PROJECT#2B: 3-PHASE SYSTEM

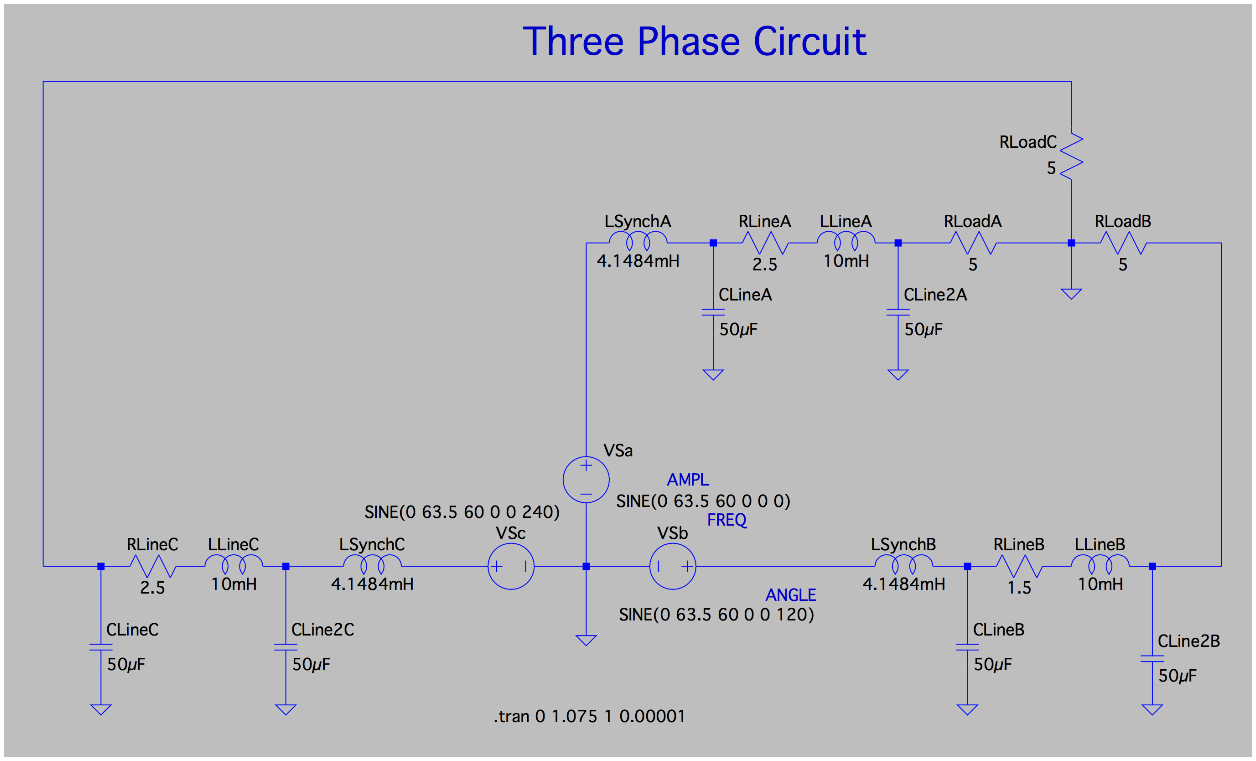
ELC 470: Power Systems

Kevin Cao & Dhruvit Naik

Step #1:
To find the Synchronous Inductor, we added L and M to get 4.1484mH.
To find the Line to Neutral voltage:

$$\frac{\sqrt{2}}{\sqrt{3}} * \frac{110V}{\sqrt{2}} = 63.5\ V$$

Step #2: 3-Phase Linear Power System Composed of Generator, Transformer, Line, and Load



