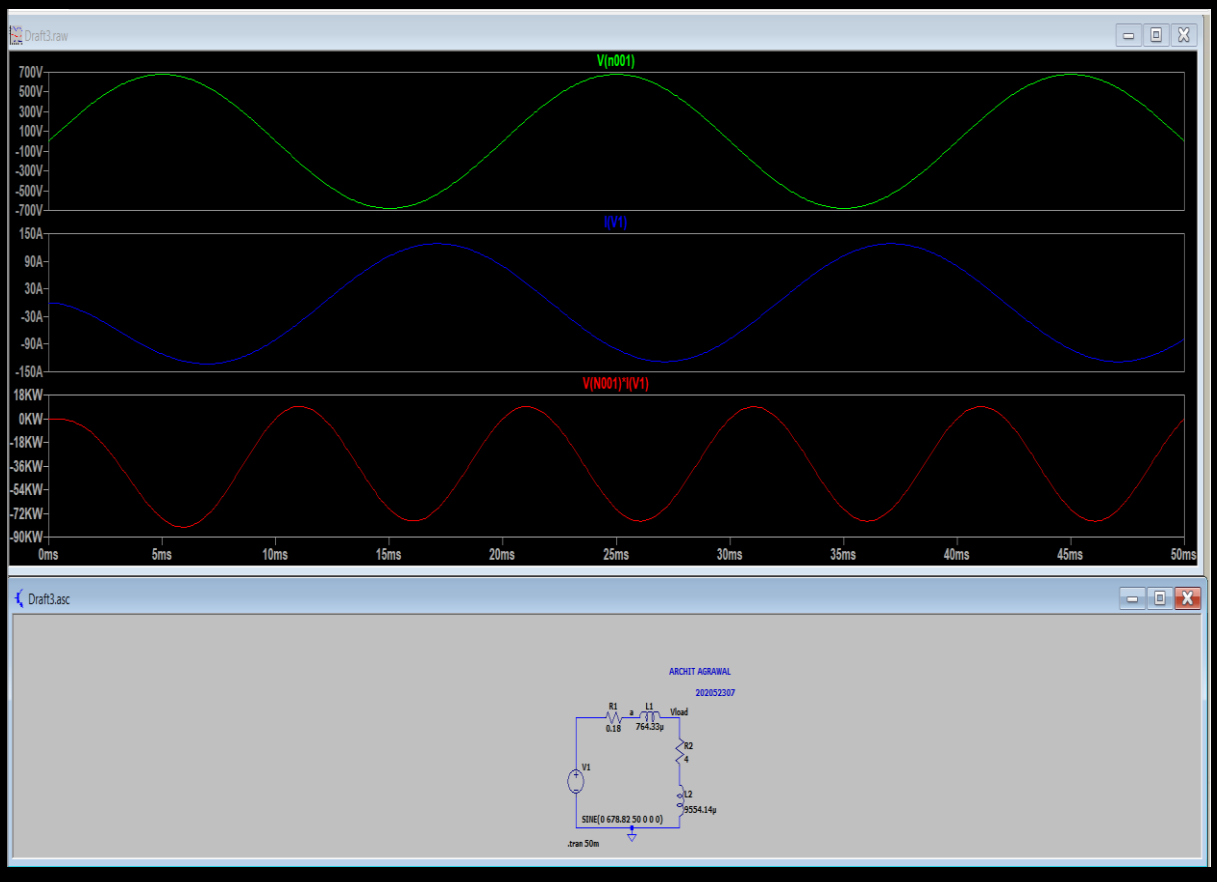
Hence, 99.964% of total power supplied by source will reach the load.

EE160 : Experiment 5

Circuit 1 (without transformer)

