

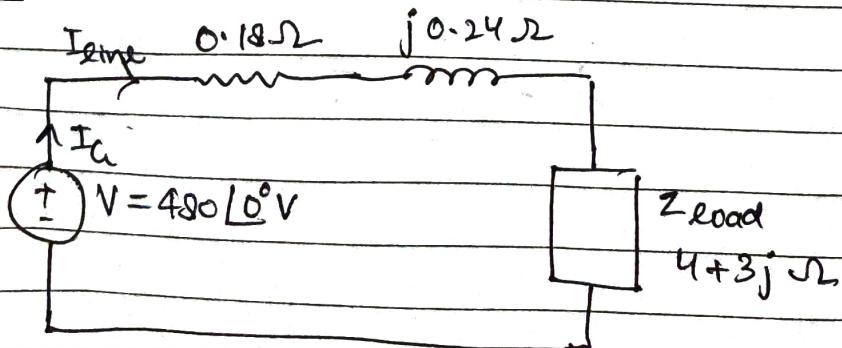
## EE160: Experiment 5

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 delivered 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,

$$\bar{I}_L = \bar{I}_{line} = \bar{I}_{load}$$

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

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

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

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

$$\bar{I}_{line} = 90.0 \angle -37.8^\circ A$$

1. Load voltage,  $\bar{V}_{load} = \bar{I}_{line} \times Z_{load}$

$$\bar{V}_{load} = 90.0 \angle -37.8^\circ \times (5 \angle 36.9^\circ)$$

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

the losses due to line transmission line.

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

$$= (90.0)^2 \times (0.18)$$

$$P_{lossL} = 1484 W$$

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and, power supplied by generator

$$P_a = V_a \cdot I_a$$

$$= (480)(90.8)$$

$$P_a = 43584 \text{ W}$$

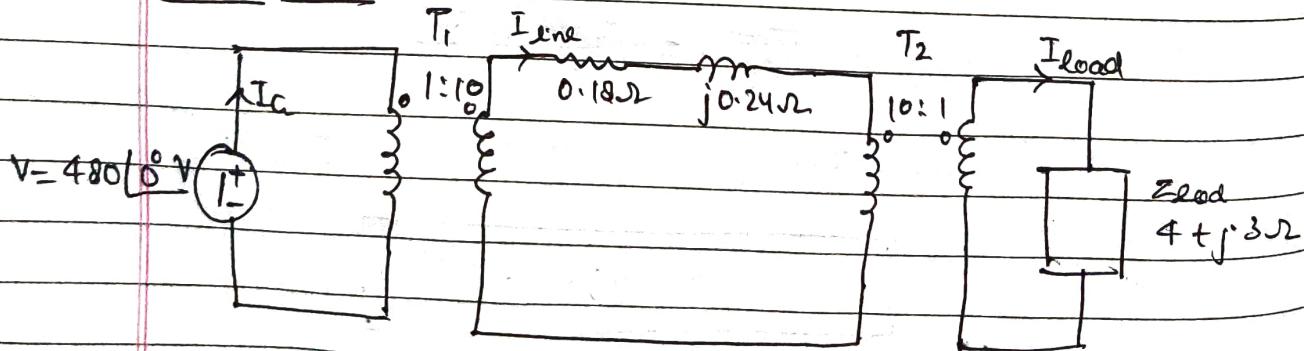
$$\therefore \text{Efficiency} = \frac{P_a - P_{lossL}}{P_a} \times 100\% -$$

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

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

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 referring the load over to the transmission line's voltage level.
- (ii) Eliminate transformer  $T_1$  by referring 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,

$$\begin{aligned} Z'_{\text{load}} &= \alpha^2 Z_{\text{load}} \\ &= (10)^2 (4\Omega + j3\Omega) \end{aligned}$$