Step #3: Can be seen on the next page…

Step #4:

$$amplitude(v_{GenA}(t)) = 59.73V$$

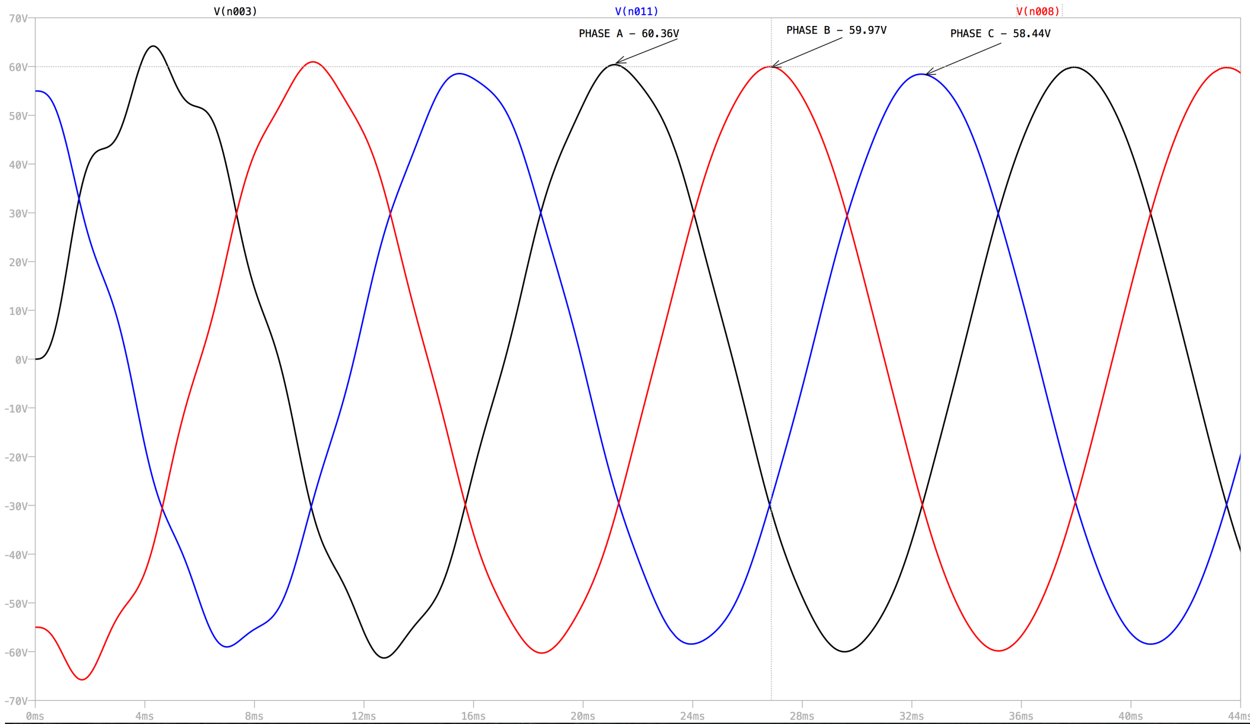
Step #5:

Due to the inductor, the 3 phase circuit has yet to reach steady state. Over time the voltage across the inductor decreases.

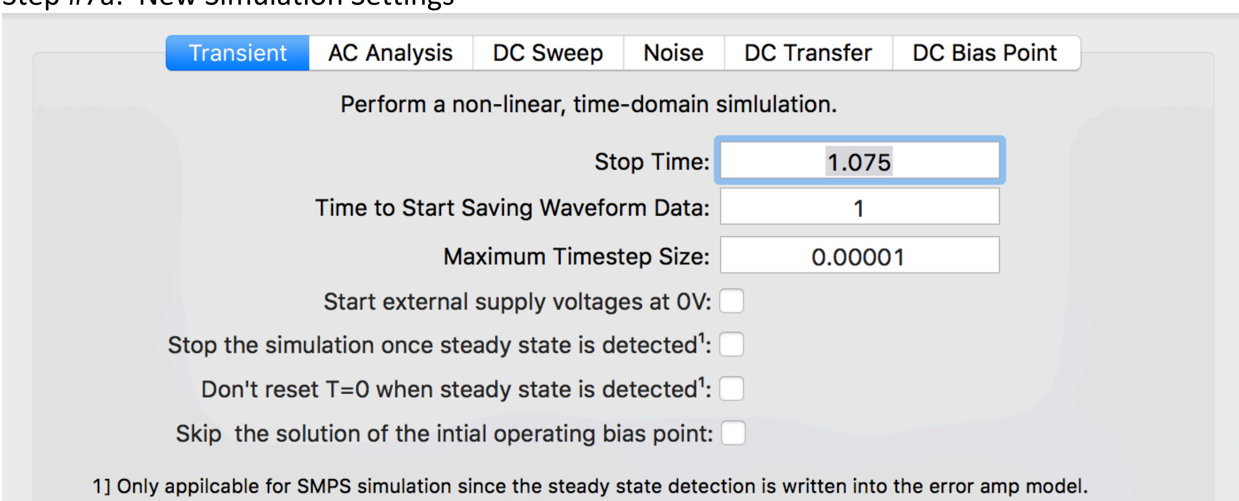
Step #6:

$$RMS(v_{GenA}(t)) = 42.236$$

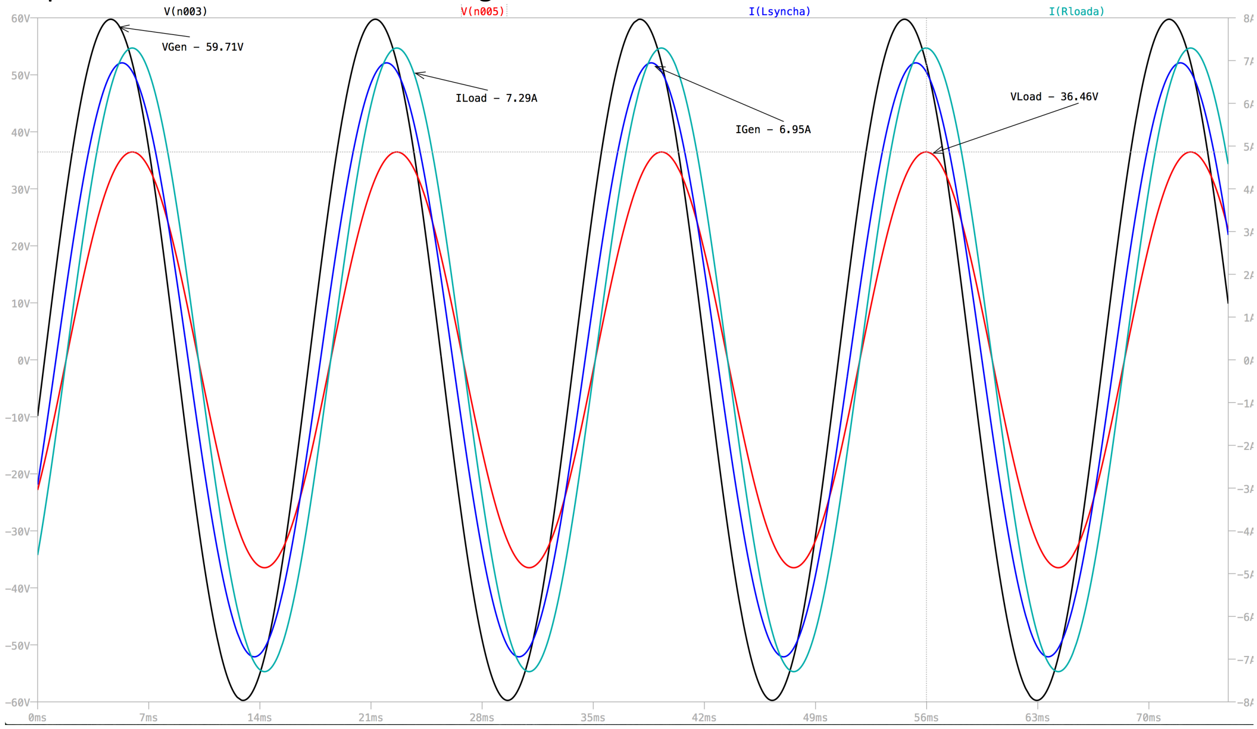
Step #3: Generator Terminal Voltage vs. Time for Circuit of Figure 2