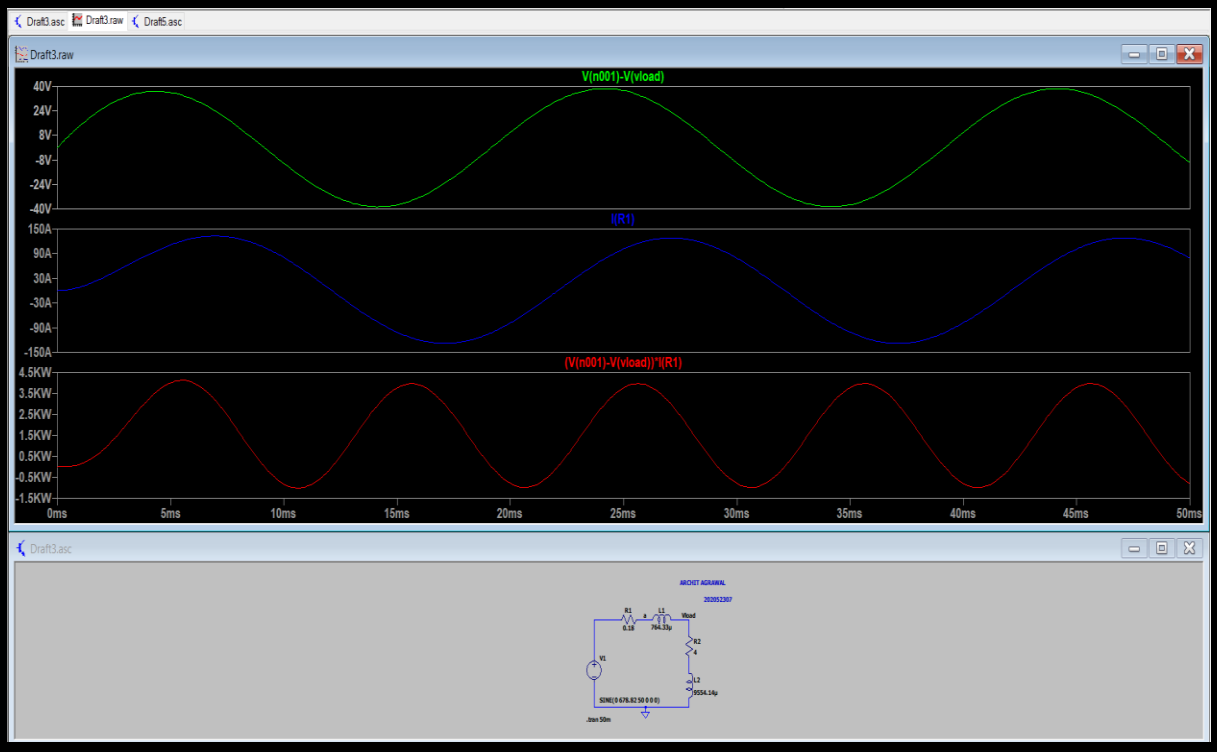


Voltage, Current and Power across Generator

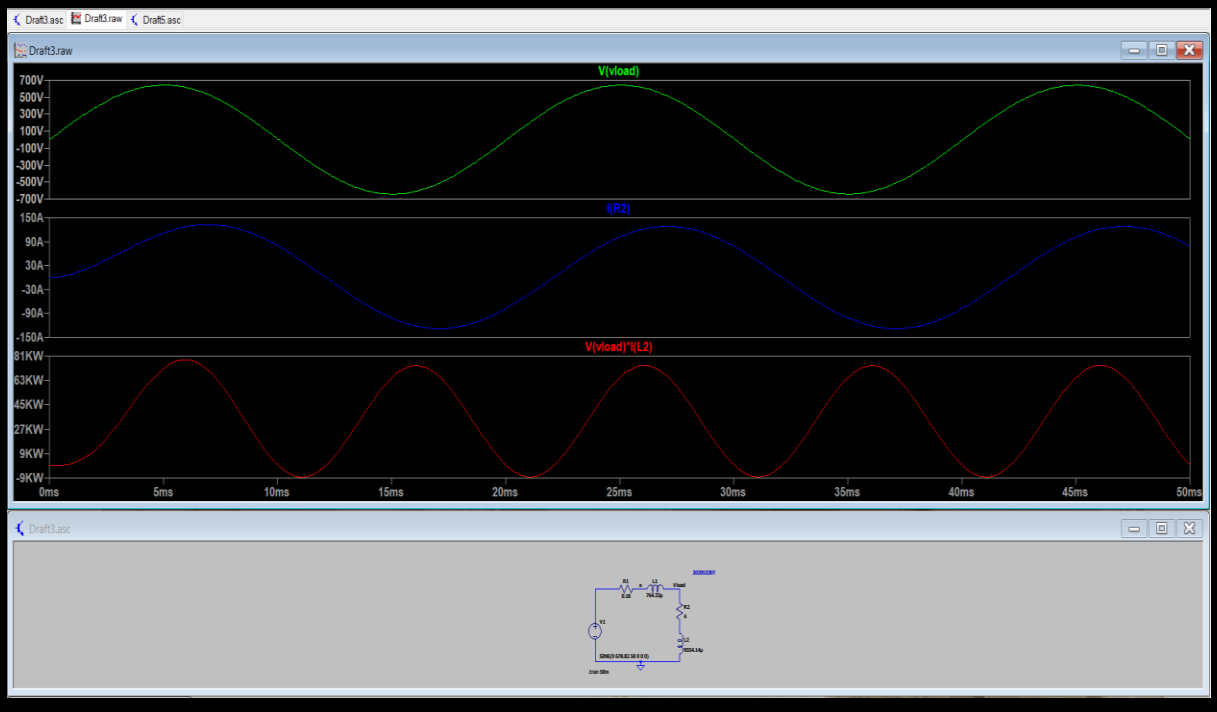


