K. J. SOMAIYA COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC CIRCUITS
AC CIRCUITS

Numerical 1: A series RLC circuit consisting of resistance of 40Ω,inductance of 0.3H and capacitor of 120μF are connected in series across a 120V, 60Hz supply.

a) Current drawn by the circuit
b) V_R, V_L *and* V_C
c) Power Factor
d) Draw voltage phasor diagram

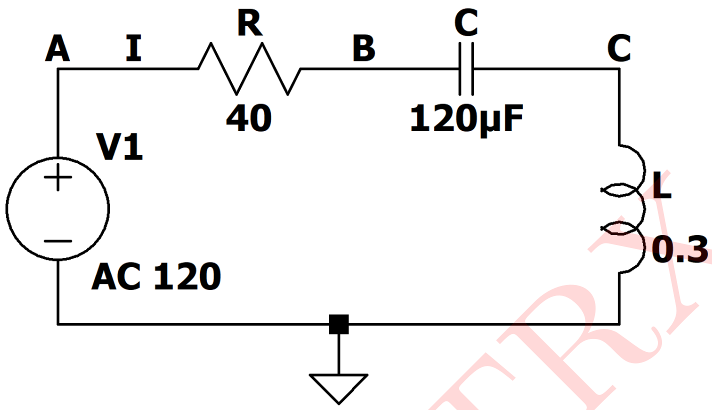

Figure 1: Circuit 1

Solution:

a) $X_L = 2\pi f L$
$= 2\times\pi \times 60 \times 0.3$
$X_L = 113.0973\Omega$

$$X_C = \frac{1}{2 \times \pi \times 60 \times 120 \times 10^{-6}}$$

$X_c = 22.1048\Omega$

$$\text{Impedance(Z)} = \sqrt{R^2 + (X_L - X_C)^2}$$
$$= \sqrt{40^2 + (113.0973 - 22.1048)^2}$$

$$\Phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

$$\Phi = \tan^{-1}\left(\frac{113.0973 - 22.1048}{40}\right)$$

$\Phi = 66.2698°$

$Z = 99.3693 \angle 66.2698°$

$$I = \frac{V}{Z}$$

$$I = \frac{120}{99.3693\angle 66.2698°}$$

I = 1.2076 $\angle$-66.2698°

b) $V_R = R \times I$
$= 40 \times 1.2076$
$V_R = 48.304V$

$V_L = X_L \times I$
$= 113.0973 \times 1.2076$
$V_L = 136.576V$

$V_C = X_C \times I$
$= 22.6937 \times 1.2076$
$V_C = 26.6937V$

c) Power Factor $= \cos(\Phi)$
$= \cos(66.2698)$ ....(Lagging)
Power Factor = 0.4025

d) Phasor Diagram:

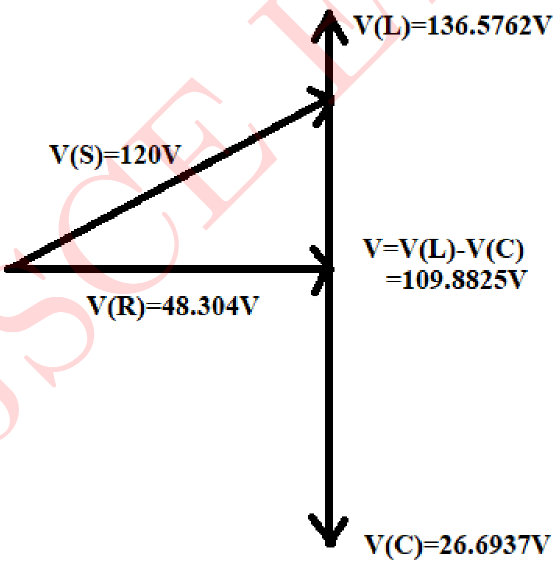

Figure 2: Phasor Diagram

SIMULATED RESULTS:
The given circuit is simulated in LTspice and the result obtained are as follows:

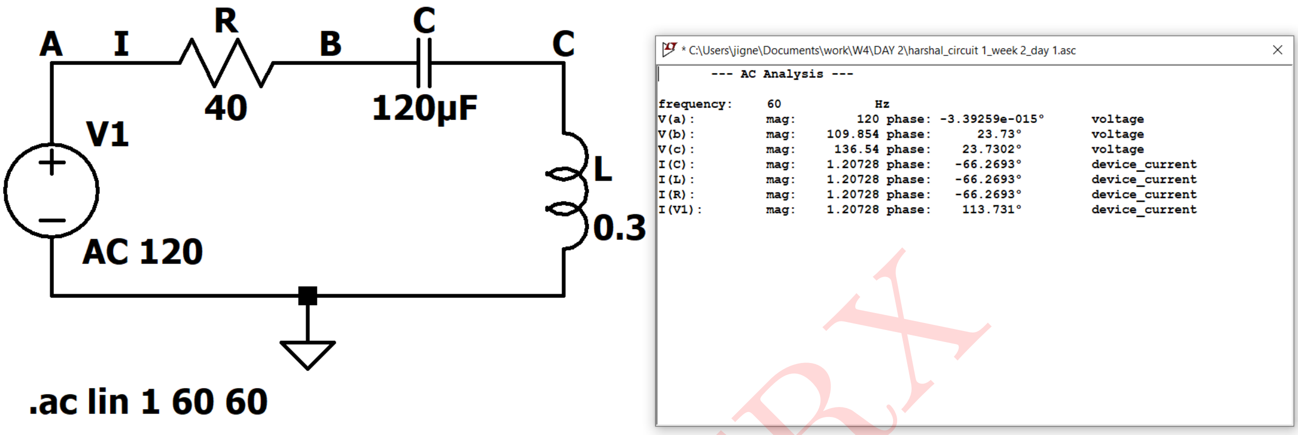

Figure 3: Circuit schematic and Simulated Results

Comparison of Theoretical and Simulated values:

Parameters	Theoretical Values	Simulated Values
I	$1.2076\angle 66.269° A$	$1.2072\angle -66.2693° A$
V_R	48.634V	48.2913V
V_L	136.5762V	136.54V
V_C	26.6937V	26.6868V
Power Factor	0.4025	0.40243

Table 1: Numerical 1

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Numerical 2: A voltage $V = 100\sin(314t)$ is applied to a circuit consisting of 27Ω resistor and $90\mu F$ capacitor in series. Determine
a) An expression for the value of current flowing at any instant
b) V_R *and* V_C
c) Power Factor

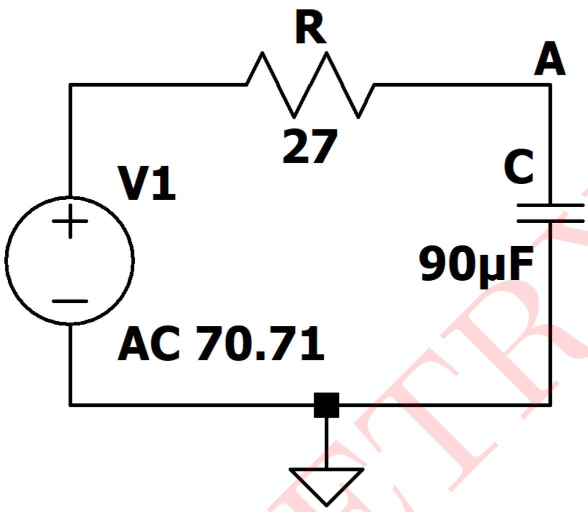

Figure 4: Circuit 2

Solution:

$$X_C = \frac{1}{2\times\pi\times f\times c}$$

$$X_C = \frac{1}{314\times 90\times 10^{-6}}$$

$$X_C = 35.3857$$

$$\text{Impedance(Z)} = \sqrt{R^2 + X_C^2}$$
$$= \sqrt{27^2 + 35.3857^2}$$

$$\Phi = \tan^{-1}\left(\frac{X_C}{R}\right)$$

$$\Phi = \tan^{-1}\left(\frac{35.3857}{27}\right)$$

$$\Phi = 52.8112^\circ$$

$$Z = 44.6692\angle 52.8112^\circ$$

$$I_{RMS} = \frac{V_{RMS}}{Z}$$

$$I_{RMS} = \frac{100}{44}$$

$$I_{RMS} = 2.2727A$$

$$I = 2.2727\sin(314t - 52.8112)$$

b) $V_R = R \times I$

$= 27 \times 1.607$

$V_R \ = 43.389V$

$V_C = X_C \times I$

$= 35 \times 1.607$

$V_C = 57.1862V$

c) $\text{Power Factor} = \dfrac{R}{Z}$

$= \dfrac{27}{44.692}$

Power Factor = 0.6044W

SIMULATED RESULTS:
The given circuit is simulated in LTspice and the result obtained are as follows:

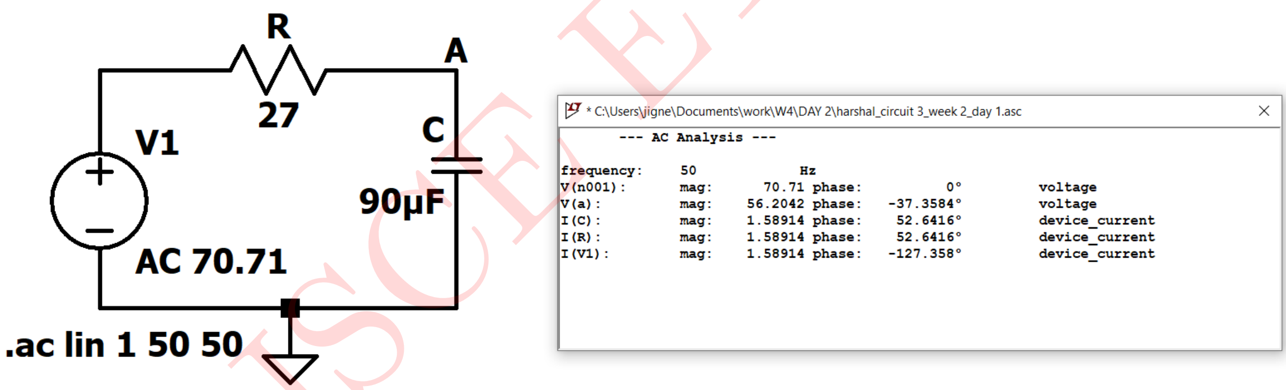

Figure 5: Circuit schematic and Simulated Results

Comparison of Theoretical and Simulated values:

Parameters	Theoretical Values	Simulated Values
I	1.607 A	1.58914A
Power Factor	0.6044	0.60679
V_R	43.389V	42.9067V
V_C	57.1862V	56.2042V

Table 2: Numerical 2

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Numerical 3: A circuit consists of resistance of 10Ω, an inductor of 24mH and a capacitor of $40\mu F$ are connected in parallel across a 110V, 50Hz supply.
Calculate: a) Individual current by each element
b) Total current
c) Overall Power Factor
d) Phasor Diagram

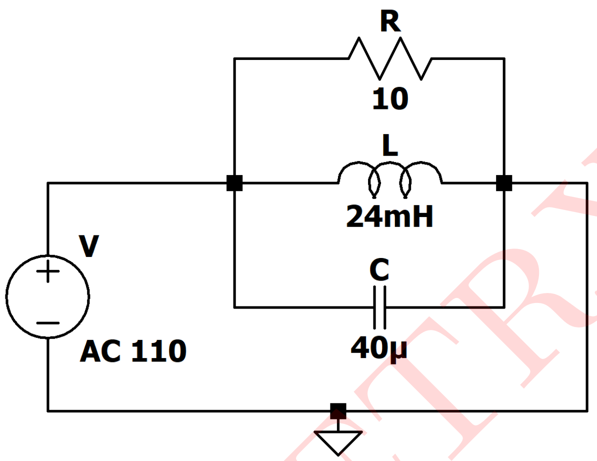

Figure 6: Circuit 3

Solution:

a) $X_L = 2\pi f L$

$= 2\times\pi \times 50 \times 0.024$

$X_L = 7.5398\Omega$

$$X_C = \frac{1}{2 \times \pi \times 50 \times 40 \times 10^{-6}}$$

$X_c = 79.5774\Omega$

$R = Z_1 = 10\Omega$
$Z_2 = jX_L = 7.5398j\Omega$
$Z_3 = jX_C = -79.5774j\Omega$

$$I_1 = \frac{V}{Z_1}$$

$$I_1 = \frac{110}{10}$$

$I_1 = 11A$

$$I_2 = \frac{V}{Z_2}$$

$$I_2 = \frac{110}{7.5398j}A$$

$I_2 = 14.5892\angle -90^\circ A$

$$I_3 = \frac{V}{Z_3}$$

$I_3 = \frac{110}{-79.5774j}A$

$I_3 = 1.3826\angle 90° A$

b) Total Current:

$I = I_1 + I_2 + I_3$
$I = (11\angle 0 + 14.5892\angle -90° + 1.3823\angle 90°)$A
$I = 17.1878\angle -50.2091°$A

c) Power Factor:

Power Factor = $\cos(\Phi)$
Power Factor = $\cos(50.2091°)$
Power Factor = 0.6399 (lagging)

d) Phasor Diagram:

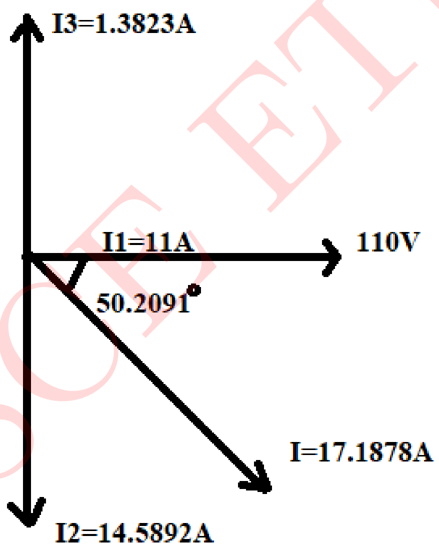

Figure 7: Phasor Diagram

SIMULATED RESULTS:
The given circuit is simulated in LTspice and the result obtained are as follows:

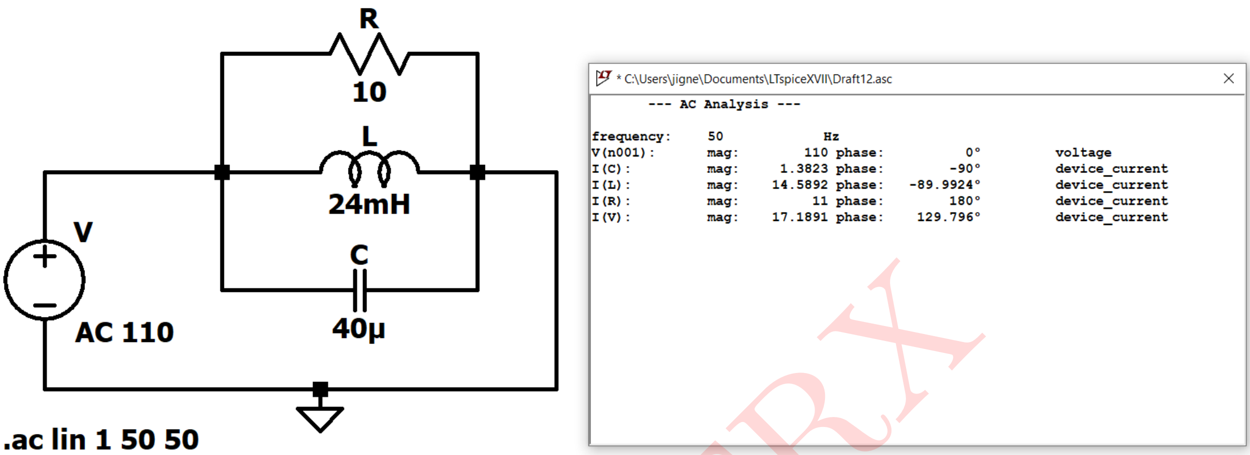

Figure 8: Circuit schematic and Simulated Results

Comparison of Theoretical and Simulated values:

Parameters	Theoretical Values	Simulated Values
I_R	11A	11A
I_L	$14.5892\angle-90°A$	$14.5892\angle-89.99°A$
I_C	$1.3826\angle 90°A$	$1.3823\angle 90°A$
Power Factor	0.6399	0.6400

Table 3: Numerical 3

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Numerical 4: A coil haing a resistance of $R_1 = 4.5\Omega$ and inductance of $L_1 = 0.01H$ is arranged in parallel with another coil having $R_2 = 2\Omega$ and $L_2 = 0.06H$. Calculate I, I_1 and I_2 when voltage $V_1 = 110V$ at 60Hz is applied. Also calculate the power factor.

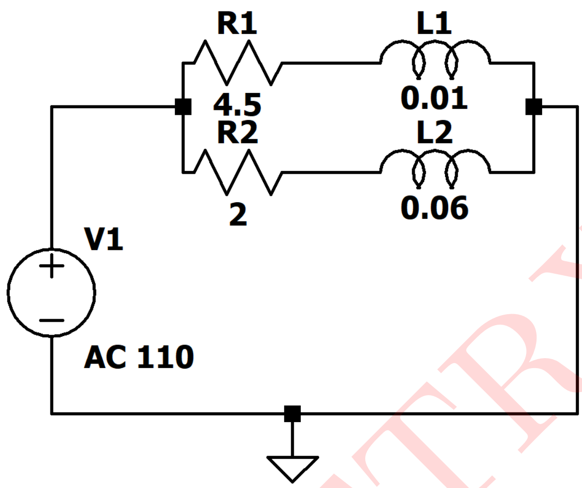

Figure 9: Circuit 4

Solution:

$X_{L1} = 2\pi f L_1$
$\quad = 2\times\pi \times 60 \times 0.01$
$X_{L1} = 3.7699\Omega$

$X_{L2} = 2\pi f L_2$
$\quad = 2\times\pi \times 60 \times 0.06$
$X_{L2} = 22.6914\Omega$

$Z_1 = R + jX_{L1}$
$Z_1 = 4.5 + 3.7699j$
$Z_1 = 5.8704\angle 39.954°\Omega$

$Z_2 = R + jX_{L2}$
$Z_2 = 2 + 22.6194j$
$Z_2 = 22.7076\angle 84.947°\Omega$

$$I_1 = \frac{V}{Z_1}$$

$$I_1 = \frac{110}{5.8704\angle 39.954°}$$

$I_1 = 18.7380\angle -39.954° A$

$$I_2 = \frac{V}{Z_2}$$

$$I_2 = \frac{110}{22.7076\angle 84.947°}$$

$I_2 = 4.8441\angle -84.947° A$

Total Current:

$I = I_1 + I_2$
$I = (18.7380\angle -39.54^\circ + 4.8441\angle -84.94^\circ)A$
$I = 22.4268\angle -43.7388^\circ A$

Power Factor $= \cos(\Phi)$
Power Factor $= \cos(48.7388^\circ)$
Power Factor $= 0.6594$ (lagging)

SIMULATED RESULTS:
The given circuit is simulated in LTspice and the result obtained are as follows:

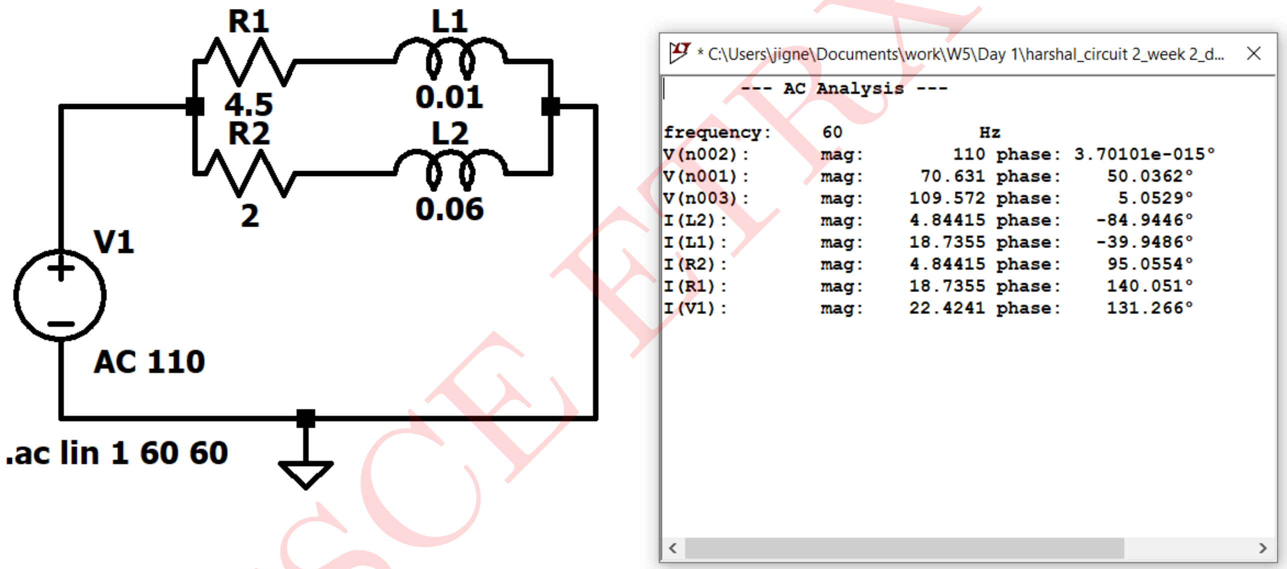

Figure 10: Circuit schematic and Simulated Results

Comparison of Theoretical and Simulated values:

Parameters	Theoretical Values	Simulated Values
I_{R1}	$18.7380\angle -39.954^\circ A$	$18.7355\angle -39.9486^\circ A$
I_{R2}	$4.8441\angle -84.947^\circ A$	$4.84415\angle 95.0554^\circ A$
I_{Total}	$22.4268\angle -43.7388^\circ A$	$22.4241\angle 131.266^\circ A$
Power Factor	0.6594	0.6595

Table 4: Numerical 4

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Numerical 5: Find I, I_1 and I_2 and voltage drop in the ciruit 3. If $R_1 = 6\Omega$, $L_1 = 4j\Omega$, $R_2 = 20\Omega$, $L_2 = 8j\Omega$, $R_3 = 9\Omega$, $C_1 = -6j\Omega$, $V = 100V$ and $f = 50Hz$.