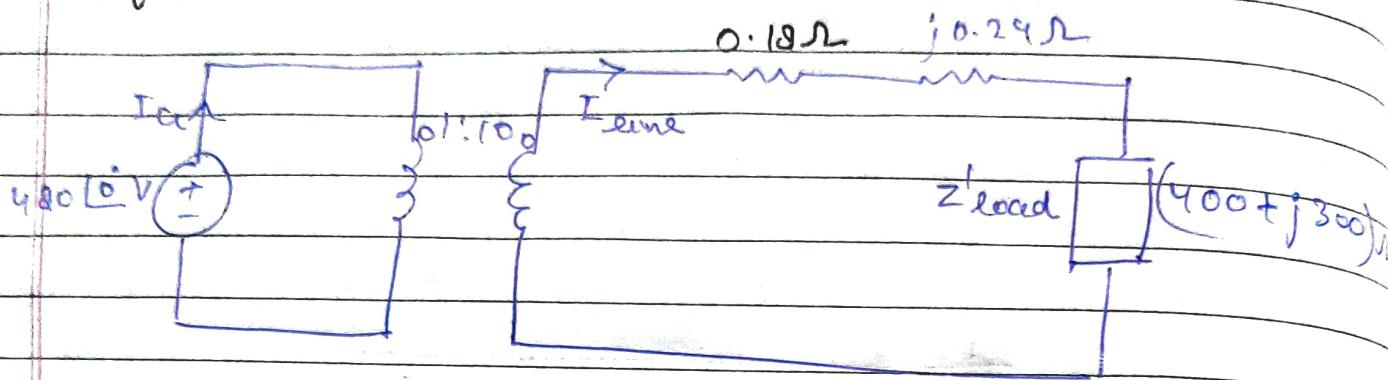
$$Z'_{\text{load}} = (400 + j300) \Omega$$

The total impedance at transmission line level is now,

$$\begin{aligned} Z_{\text{eq}} &= Z_{\text{line}} + Z'_{\text{load}} \\ &= 400.18 + j(300.24) \Omega \end{aligned}$$

$$Z_{\text{eq}} = 500.3 |36.88^\circ| \Omega$$

## Equivalent circuit



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

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

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

$$Z'_{\text{eq}} = \frac{1}{100} (400 \cdot 10 + j 300 \cdot 24) \Omega$$

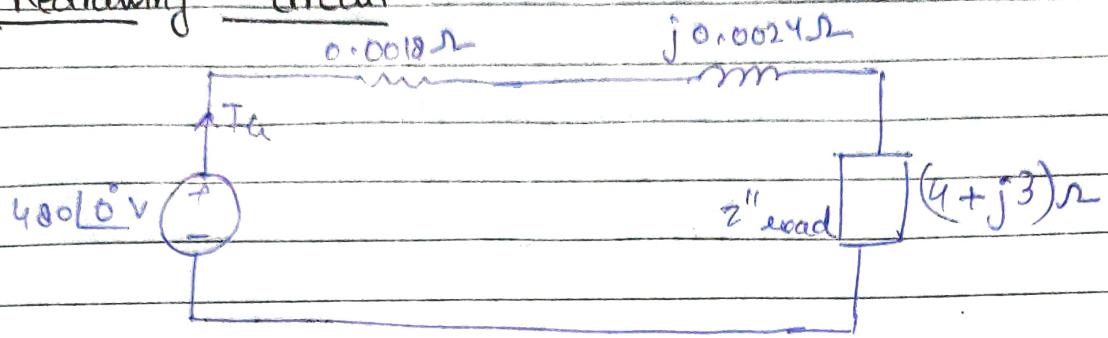
$$Z'_{\text{eq}} = 5.003 \angle 36.88^\circ \Omega$$