EE160 : Experiment 5

Voltage, Current and Power across Transmission Line

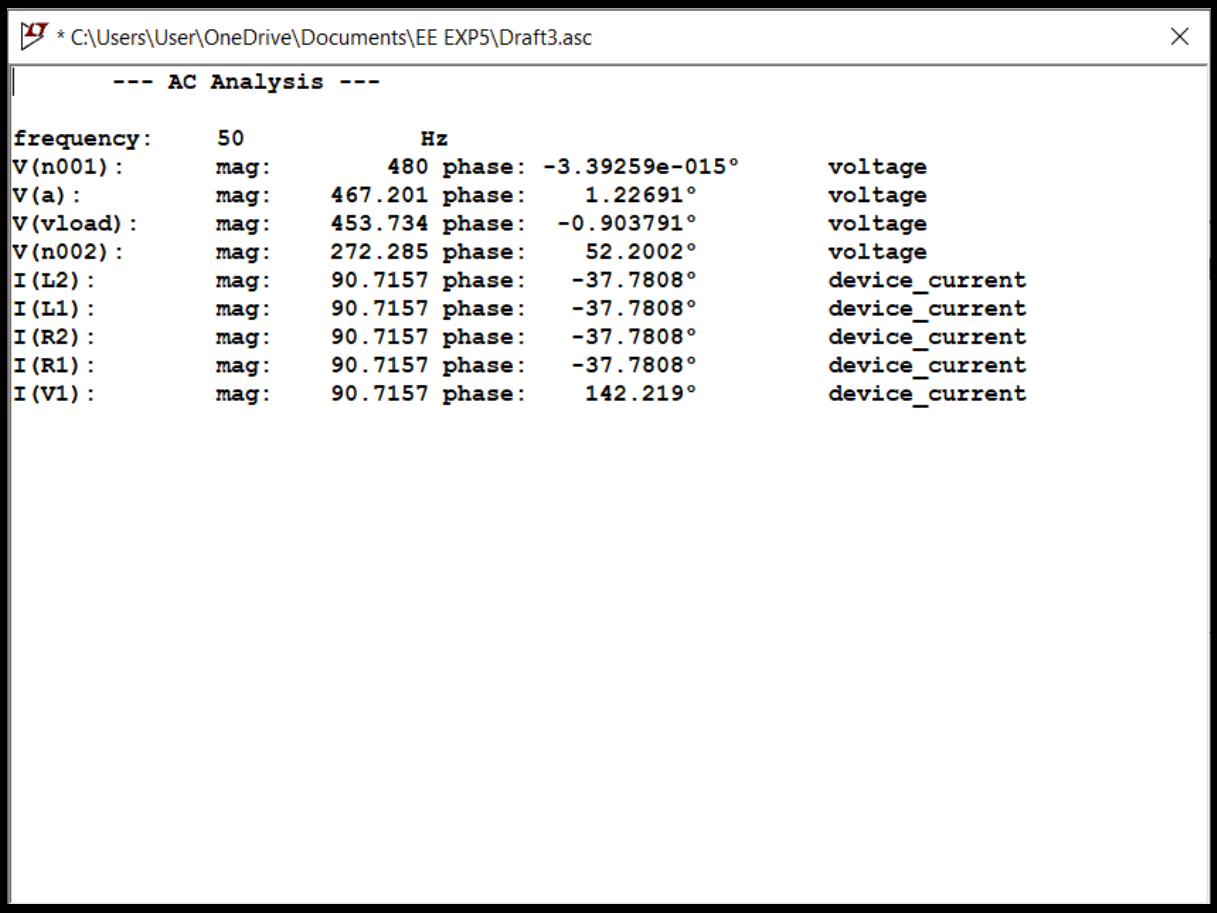