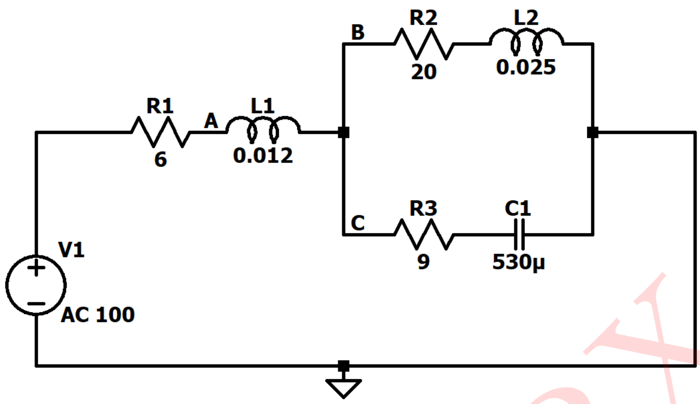

Figure 11: Circuit 5

Solution:

$Z_1 = 6 + 4j = 7.211\angle 33.690°$

$Z_2 = 20 + 8j = 21.54\angle 21.801°$

$Z_3 = 9 - 6j = 10.8166\angle - 33.690°$

$$Z = Z_1 + \frac{Z_2 - Z_3}{Z_2 + Z_3}$$

$$Z = (16+4j) \times \frac{(20 + 8j)(9 - 6j)}{20 + 8j + 9 - 6j}$$

$Z = 13.830\angle 7.533°\Omega$

$$I = \frac{V}{Z}$$

$$I = \frac{100}{13.830\angle 7.533°}$$

$I = 7.2306\angle - 7.533° A$

By Current Divison Rule,

$$I_1 = \frac{I \times Z_3}{Z_2 + Z_3}$$

$$I_1 = \frac{7.2306\angle - 7.533° \times 10.8166\angle - 33.690°}{10.8166\angle - 33.690° + 21.54\angle 21.801°}$$

$I_1 = 2.6905\angle - 10.634°$A

$I_2 = I - I_1$

$I_2 = 7.2306\angle - 7.533° - 2.6905\angle - 10.634°$

$I_2 = 5.343\angle 44.9071° A$

Voltage drop across branch B,

$V_B = I \times Z_1$

$V_B = 7.2306\angle -7.533^\circ \times 7.2111\angle 33.690^\circ$

$V_B = 52.140\angle 26.157^\circ V$

Voltage drop across branch C,

$$V_B = I \times \frac{Z_2 \times Z_3}{Z_2 + Z_3}$$

$V_B = 57.9525\angle -23.66^\circ V$

SIMULATED RESULTS:
The given circuit is simulated in LTspice and the result obtained are as follows:

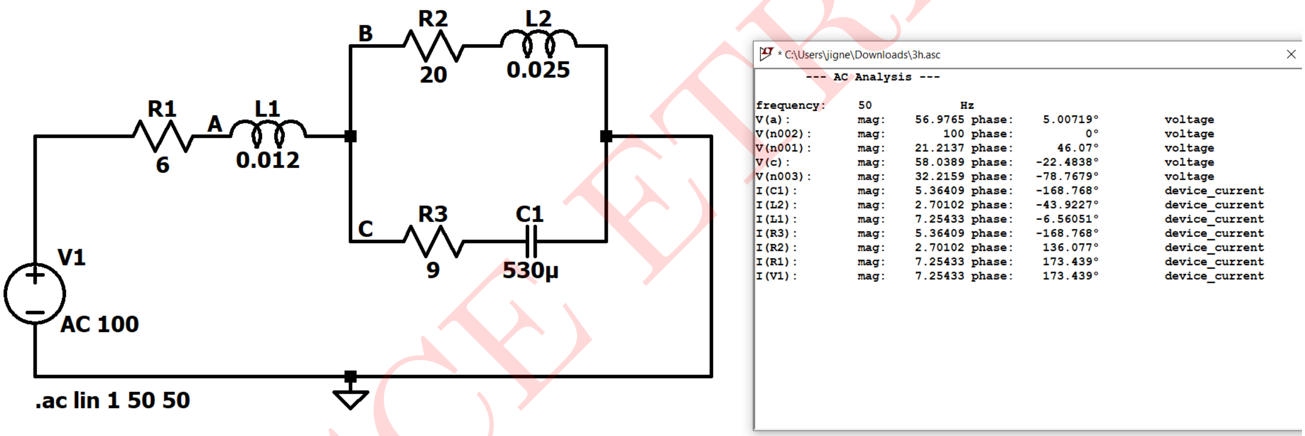

Figure 12: Circuit schematic and Simulated Results

Comparison of Theoretical and Simulated values:

Parameters	Theoretical Values	Simulated Values
I	$7.2306\angle -7.533^\circ A$	$7.254\angle -6.5605^\circ A$
I_1	$2.6905\angle -10.634^\circ A$	$2.7010\angle -43.9227^\circ A$
I_2	$5.343\angle 44.9071^\circ A$	$5.3640\angle -168.768^\circ A$
V_B	$52.140\angle 26.157^\circ V$	$56.9765\angle 5.00719^\circ V$
V_C	$57.9525\angle -23.66^\circ V$	$58.0389\angle -22.4838^\circ V$

Table 5: Numerical 5

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Numerical 6: A 60Hz sinusoidal voltage $V = 141 \sin wt$ is applied to a series R-L circuit.The values of resistance and inductor are 4Ω and 0.02H.
a) Calculate peak voltage across resistor and inductor and also find the peak value of source current.
b) Plot $V_S(t)$ vs $I_S(t)$
c) Measure phase delay between $V_S(t)$ and $I_S(t)$
d) Plot $V_S(t)$ vs $V_R(t)$
e) Measure phase delay between $V_S(t)$ and $V_R(t)$
f) Plot $V_S(t)$ vs $V_L(t)$
g) Measure phase delay between $V_S(t)$ and $V_L(t)$
h) Calculate the Power Factor

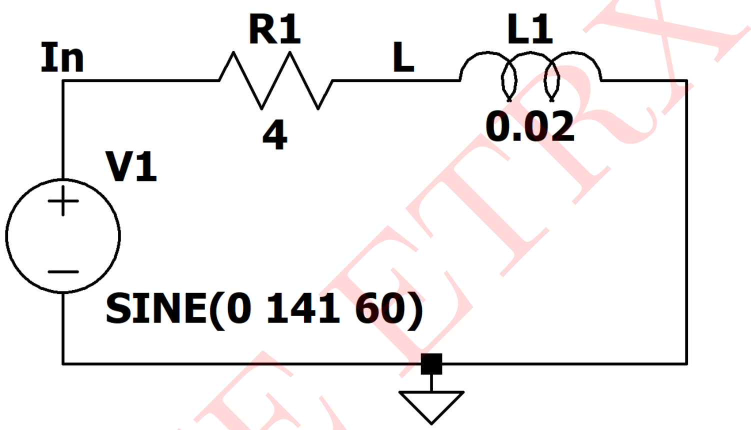

Figure 13: Circuit 6

Solution:

a) $X_L = 2\pi f \times L_1$
$= 2\times\pi \times 60 \times 0.02$
$X_L = 7.539\Omega$

$$\text{Impedance(Z)} = \sqrt{R^2 + X_L^2}$$
$$= \sqrt{4^2 + 7.539^2}$$

$$\Phi = \tan^{-1}\left(\frac{X_{L1}}{R_1}\right)$$

$$\Phi = \tan^{-1}\left(\frac{7.539}{4}\right)$$

$$\Phi = 63.05°$$

$$Z = 8.534\angle 63.05°$$

$$I_{peak} = \frac{V_{peak}}{Z}$$

$$I_{peak} = \frac{141}{8.534\angle 63.050°}$$
I_{peak}= $16.5221\angle -63.050°$A

Peak value of voltage across resistor $= \mathrm{I}_{peak} \times R$
$= 66.0884\angle -63.050° \text{ V}$

Peak value of voltage across inductor $= \mathrm{I}_{peak} \times X_L$
$= 124.5601\angle 26.95° \text{ V}$

b) $V_S(t)$ vs $I_S(t)$

Figure 14: Plot of $V_S(t)$ vs $I_S(t)$

c) Phase delay between $V_S(t)$ vs $I_S(t)$:
V $= 140\angle 0°$
I $= 16.5221\angle -63.050°\text{A}$
$\phi = 180 - 63.05°$
$\phi = 116.95°$

$$\Delta t = \frac{\phi}{T}$$

$$\Delta t = \frac{116.95° \times 20}{360°}$$

$\Delta t = 6.4972ms$

d) $V_S(t)$ vs $V_R(t)$

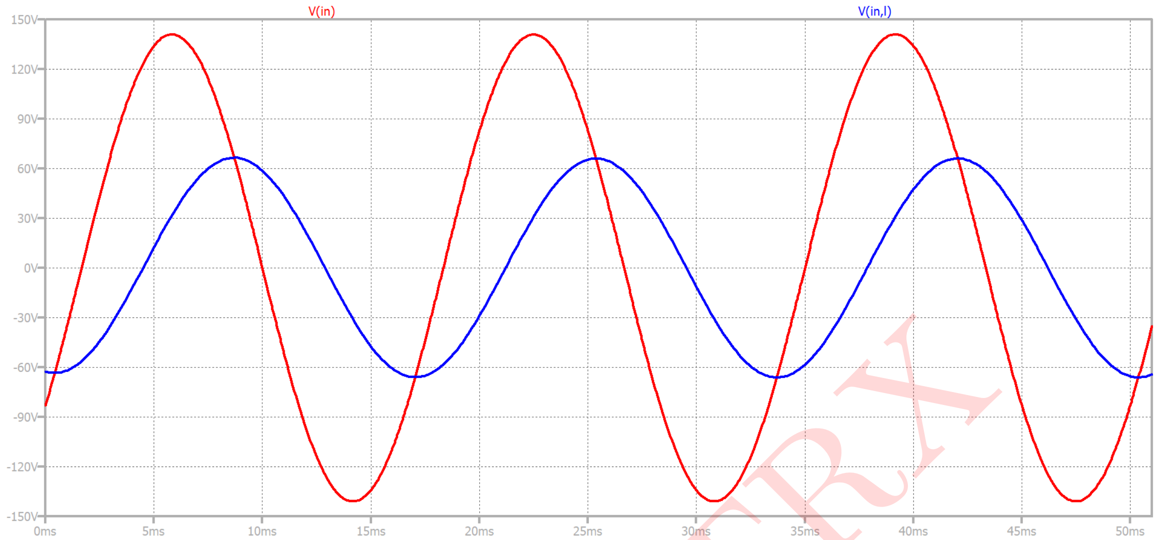

Figure 15: Plot of $V_S(t)$ vs $V_R(t)$

e) Phase delay between $V_S(t)$ vs $V_R(t)$:
V $= 140\angle 0°$
V$_R$= $66.0884\angle -63.050°$ V
$\phi = 63.05°$

$$\Delta t = \frac{\phi}{T}$$

$$\Delta t = \frac{63.05° \times 20}{360°}$$

$$\Delta t = 3.50277ms$$

f) $V_S(t)$ vs $V_L(t)$

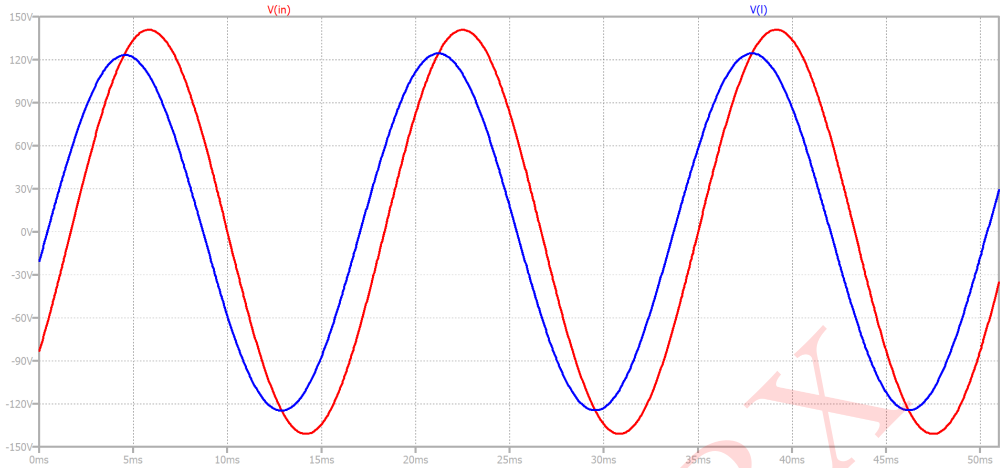

Figure 16: Plot of $V_S(t)$ vs $V_L(t)$

g) Phase delay between $V_S(t)$ vs $V_L(t)$:
V = $140\angle 0°$
V_L= $124.5601\angle 26.95°$ V
$\phi = 26.95°$

$$\Delta t = \frac{\phi}{T}$$

$$\Delta t = \frac{26.95° \times 20}{360°}$$

$$\Delta t = 1.49722ms$$

h) Power Factor :
Power Factor = $\cos(\Phi)$
Power Factor = $\cos(63.050°)$
Power Factor = 0.4532 (lagging)