Now, we can say that

$$Z''_{\text{load}} = 4 + j 3 \Omega$$

$$Z'_{\text{line}} = 0.0010 \Omega + j 0.0024 \Omega$$

Redrawing circuit



Now, generator's current  $I_a$ ,

$$I_a = \frac{\bar{V}}{Z_{eq}}$$

$$\bar{I}_a = \frac{400 [0^\circ] V}{5.003 / 36.88}$$

$$\boxed{\bar{I}_a = 95.94 [-36.88^\circ] A}$$

working back through  $T_1$ , we get

$$N_p, \bar{I}_a = N_s, \bar{I}_{line}$$

$$\therefore \bar{I}_{line} = \frac{N_p}{N_s} \bar{I}_a$$

$$\bar{I}_{line} = \frac{1}{10} (95.94 [-36.88^\circ])$$

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

Now, working back through  $T_2$ ,

$$N_p, I_{line} = N_{L2}, I_{load}$$

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

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

Now,

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

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

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

Now, line losses  $P_{loss,L}$

$$P_{loss,L} = (I_{line})^2 \times R_{line}$$

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

$$\boxed{P_{loss,L} = 16.7 W}$$

and, power supplied by generator

$$P_g = \bar{I}_g \bar{V}_g$$

$$= (480) (95.94 A)$$

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$$P_L = 46051.2 \text{ W}$$

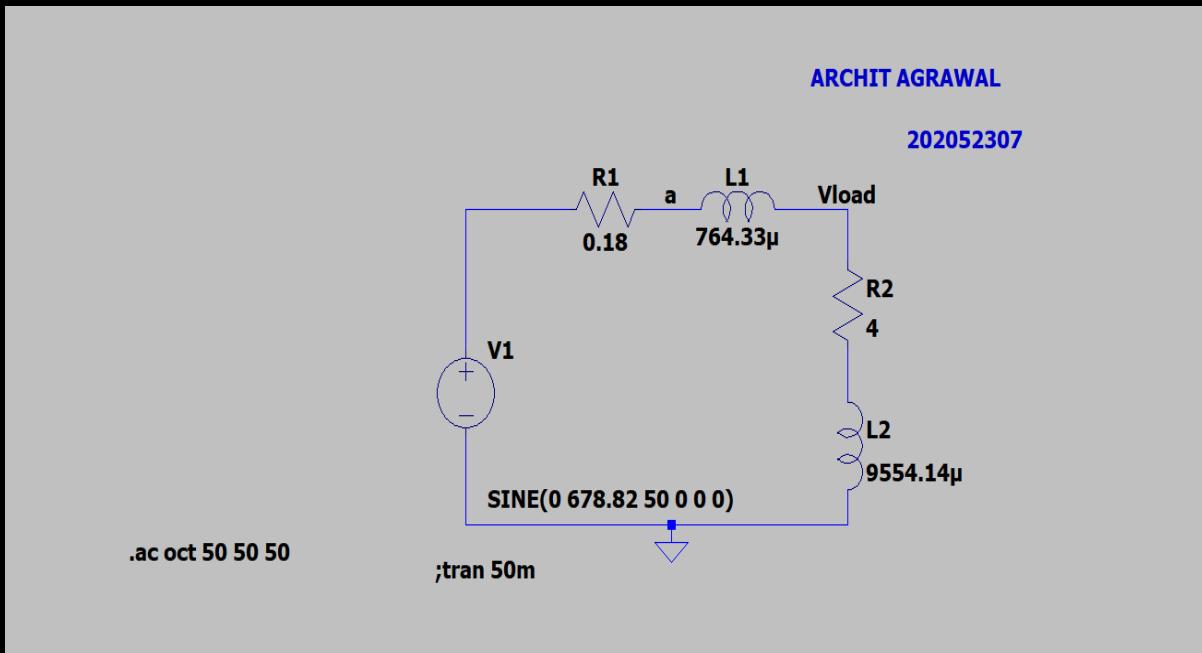
$$\therefore \text{Efficiency} = \frac{46051.2 - 16.7}{46051.2} \times 100\%$$