Voltage, Current and Power across Load



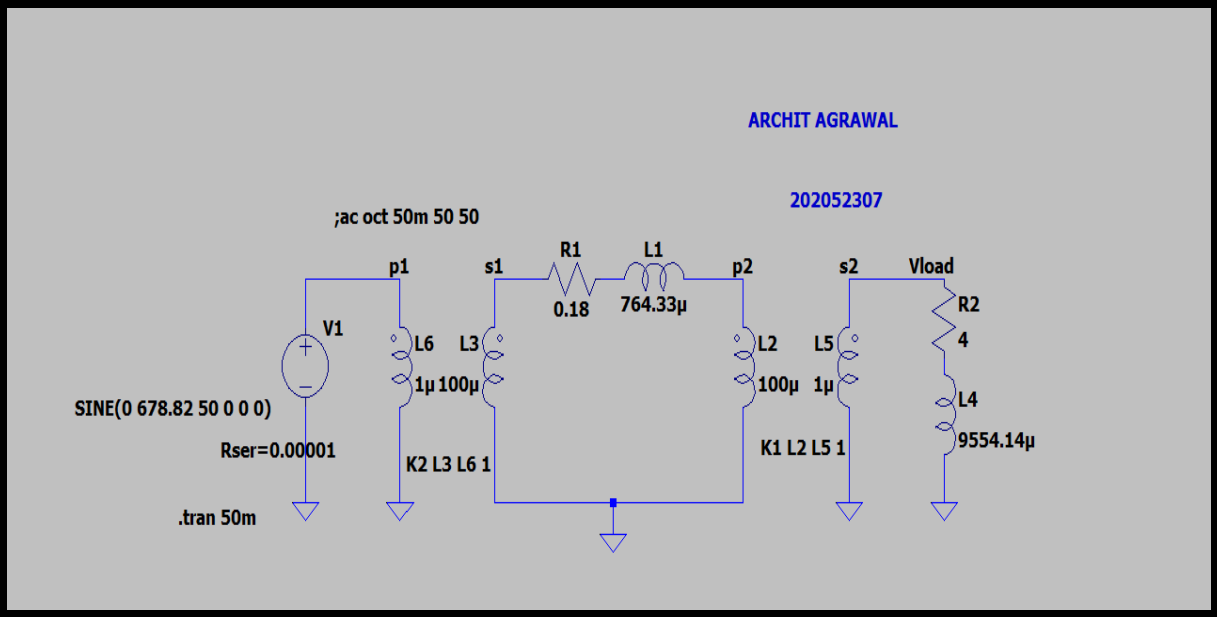
EE160 : Experiment 5