SIMULATED RESULTS:
The given circuit is simulated in LTspice and the result obtained are as follows:

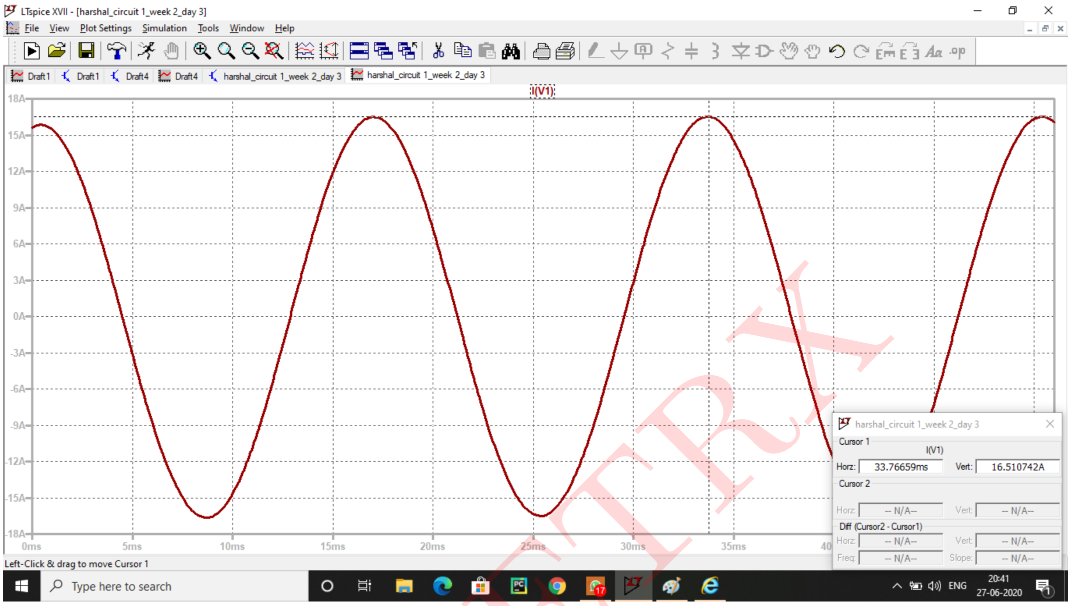

Figure 17: Simulated Results of Source Current

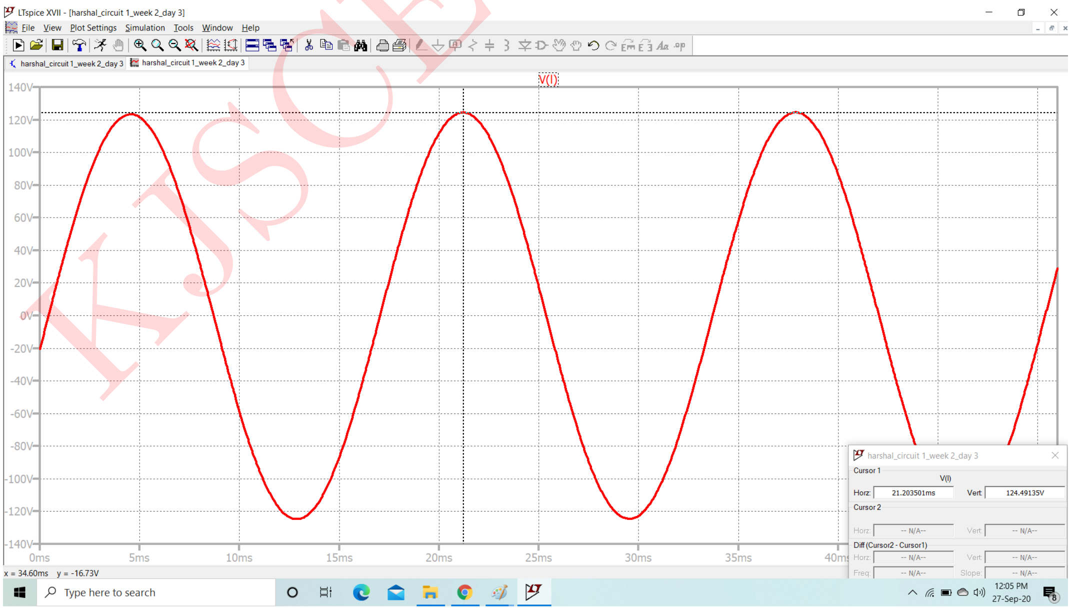

Figure 18: Simulated Results of Voltage across Resistor

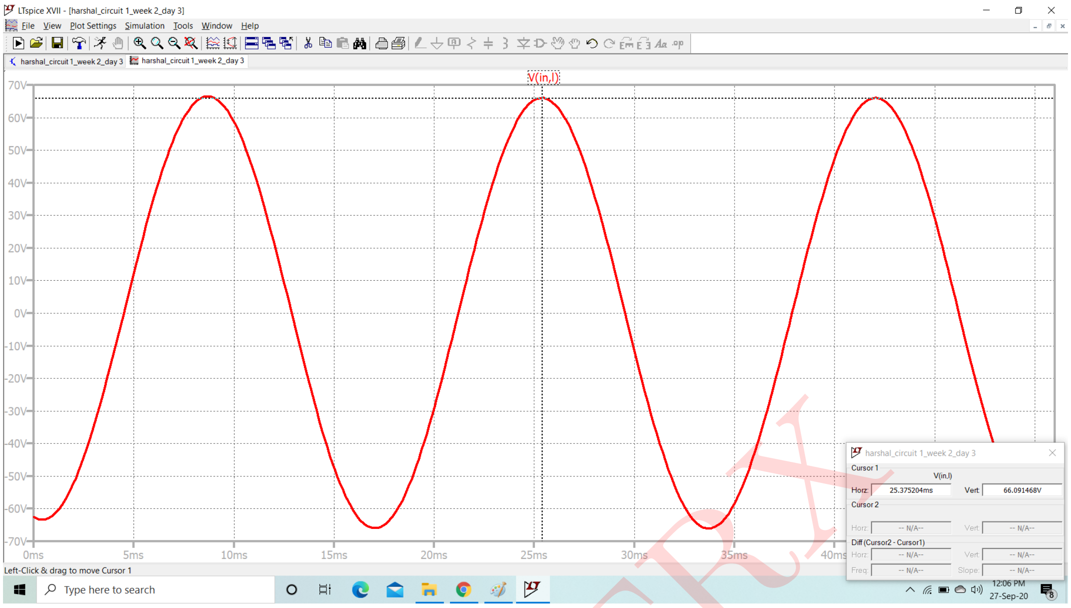

Figure 19: Simulated Results of Voltage across Inductor

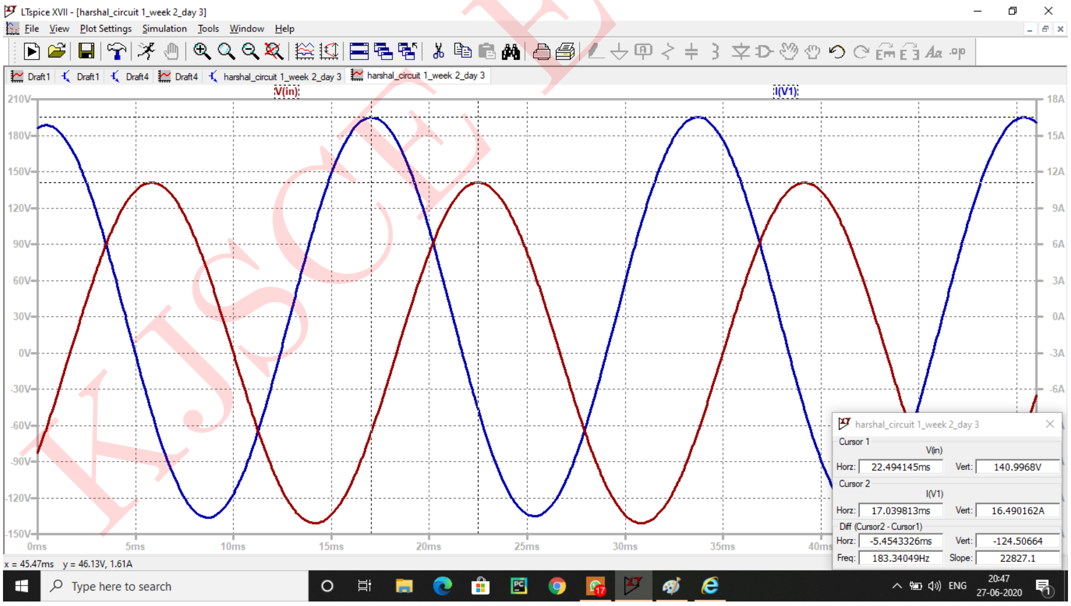

Figure 20: Simulated Results of Voltage for $V_S(t)$ vs $I_S(t)$

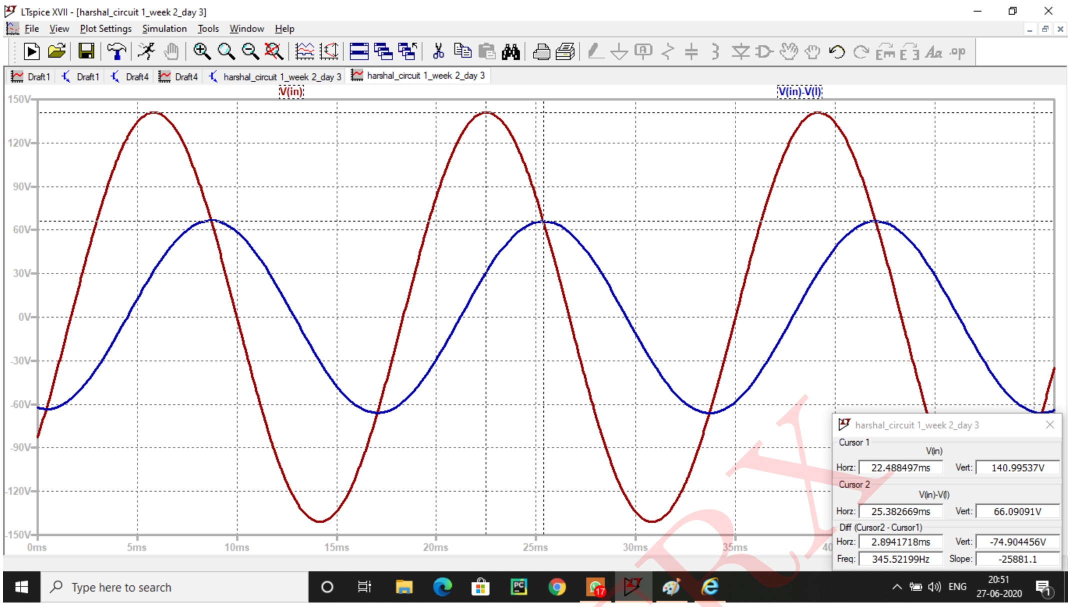

Figure 21: Simulated Results of Voltage for $V_S(t)$ vs $V_R(t)$

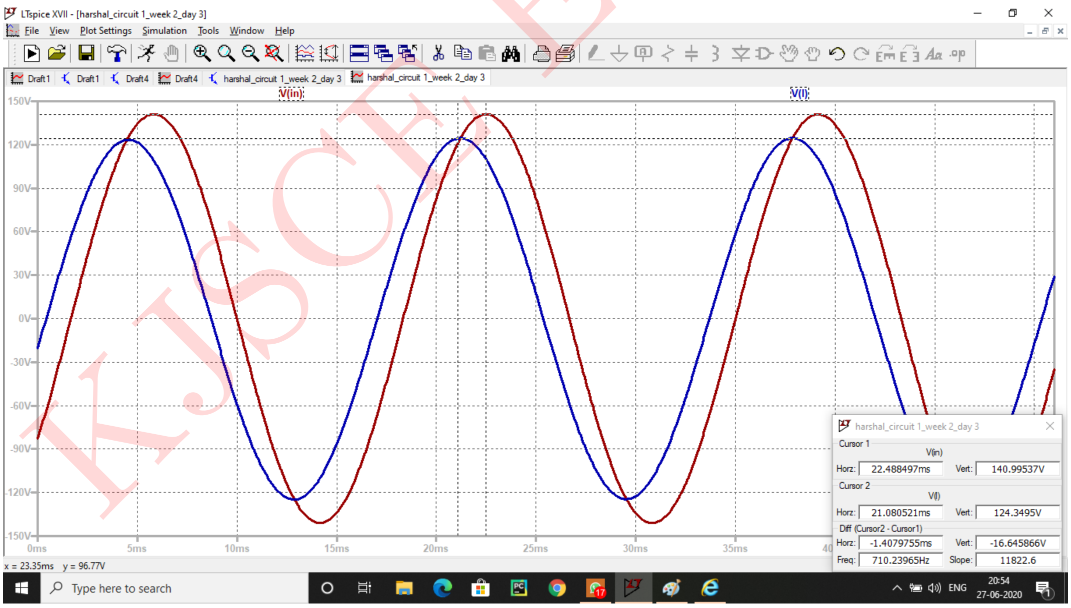

Figure 22: Simulated Results of Voltage for $V_S(t)$ vs $V_L(t)$

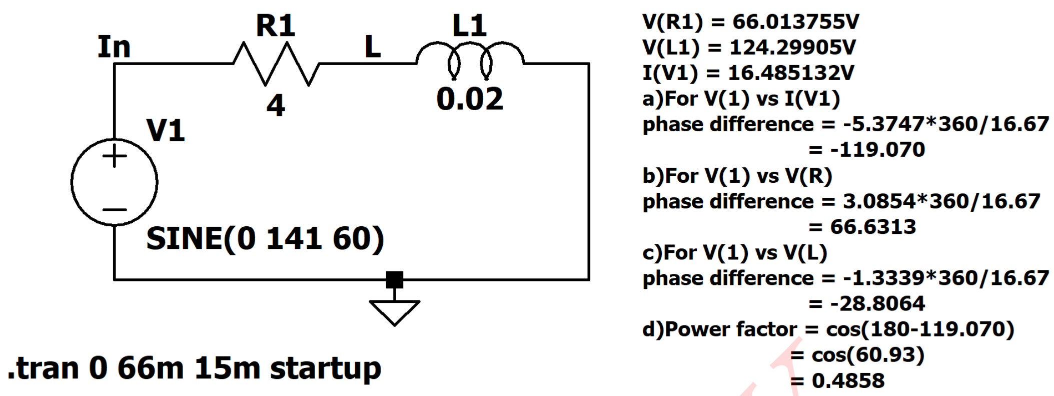

Figure 23: Simulated Circuit

Comparison of Theoretical and Simulated values:

Parameters	Theoretical Values	Simulated Values
Peak Voltage(Resistor)	66.0884V	66.013755V
Peak Voltage(Inductor)	124.5601V	124.29905V
Peak Value(Source Current)	16.5221A	16.485132A
Phase difference $V_S(t)$ vs $I_S(t)$	$63.050°$, $6.4972ms$	$60.93°$, 5.4554ms
Phase difference $V_S(t)$ vs $V_R(t)$	$63.050°$, $3.50277ms$	$63.050°$, $2.89417ms$
Phase difference $V_S(t)$ vs $V_L(t)$	$26.95°$, $1.49722ms$	$28.80°$, $1.40797ms$
Power Factor	0.4532(lagging)	0.4858(lagging)

Table 6: Numerical 6

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Numerical 7: A pure resistor of 30Ω in series with capacitor of 100μF.It is connected across 120V,50Hz.
a) Calculate peak voltage across resistor and capacitor and also find the peak value of peak current.
b) Plot $V_S(t)$ vs $I_S(t)$