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

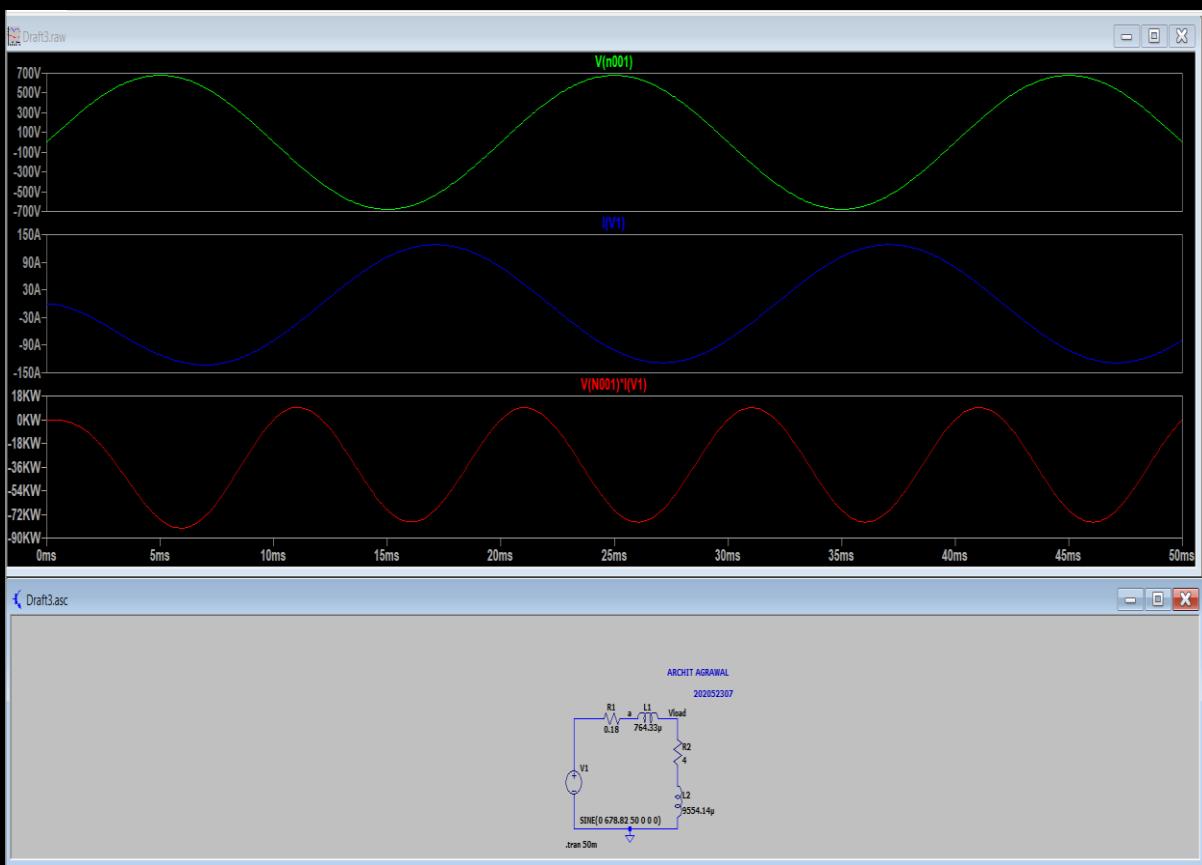
Hence, 99.964% of total power supplied by source will reach the load.