AC Analysis

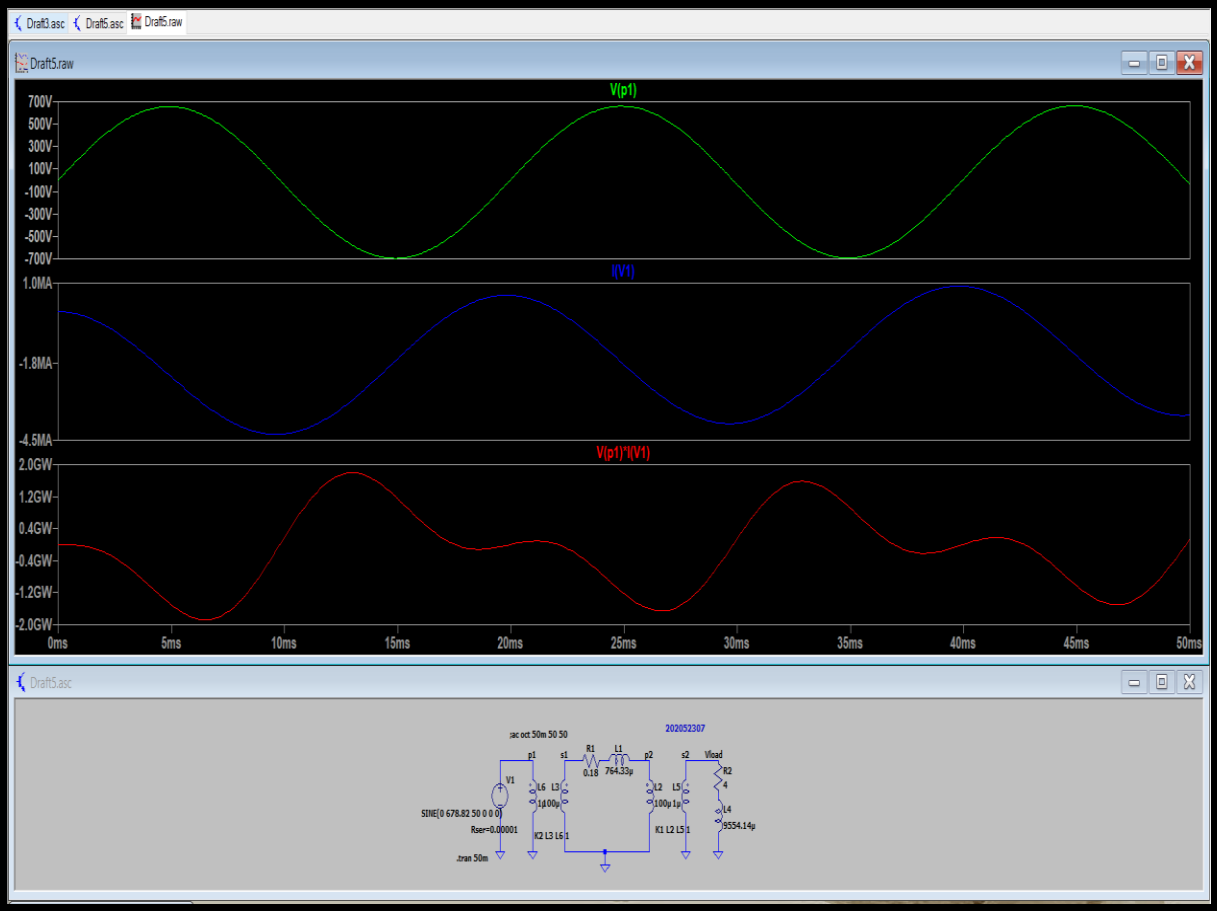


EE160 : Experiment 5

Circuit 2 (with transformer)