c) Measure phase difference between $V_S(t)$ and $I_S(t)$
d) Plot $V_S(t)$ vs $V_R(t)$
e) Measure phase difference between $V_S(t)$ and $V_R(t)$
f) Plot $V_S(t)$ vs $V_C(t)$
g) Measure phase delay between $V_S(t)$ and $V_C(t)$
h) Calculate the Power Factor

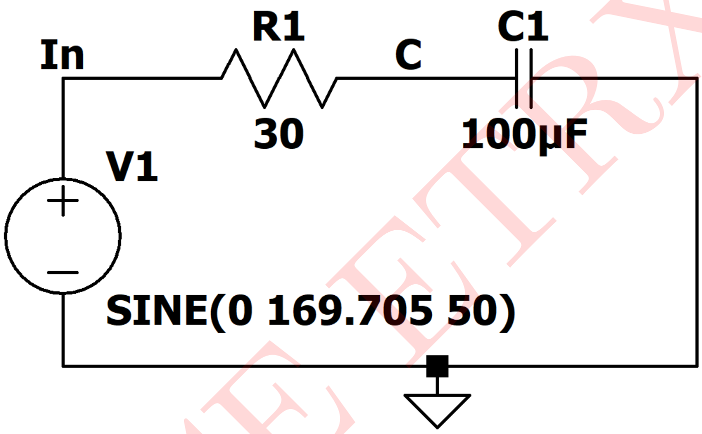

Figure 24: Circuit 7

Solution:

$$X_{C1} = \frac{1}{2 \times \pi \times f \times C_1}$$

$$X_{C1} = \frac{1}{2\pi \times 50 \times 100 \times 10^{-6}}$$

$$X_{C1} = 31.8359\Omega$$

$$\text{Impedance(Z)} = \sqrt{R^2 + X_C^2}$$

$$= \sqrt{30^2 + 31.8359^2}$$

$$\Phi = \tan^{-1}\left(\frac{X_{C1}}{R_1}\right)$$

$$\Phi = \tan^{-1}\left(\frac{31.8359}{30}\right)$$

$$\Phi = 46.6961°$$

$$Z = 43.7402\angle 46.6961°$$

$$I_{peak} = \frac{V_{peak}}{Z}$$

$$I_{peak} = \frac{120 \times 1.414}{43.7402\angle -46.6961°} A$$

$\mathrm{I}_{peak} = 3.8798\angle - 46.6961$

Peak value of voltage across resistor $= \mathrm{I}_{peak} \times R$

$= 116.394\angle - 46.6961°$ V

Peak value of voltage across capacitor $= \mathrm{I}_{peak} \times X_C$

$= 123.4975\angle - 136.6961°$ V

b) $V_S(t)$ vs $I_S(t)$

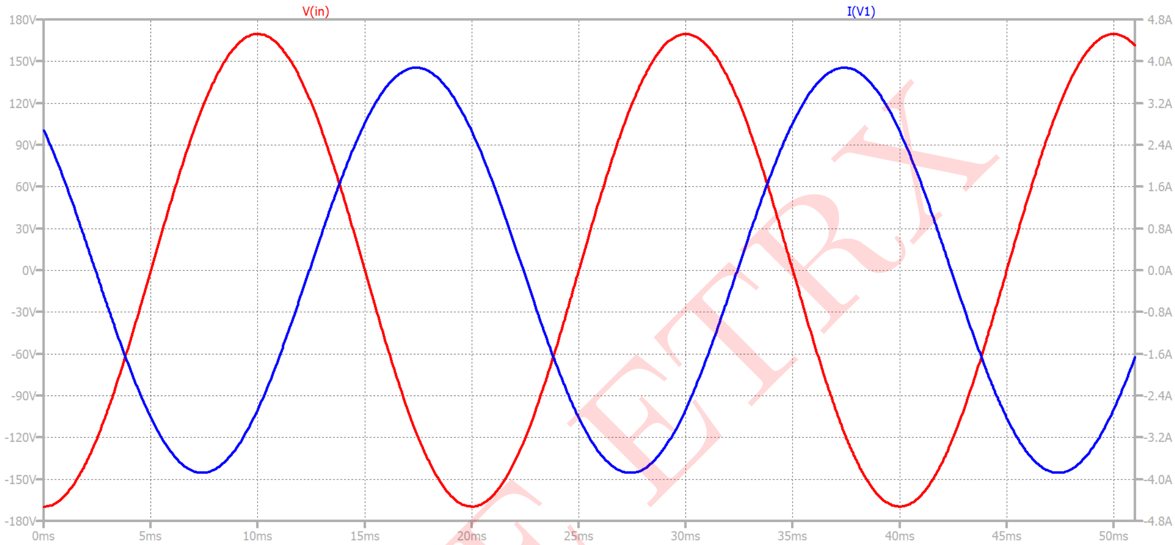

Figure 25: Plot of $V_S(t)$ vs $I_S(t)$

c) Phase delay between $V_S(t)$ vs $I_S(t)$:

V $= 12\angle 0°$

I $3.8798\angle - 46.6961$

$\phi = 180 - 46.6961°$

$\phi = 133.3039°$

$$\Delta t = \frac{\phi}{T}$$

$$\Delta t = \frac{133.30395° \times 20}{360°}$$

$\Delta t = 7.4057ms$

d) $V_S(t)$ vs $V_R(t)$

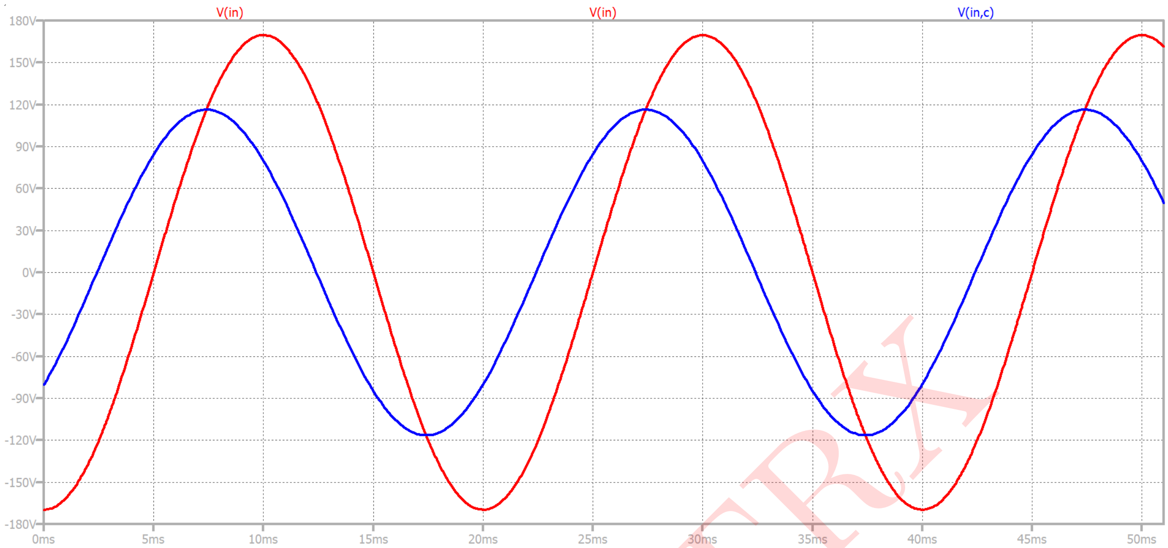

Figure 26: Plot of $V_S(t)$ vs $V_R(t)$

e) Phase delay between $V_S(t)$ vs $V_R(t)$:
V $= 140\angle 0°$
V$_R$= $116.394\angle -46.6961°$ V
$\phi = 46.6961°$