# EE160 : Experiment 5

## Circuit 1 (without transformer)

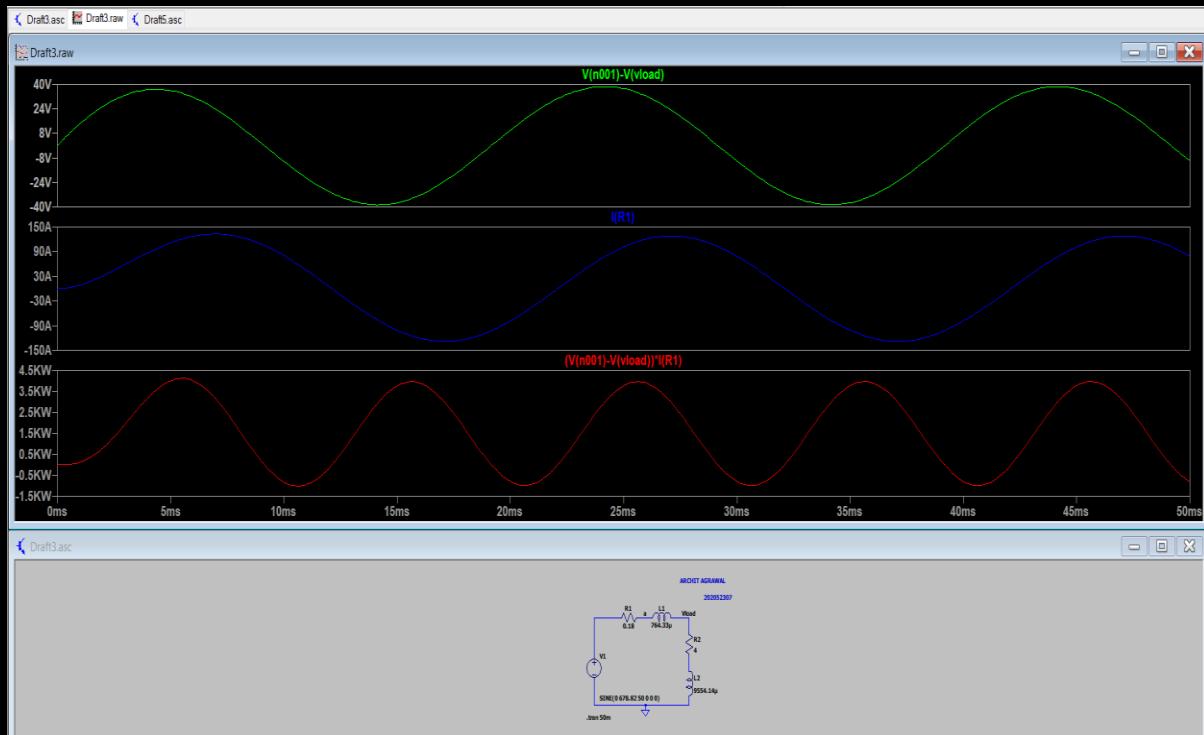


## Voltage, Current and Power across Generator

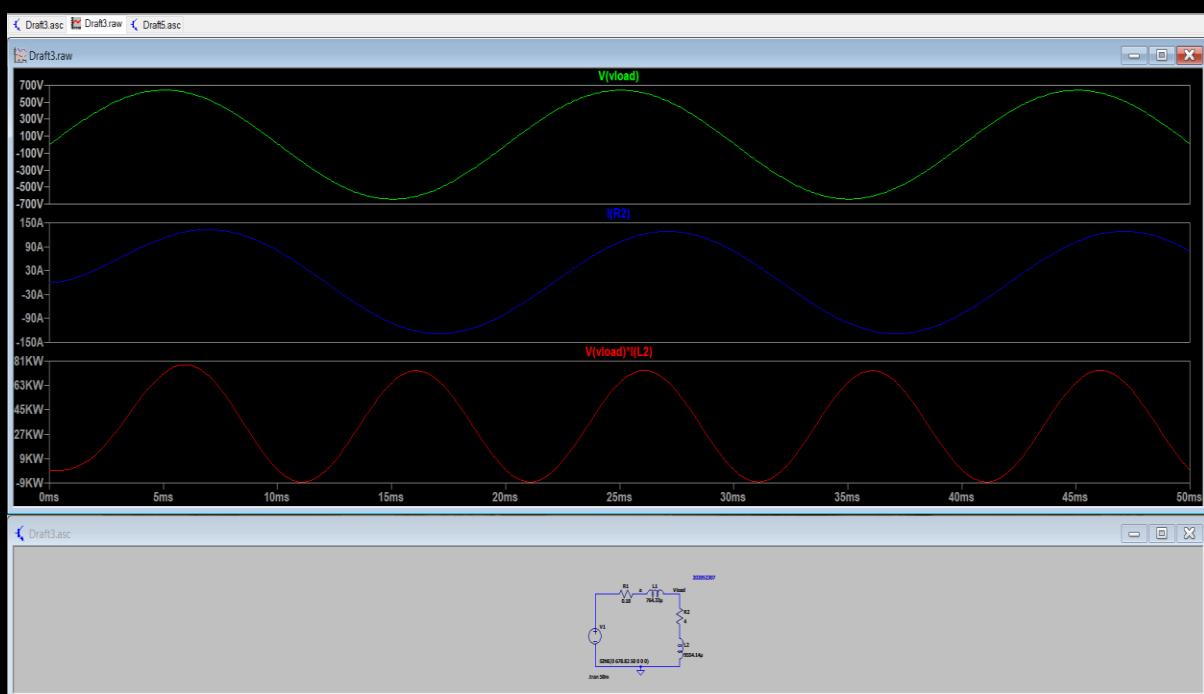


# EE160 : Experiment 5

## Voltage, Current and Power across Transmission Line



## Voltage, Current and Power across Load



# EE160 : Experiment 5

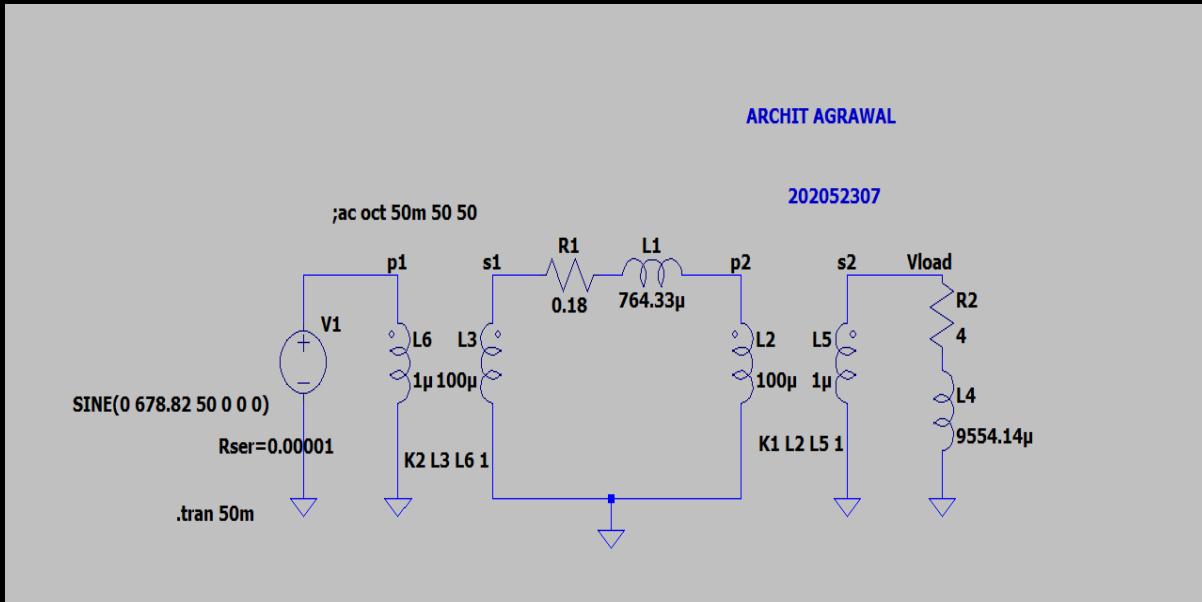