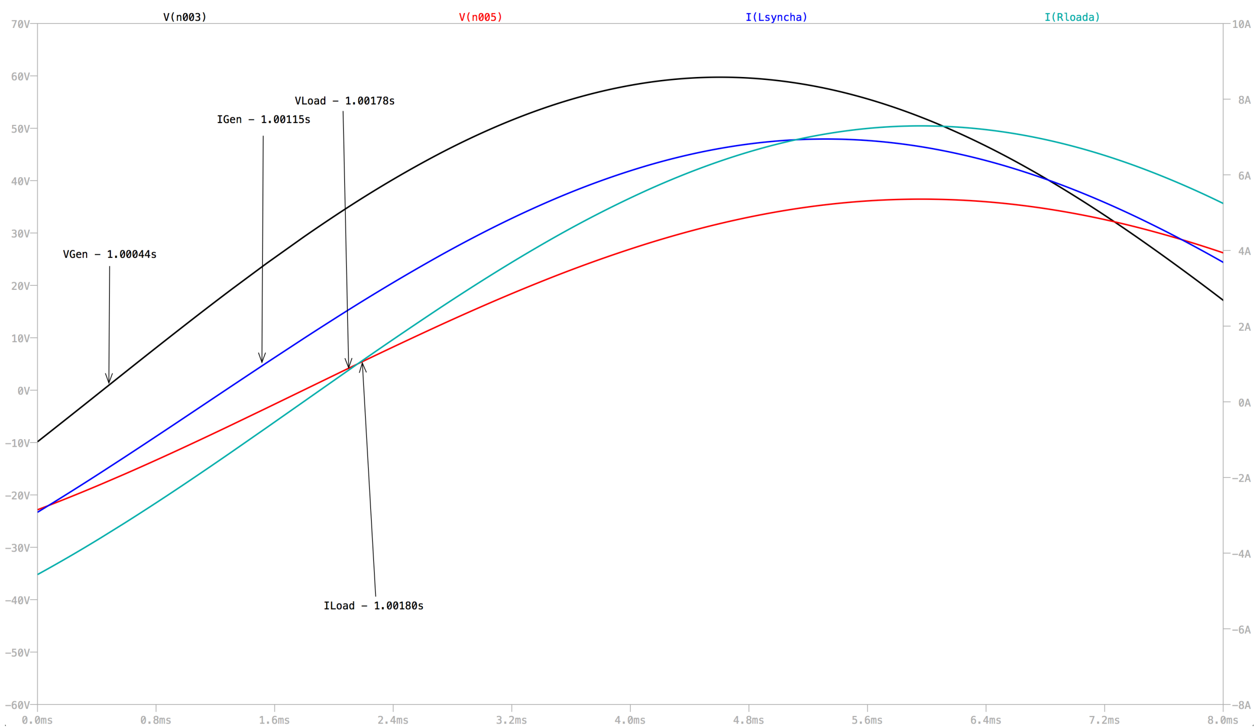
Step #7a: New Simulation Settings



Step #7b: Generator and Load Voltages and Currents vs. Time for Three-Phase Circuit



Step #8: Zoomed Generator and Load Voltages and Currents vs. Time for Three-Phase Circuit



Step #9: Waveform Parameters Derived from Step #8 and #9

name	amplitude (line-to-neutral)	RMS (line-to-line)	zero-crossing (s)	Δt	period(T)	Δθ(deg)
vGen	59.73	73.1540	1.00044	Ref	1/60	Ref
vLoad	36.45	44.6430	1.00178	0.0013	1/60	-28.94
iGen	6.95	8.5120	1.00115	0.0007	1/60	-15.34
iLoad	7.30	8.9406	1.00180	0.0014	1/60	-29.37

Step #10:

Using the equations (4,5,6,7) provided in the lab handout, we developed a Matlab script, below is the source code.

```
%   Step 9/10
% (Amplitude, Zero Crossing, RMS, dt, angle)
vGen = [59.73, 1.00044, 0, 0, 0];
vLoad = [36.45, 1.00178, 0, 0, 0];
iGen = [6.95, 1.00115, 0, 0, 0];
iLoad = [7.30, 1.00180, 0, 0, 0];
%   RMS
vGen(3) = (sqrt(3)/sqrt(2)) * vGen(1);
vLoad(3) = (sqrt(3)/sqrt(2)) * vLoad(1);
iGen(3) = (sqrt(3)/sqrt(2)) * iGen(1);
iLoad(3) = (sqrt(3)/sqrt(2)) * iLoad(1);
%   delta T
vGen(4) = 0;
vLoad(4) = vLoad(2)-vGen(2);
iGen(4) = iGen(2)-vGen(2);
iLoad(4) = iLoad(2)-vGen(2);
%   angle
vGen(5) = 0;
vLoad(5) = 360 * vLoad(4)/(1/f);
iGen(5) = 360 * iGen(4)/(1/f);
iLoad(5) = 360 * iLoad(4)/(1/f);
```

Step #11:

$$\overrightarrow{V_{GenA}}(RMS\ line-to-neutral) = 42.236\angle 0°\ V$$
$$\overrightarrow{I_{GenA}}(RMS\ line) = 4.914\angle -15.336°\ A$$
$$\overrightarrow{V_{LoadA}}(RMS\ line-to-neutral) = 25.774\angle -28.944°\ V$$
$$\overrightarrow{I_{LoadA}}(line) = 5.162\angle -29.376°\ A$$

Step #12:

$$\overrightarrow{S_{GenA}}(polar\ form) = 207.56\angle 15.336°\ VA$$
$$\overrightarrow{S_{GenA}}(rectangular\ from) = 200.17\ Watts + 54.89j\ VAR$$
$$\overrightarrow{S_{LoadA}}(polar\ form) = 133.04\angle 0.432°\ VA$$
$$\overrightarrow{S_{LoadA}}(rectangular\ from) = 133.05\ Watts + 1.0031j\ VAR$$

Step #13:
With the knowledge gained from project 1 and equation 8, we calculated our results with a Matlab script. Below is the source code.

Step #13:

```
%   Step 12
%   Polar
sGen_P = [0, 0];
sGen_P(1)= PHvGen(1) * PHiGen(1);
sGen_P(2)= PHvGen(2) - PHiGen(2);
sLoad_P = [0, 0];
sLoad_P(1)= PHvLoad(1) * PHiLoad(1);
sLoad_P(2)= PHvLoad(2) - PHiLoad(2);
%   Polar to Rectangular
sGen_R = sGen_P(1) * cosd(sGen_P(2)) +  j* sGen_P(1) * sind(sGen_P(2))
sLoad_R = sLoad_P(1) * cosd(sLoad_P(2)) +  j* sLoad_P(1) * sind(sLoad_P(2))
```

Step #14:

In order to calculate the real and reactive power loss, we found the difference between the power generated and the power at the load. Below is the Matlab script we used.

```
sLoss = sGen_R - sLoad_R;
sLoss =

  67.1321 +53.8926i
```

$P_{Loss} = 67.1321\, Watts$
$Q_{Loss} = 53.8926\, VAR$

Step #15:

For sinusoidal currents, the displacement power factor is the same as apparent power factor. Using:
$DPF = \cos(\theta_V - \theta_I) = \cos(0 - (-15.33)) = 0.9644$

Step #16:

In order to calculate the equivalent impedance, we combined the following components: RLineA, CLineA, CLineA2, LLineA, and RLoadA. Step #18, shows the Matlab script we used to calculate:

$$Z_{equivalent} = 0.1574 - 6.2194j\Omega$$

Step #17:

Looking at the equation we used for the previous project, we calculated the power correct capacitance. Voltage is the generator voltage and Z is the reactive power from the generator.