$$\Delta t = \frac{\phi}{T}$$

$$\Delta t = \frac{46.6961° \times 20}{360°}$$

$\Delta t = 2.5942ms$

f) $V_S(t)$ vs $V_C(t)$

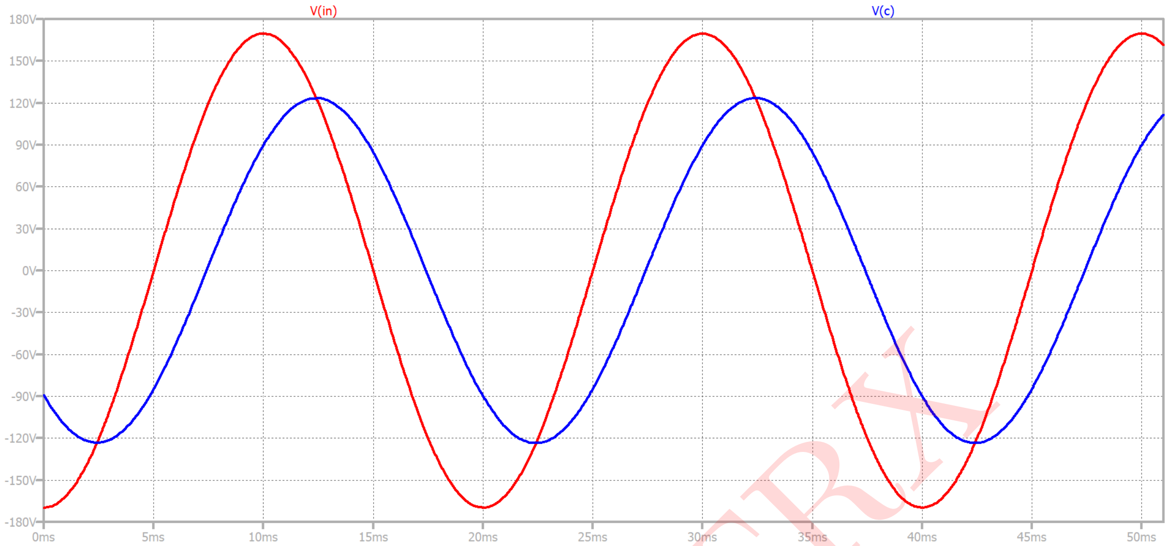

Figure 27: Plot of $V_S(t)$ vs $V_C(t)$

g) Phase delay between $V_S(t)$ vs $V_C(t)$:
V $= 140\angle 0°$
V$_C$= $123.4975\angle -136.6961°$ V
$\phi = 43.3039°$

$$\Delta t = \frac{\phi}{T}$$

$$\Delta t = \frac{43.3039° \times 20}{360°}$$

$\Delta t = 2.40577ms$

h) Power Factor :
Power Factor = $\cos(\Phi)$
Power Factor = $\cos(46.6961°)$
Power Factor = 0.6858

SIMULATED RESULTS:
The given circuit is simulated in LTspice and the result obtained are as follows:

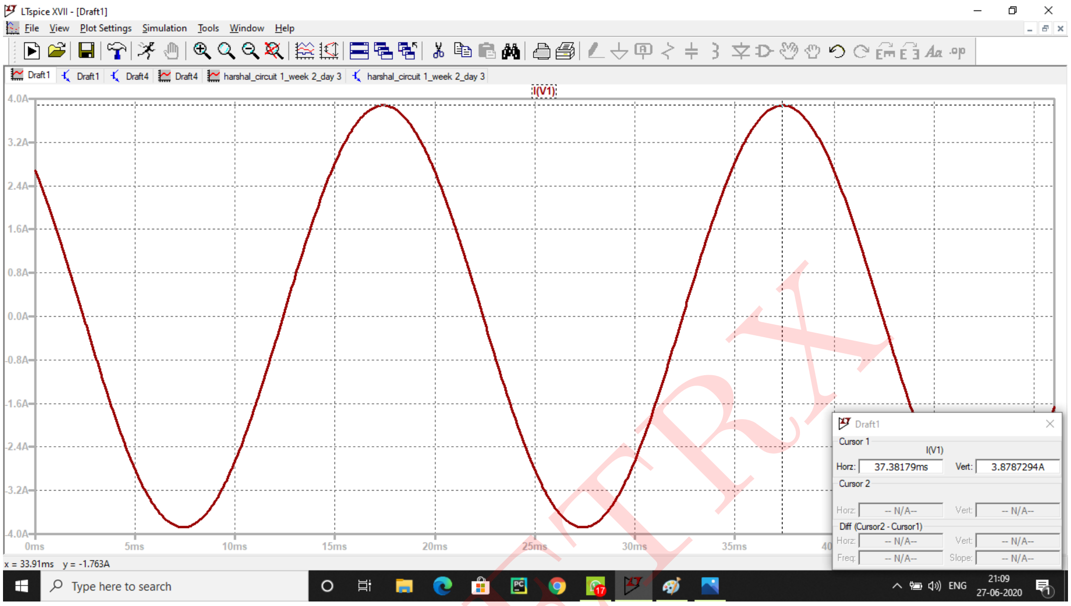

Figure 28: Simulated Results of Source Current

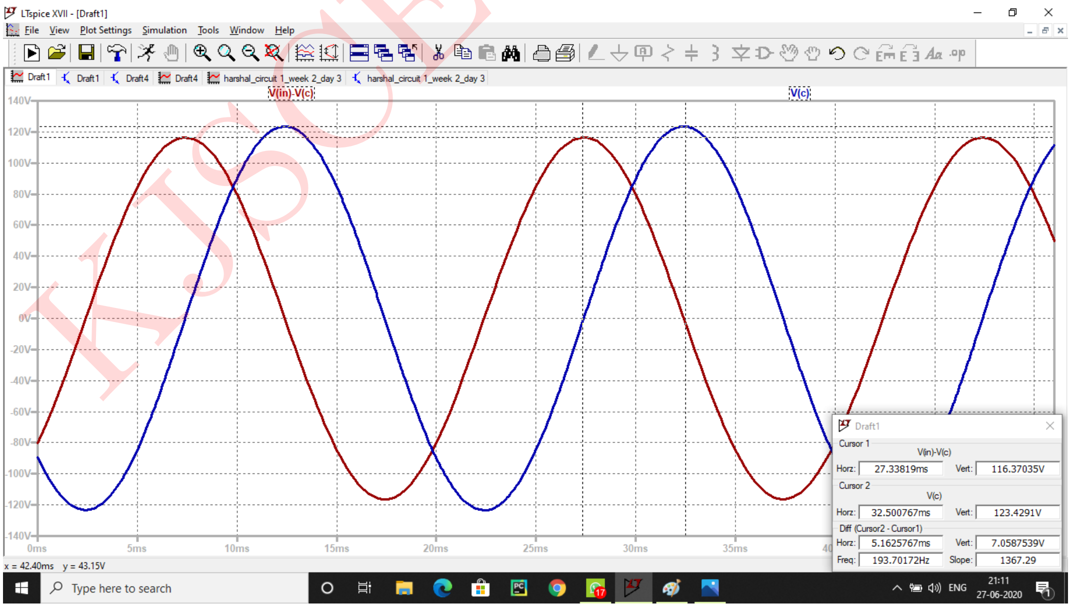

Figure 29: Simulated Results of Voltage across Resistor and Capacitor

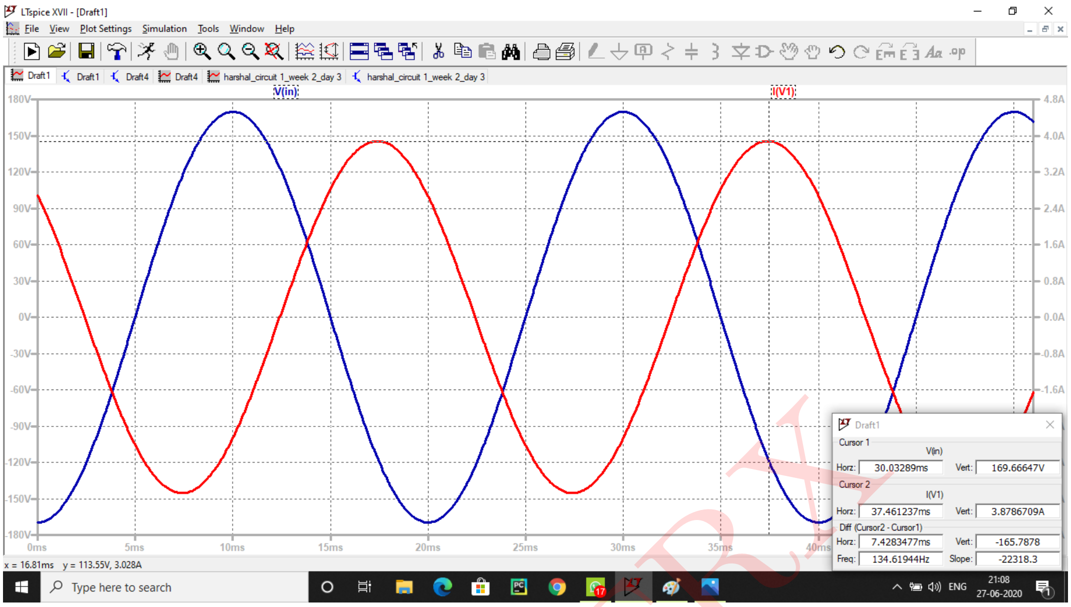

Figure 30: Simulated Results of Voltage for $V_S(t)$ vs $I_S(t)$

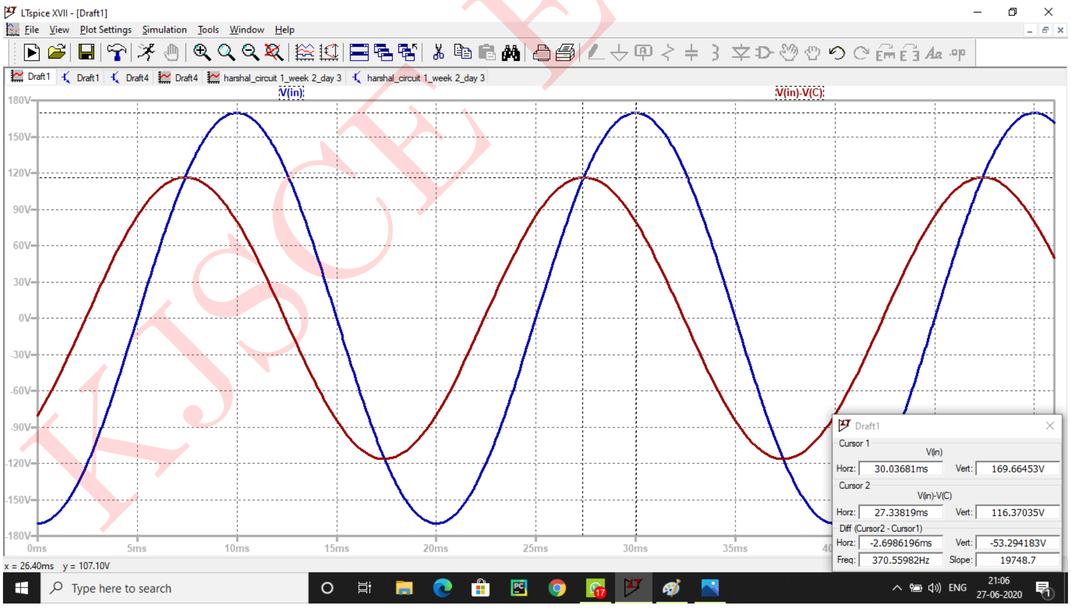

Figure 31: Simulated Results of Voltage for $V_S(t)$ vs $V_R(t)$

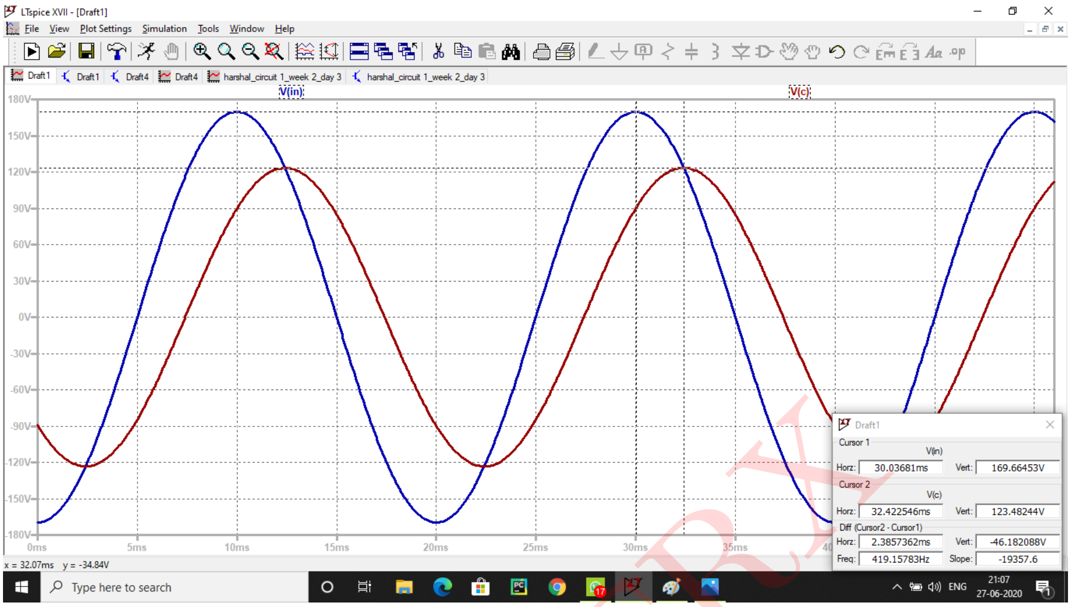

Figure 32: Simulated Results of Voltage for $V_S(t)$ vs $V_C(t)$

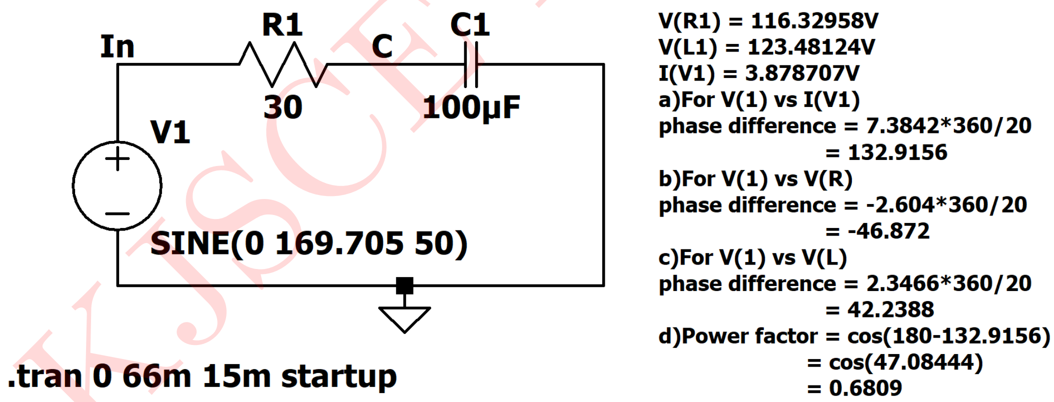

Figure 33: Simulated Circuit

Comparison of Theoretical and Simulated values:

Parameters	Theoretical Values	Simulated Values
Peak Voltage(Resistor)	116.394V	116.3295V
Peak Voltage(Capacitor)	123.4975V	123.4812V
Peak Value(Source Current)	3.8798A	3.8787A
Phase difference $V_S(t)$ vs $I_S(t)$	$46.6961°$, $7.4057ms$	$47.0844°$, $7.4283ms$
Phase difference $V_S(t)$ vs $V_R(t)$	$-46.6961°$, $2.5942ms$	$-46.872°$, $2.6986ms$
Phase difference $V_S(t)$ vs $V_C(t)$	$43.3039°$, $2.40577ms$	$42.2388°$, $2.3857ms$
Power Factor	0.6858	0.6809

Table 7: Numerical 7

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Numerical 8: A series resonance network consisting of 40Ω resistor, 3μF capacitor and 35mH inductor is connected to sinusoidal supply of AC 9Volts. Calculate resonant frequency, current at resonance,voltage across inductor and capacitor at resonance quality factor and bandwidth.

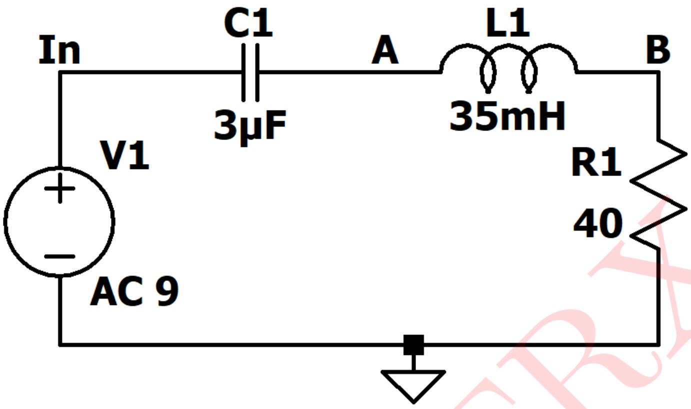

Figure 34: Circuit 8

Solution:

$$\text{Resonant frequency} = \frac{1}{2\pi\sqrt{L_1C_1}}$$

$$\text{Resonant frequency} = \frac{1}{2\pi\sqrt{35\times10^{-3}\times3\times10^{-6}}}$$