## AC Analysis

```
✓ * C:\Users\User\OneDrive\Documents\EE EXP5\Draft3.asc X
--- AC Analysis ---

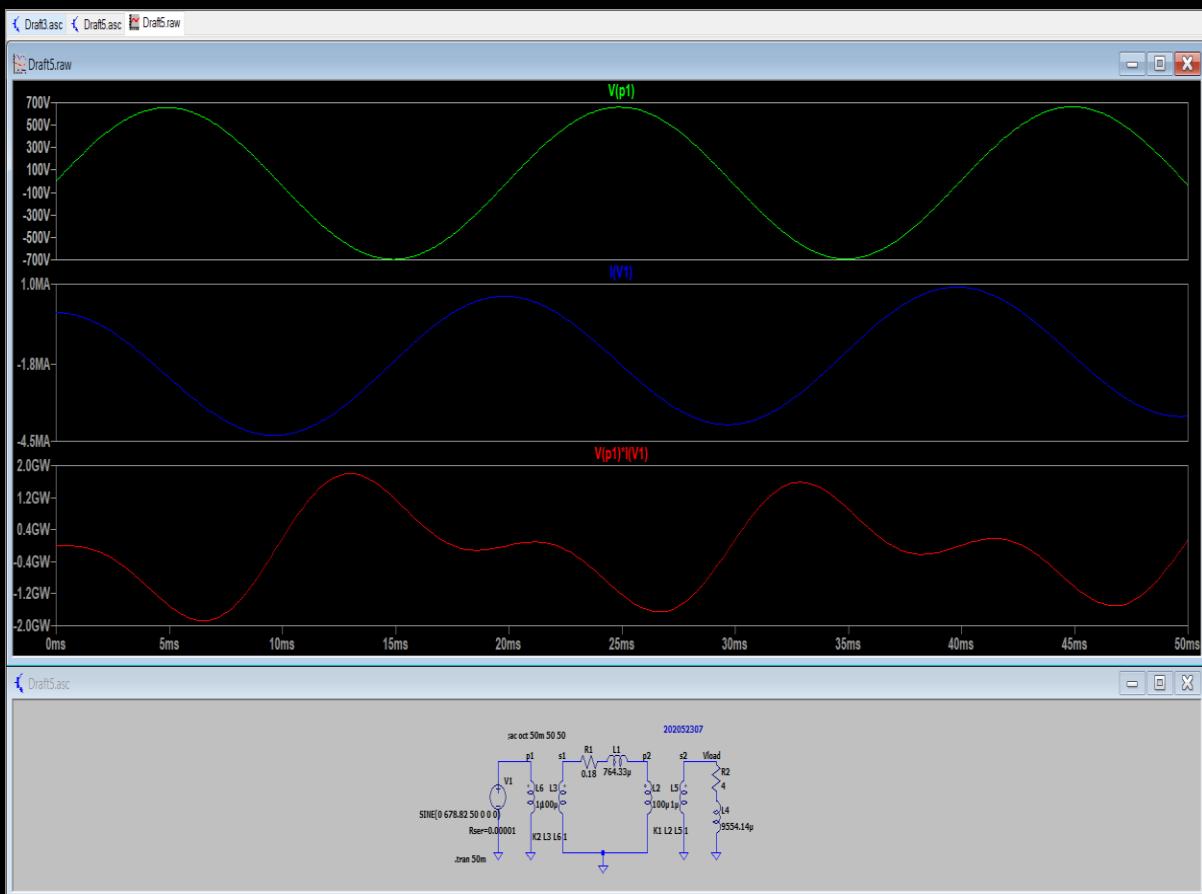
frequency:      50          Hz
V(n001):        mag:    480 phase: -3.39259e-015°      voltage
V(a):           mag:  467.201 phase:   1.22691°      voltage
V(vload):       mag:  453.734 phase: -0.903791°      voltage
V(n002):        mag: 272.285 phase:  52.2002°      voltage
I(L2):          mag: 90.7157 phase: -37.7808°      device_current
I(L1):          mag: 90.7157 phase: -37.7808°      device_current
I(R2):          mag: 90.7157 phase: -37.7808°      device_current
I(R1):          mag: 90.7157 phase: -37.7808°      device_current
I(V1):          mag: 90.7157 phase: 142.219°      device_current
```