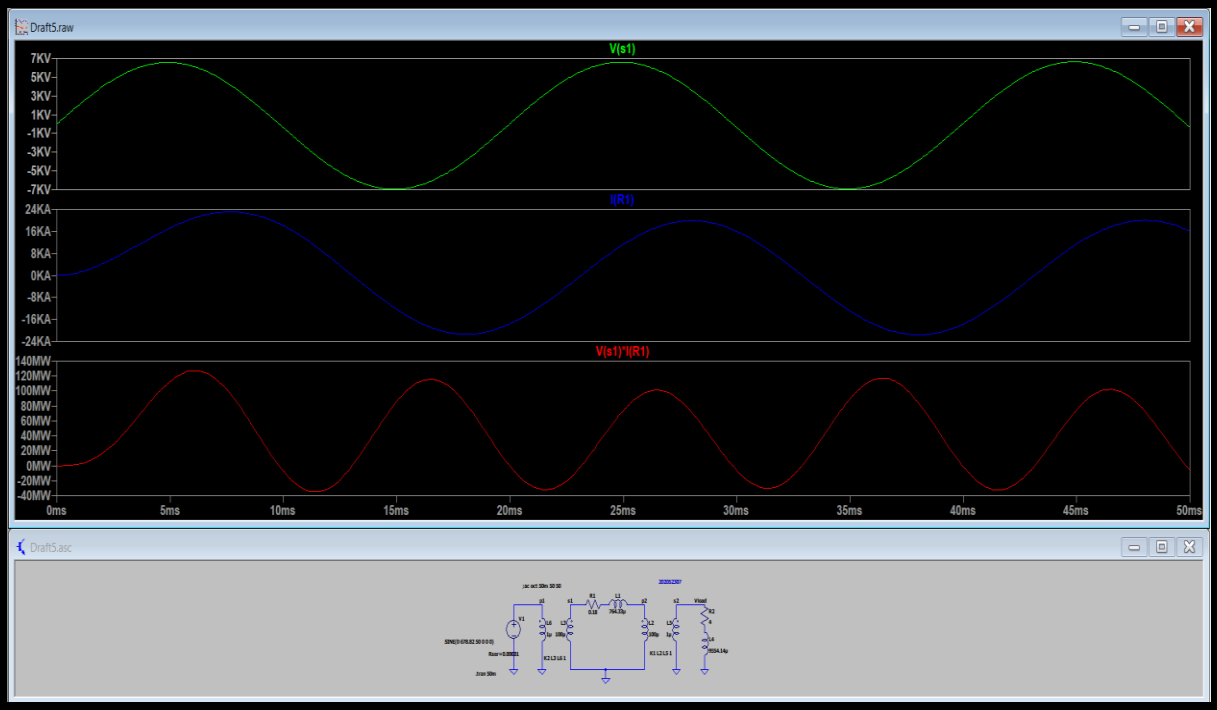


Voltage, Current and Power across Generator

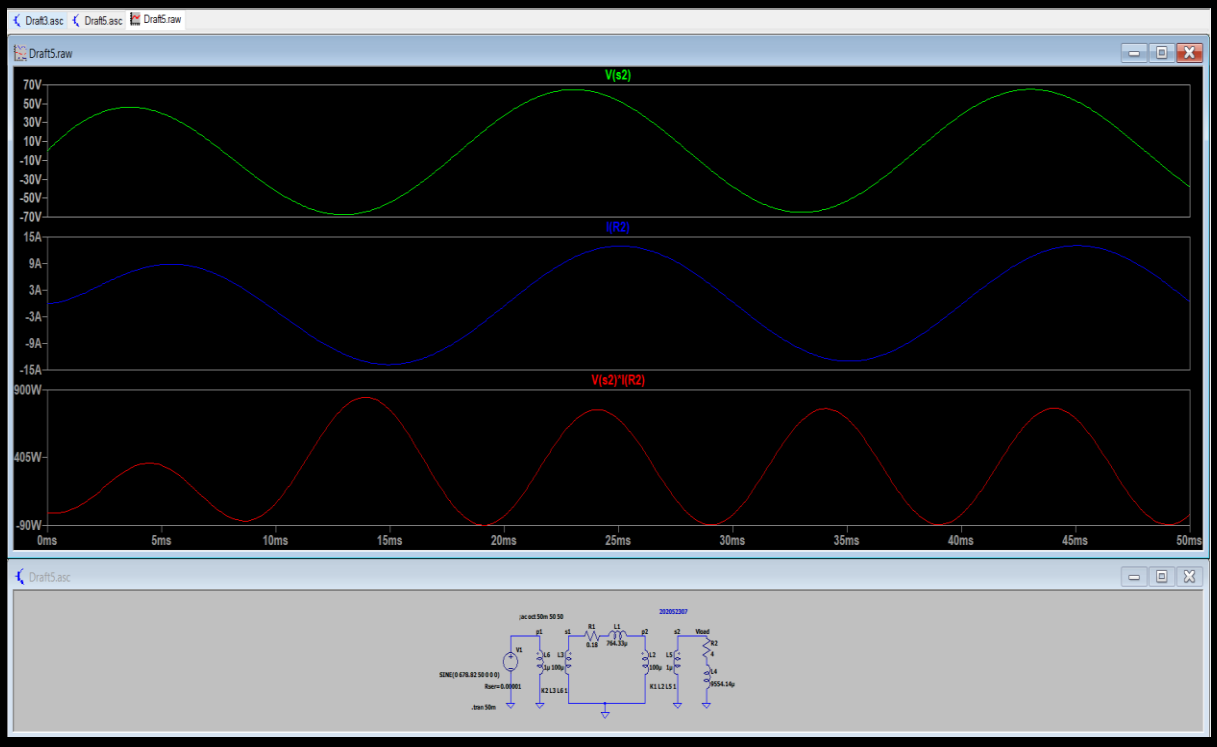


EE160 : Experiment 5

Voltage, Current and Power across Transmission Line



Voltage, Current and Power across Load



EE160 : Experiment 5

AC Analysis