Resonant frequency (f_0) $= 491.162Hz$

Current at resonance

$$I_{rms} = \frac{V}{R_1}$$

$$I_{rms} = \frac{9}{40}$$

$I_{rms} = 225mA$

$I_{peak} = I_{rms} \times \sqrt{2}$

$I_{peak} = 318.198A$

At resonance voltage through L and C are same

V$_c = V_L$

V$_L = I \times X_L$

V$_L = 225 \times 10^{-3} \times 2\pi \times 491.162 \times 35 \times 10^{-3}$

(V$_L)_{peak} = (V_C)_{peak} = (V_L)_{rms} \times \sqrt{2} = 34.3692V$

Quality Factor $= \dfrac{X_L}{R}$

Quality Factor $= \dfrac{2\pi 491.162 \times 35 \times 10^{-3}}{40}$

Quality Factor $= 2.7$

Bandwidth $= \dfrac{F_0}{Q}$

Bandwidth $= \dfrac{491.161}{2.7}$

Bandwidth $= 181.9118$Hz

Graph of current at resonance

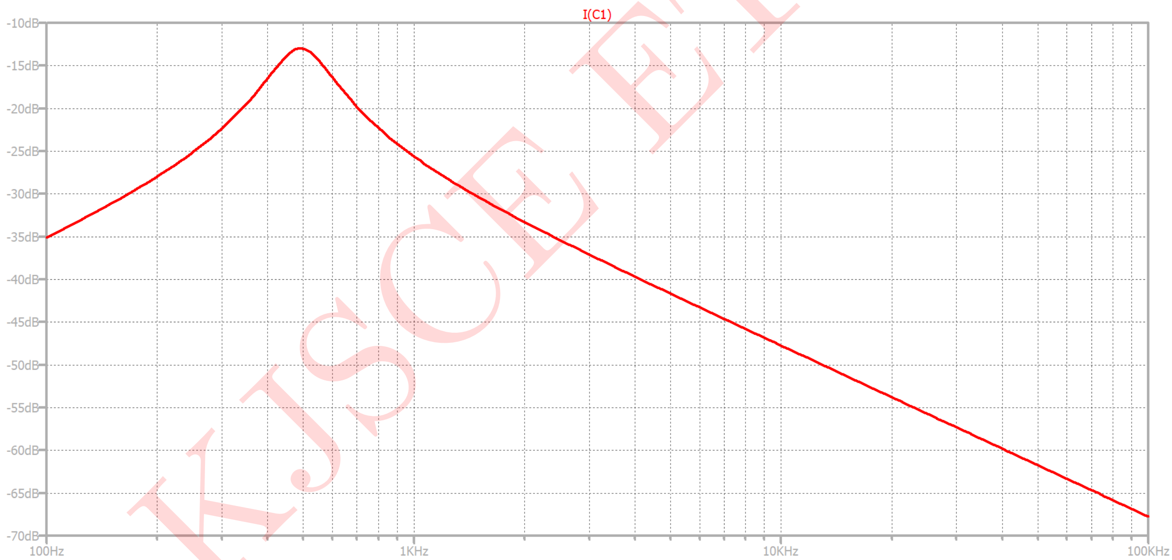

Figure 35: Current at resonance

Graph of resonance curve

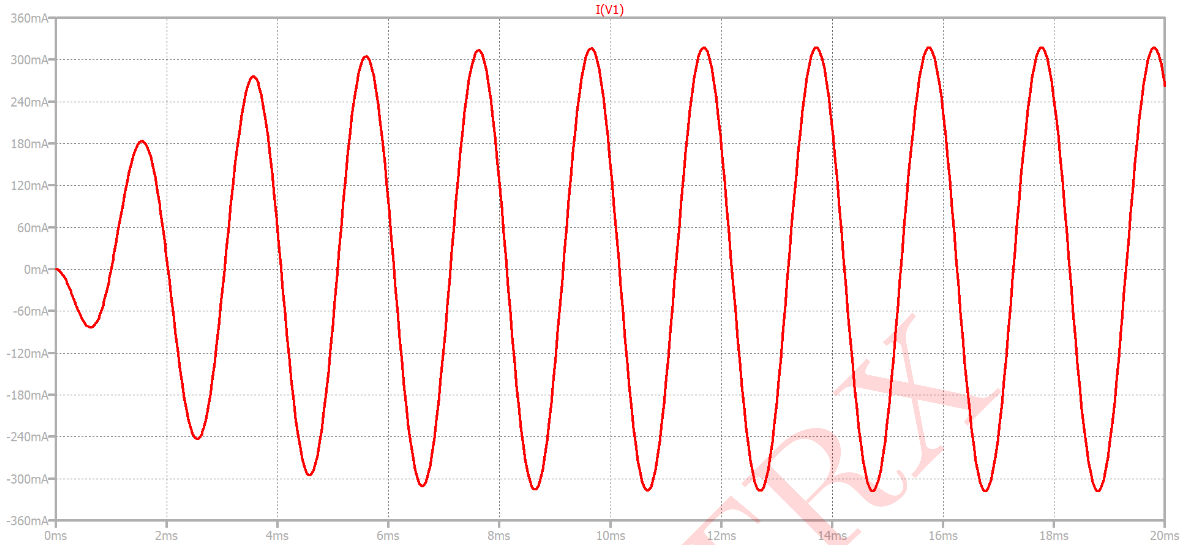

Figure 36: Voltage at resonance

Graph of voltage across inductor

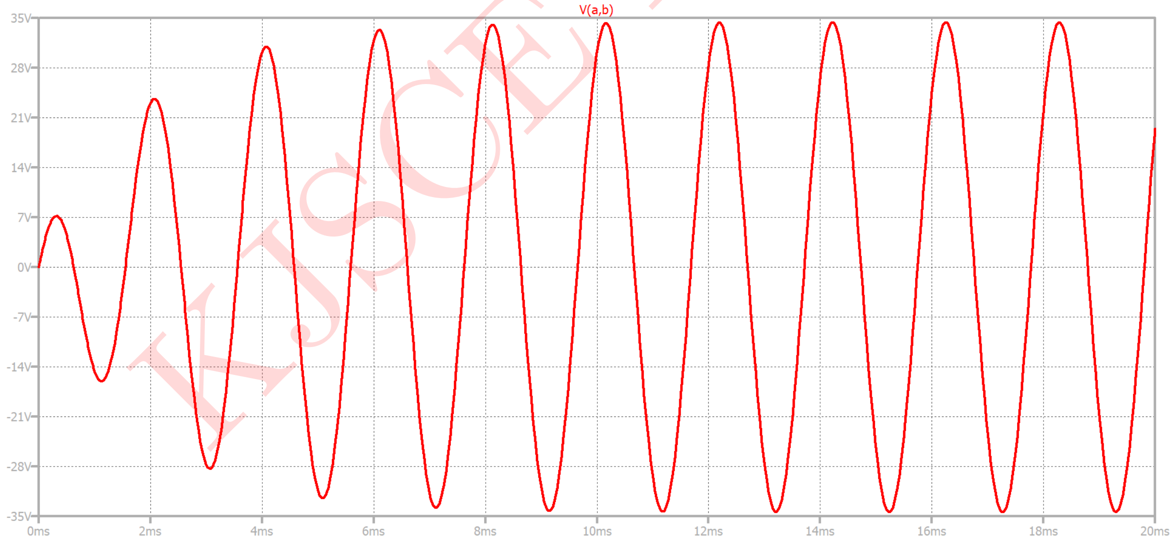

Figure 37: Voltage at resonance

Graph of voltage across capacitor

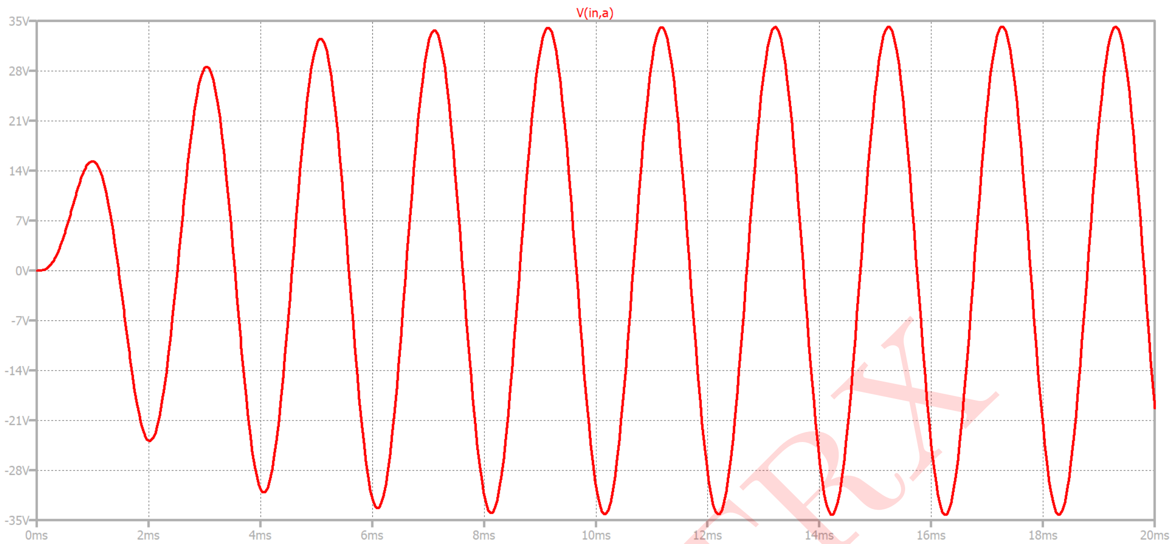

Figure 38: Voltage at resonance

SIMULATED RESULTS:
The given circuit is simulated in LTspice and the result obtained are as follows:

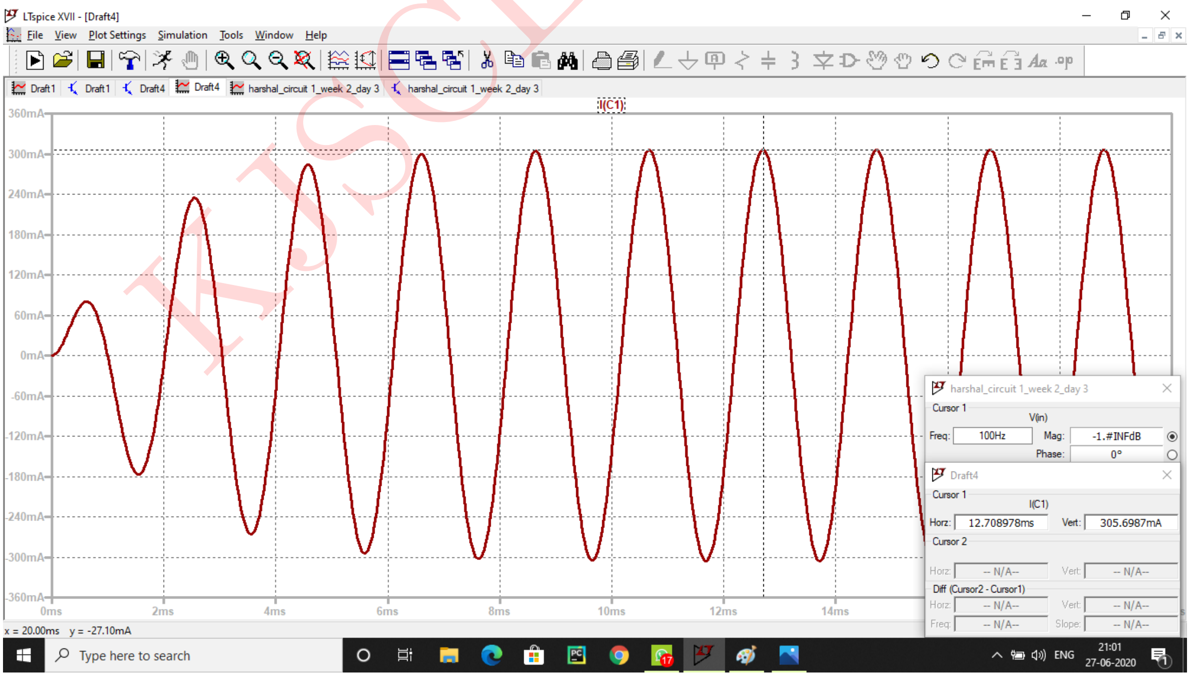

Figure 39: Simulated Results for resonance curve

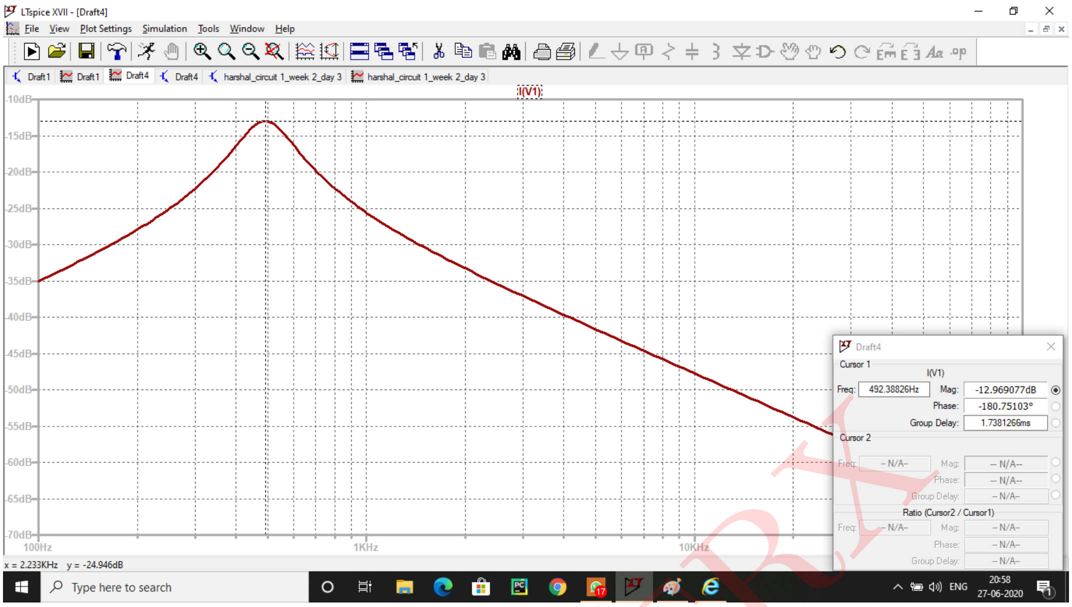

Figure 40: Simulated Results for current at resonance

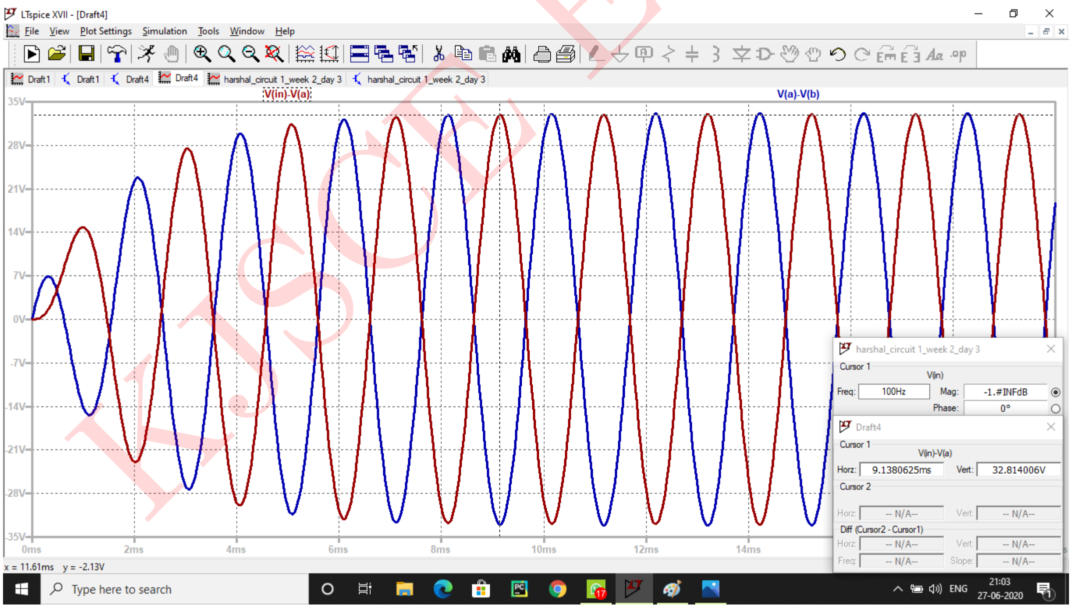

Figure 41: Simulated Results for voltages across capacitor and inductor

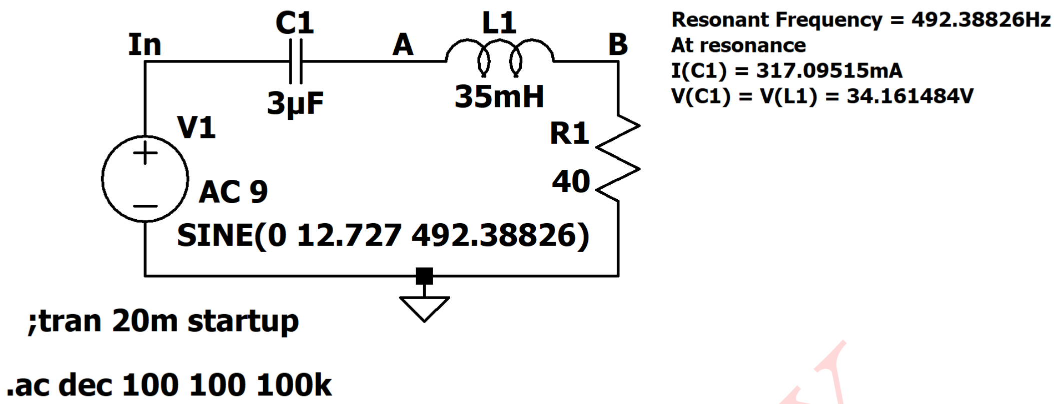

Figure 42: Simulated Circuit

Comparison of Theoretical and Simulated values:

Parameters	Theoretical Values	Simulated Values
Resonant Frequency	491.162Hz	492.38826Hz
Current in resonance	381.168mA	317.09515mA
$V_L = V_C$	34.3692V	34.1614V

Table 8: Numerical 8

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