# EE160 : Experiment 5

## Circuit 2 (with transformer)

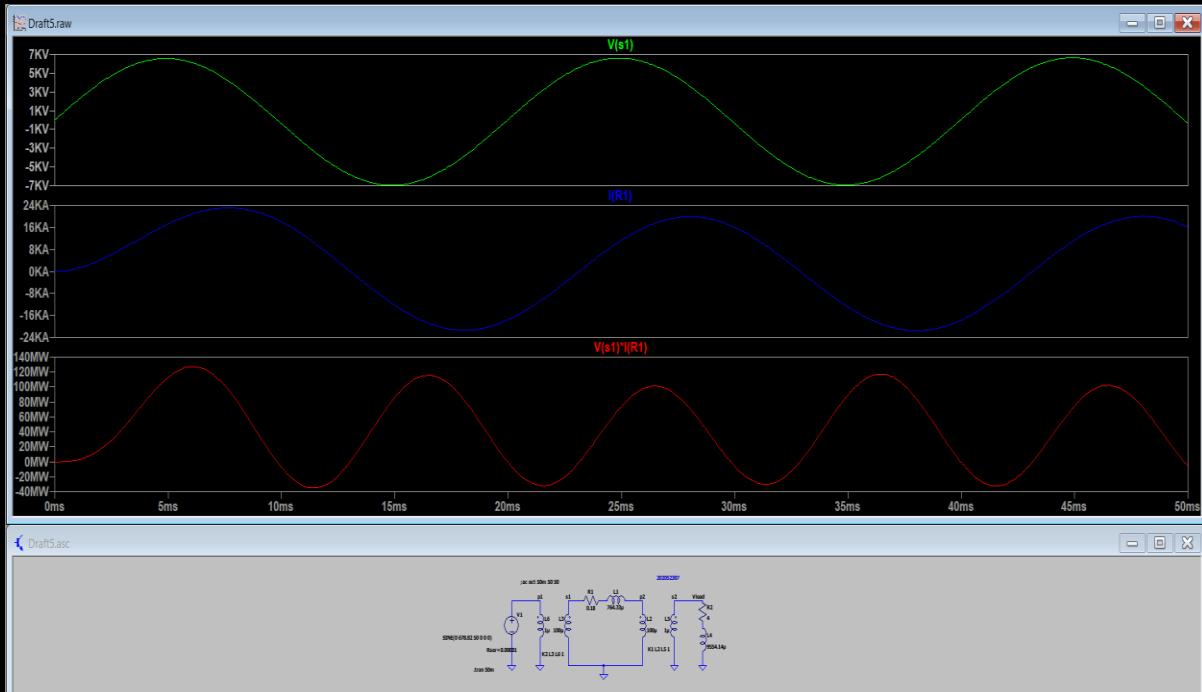


## Voltage, Current and Power across Generator

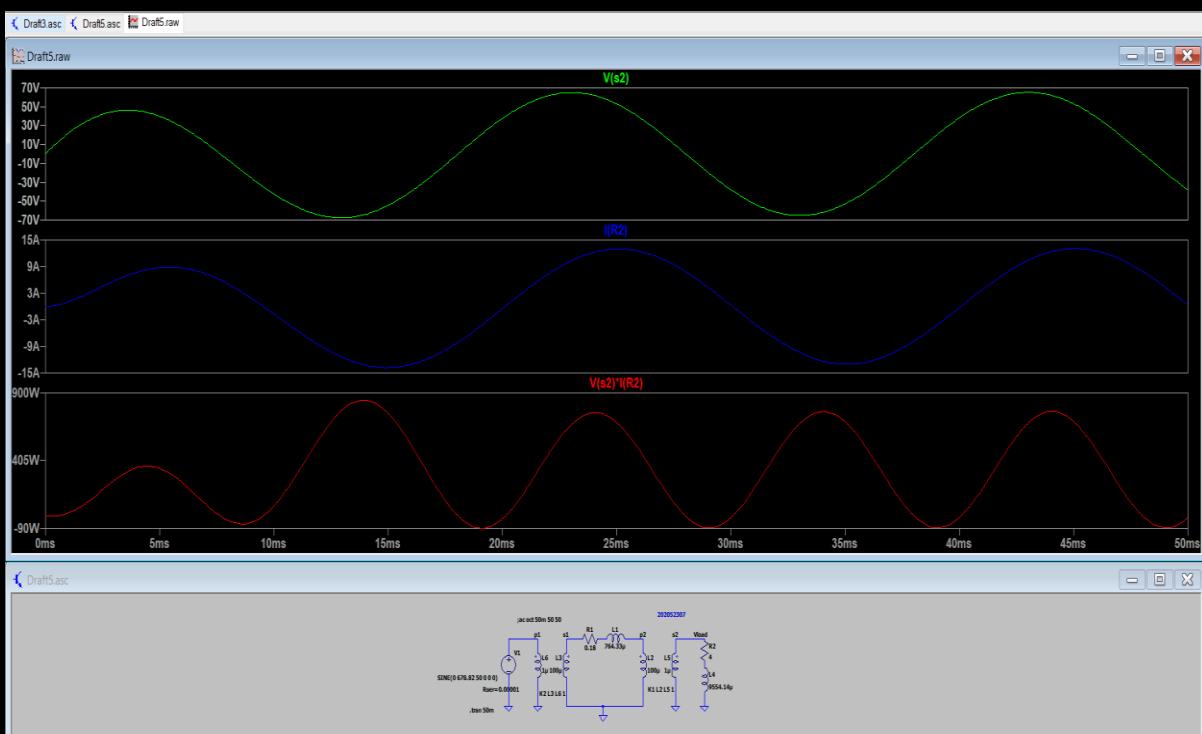


# EE160 : Experiment 5

## Voltage, Current and Power across Transmission Line



## Voltage, Current and Power across Load



# EE160 : Experiment 5

## AC Analysis

```
✓ * C:\Users\User\OneDrive\Documents\EE EXP5\Draft5.asc
X
--- AC Analysis ---

frequency:      50          Hz
V(n003):        mag:    3984.9 phase:   35.4412°      voltage
V(n002):        mag:    4789.04 phase:  1.96576°      voltage
V(n004):        mag:    461.02 phase:  35.6497°      voltage
V(vload):       mag:    46.102 phase: 35.6497°      voltage
V(n005):        mag:    27.6658 phase: 88.7536°      voltage
V(n001):        mag:    478.904 phase: 1.96576°      voltage
I(L6):          mag: 1.64852e+006 phase: 94.7959° device_current
I(L5):          mag: 9.21725 phase: -1.2273° device_current
I(L4):          mag: 9.21725 phase: -1.2273° device_current
I(L3):          mag: 14675.3 phase: -54.3475° device_current
I(L2):          mag: 14675.3 phase: 125.653° device_current
I(L1):          mag: 14675.3 phase: -54.3475° device_current
I(R2):          mag: 9.21725 phase: -1.2273° device_current
I(R1):          mag: 14675.3 phase: 125.653° device_current
I(V1):          mag: 1.64852e+006 phase: 94.7959° device_current
```