$$Z = (\frac{|V^2|}{Z})^*$$

$$Z = \left(\frac{42.23^2}{j54.89}\right)^* = 32.492$$

$$Z = -j * 32.492$$

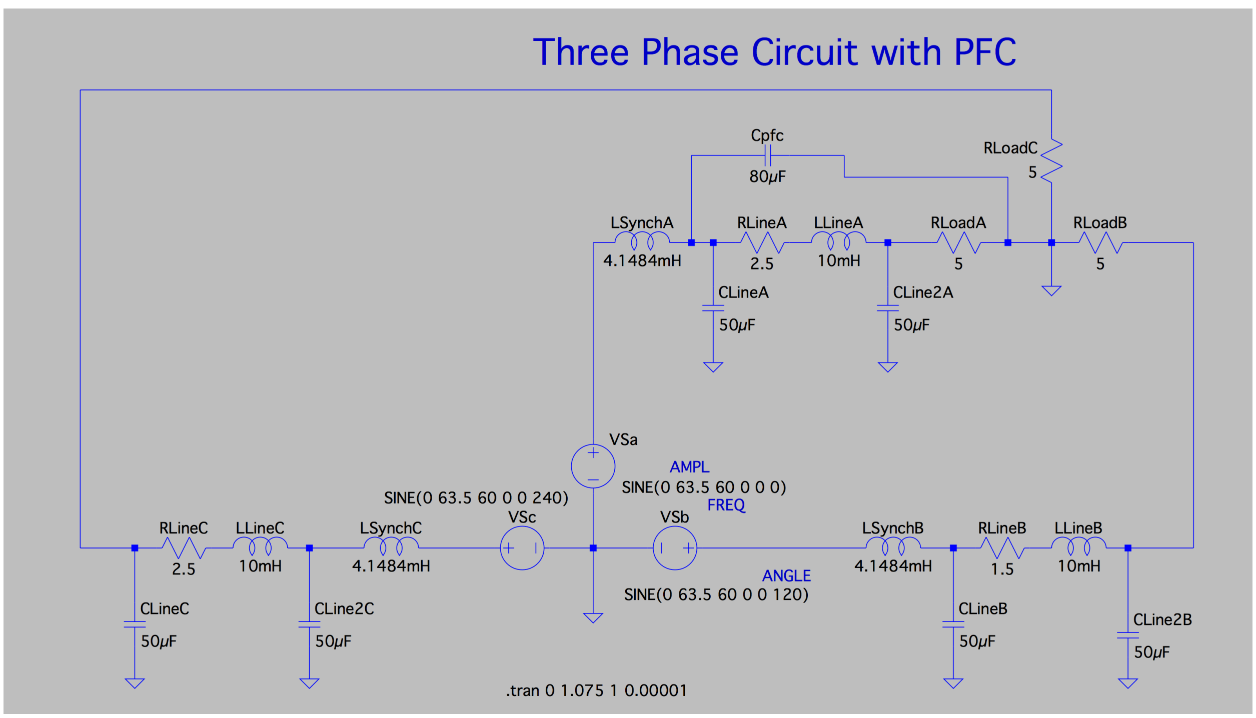
$$C_{pfc} = \frac{1}{j * 2\pi 60 * Z} \approx 80\mu F$$

Step #18:

```
zLoad = 5 + 0*j;
zRLine = 2.5 + 0*j;
zXLine = 10*10E-3 * omega * j;
zCLine1 = 1 / (50*10E-6 *omega * j);
zCLine2 = 1 / (50*10E-6 *omega * j);
zEq = 0;

zEq = (zLoad * zCLine1) /  (zLoad + zCLine1);
zEq = zEq + zRLine + zXLine;
zEq = (zEq * zCLine2) /  (zEq + zCLine2);
```

Step #19: 3-Phase Linear Power System with Power Factor Correction



Step #20:
In order to calculate the updated DPF, we found the new zero-crossing to determine the phase angles. Step #21 is the Matlab Script that outlines our calculations. Below is our result.

$$DPF = \cos(\theta_V - \theta_I) = \cos(0 - (-0.2808)) = 0.999$$

Step #21:

```
% Step 20
% Zero Crossings:
% VGen = 459us
% IGen = 472us
% (Zero Crossing, dt, angle)
UPvGen = [1.000459, 0, 0];
UPiGen = [1.000472, 0, 0];
%   delta T
UPvGen(2) = 0;
UPiGen(2) = UPiGen(1)-UPvGen(1);
%   angle
UPvGen(3) = 0;
UPiGen(3) = 360 * UPiGen(2)/(1/f);
% angle 0.2808 degrees for iGen0
```

Step #22:

The capacitance significantly improved the power factor. There is minimum lag between the generator voltage and current. The loss has actually decreased as a result, this can be seen by the increase in load current and voltage.