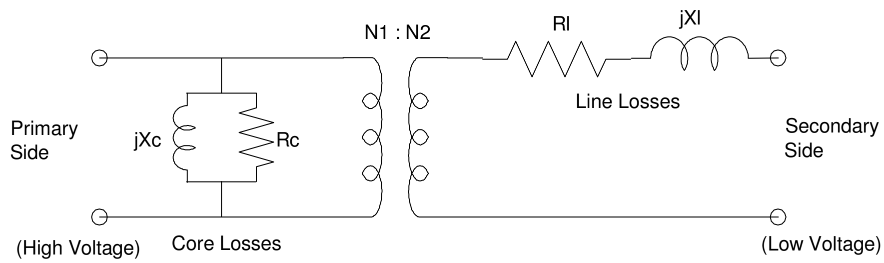
ECE 111: Homework 15

Week #15 - ECE 331 Energy Conversion. Due 11am, Tuesday December 6th

1) Determine the circuit model for a 9.6kV : 240V transformer is tested with the following test results:



Transformer Model

	V	Power	pf
Open-Circuit Test	V1 = 13.2kV	75 W	0.02
Short-Circuit Test	V2 = 24V	12 W	0.98

Open Circuit Test

The current is from

$$P = V \cdot I \cdot pf$$

$$75W = 13.2kV \cdot I \cdot 0.02$$

$$I = 0.2841A$$

The impedance in polar form is

$$Z = \left(\frac{V}{I}\right) \angle \arccos(pf)$$

$$Z = \left(\frac{13{,}200V}{0.2841A}\right) \angle \arccos(0.02)$$

$$Z = 46,464 \angle 88.854^0$$

or in rectangular form

$$Z = 929.2865 + j46,454.7\Omega$$

This is the series model. To get the parallel model, take the inverse

$$\frac{1}{Z} = \frac{1}{R} + \frac{1}{jX} = 4.3044e - 7 - j2.1518e - 5$$

The real part is 1/R, the complex part is 1/jX

$$R_c = 2.323M\Omega$$

$$jX_c = j46.47k\Omega$$

Short Circuit Test

Again

$$P = V \cdot I \cdot pf$$

$$12W = 24V \cdot I \cdot 0.98$$

$$I = 0.5102A$$

The impedance is

$$Z = \left(\frac{V}{I}\right)\angle\arccos(pf)$$

$$Z = \left(\frac{24V}{0.5102A}\right)\angle\arccos(0.98)$$

$$Z = 47.04\angle 11.4783^0\Omega$$

or in rectalgular form

$$Z = 46.0992 + j9.3608$$

This is the series model

$$R_L = 46.0992\Omega$$

$$jX_L = j9.3608\Omega$$

For the utility grid on the back of the page....

2) Convert the voltages and impeances to the 120V node (right side)

Impedances:

- Go through the transformer as the turns-ratio squared

Votlages:

- Go through the transformer as the turns-ratio

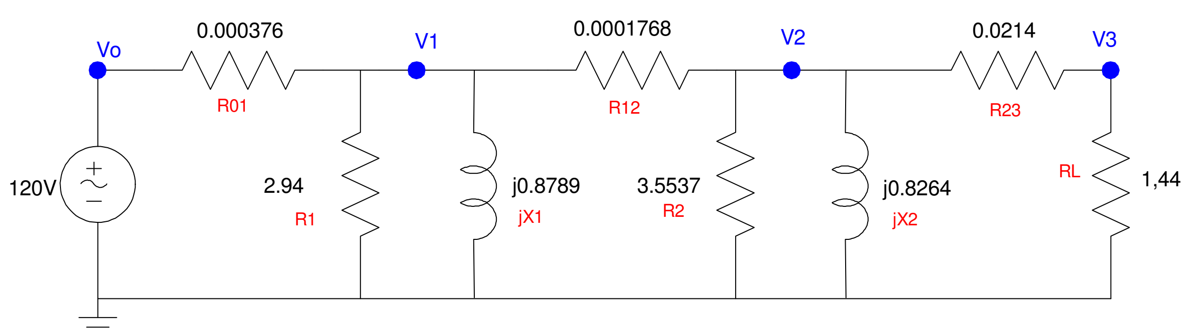
128kV >> 120V

In Matlab

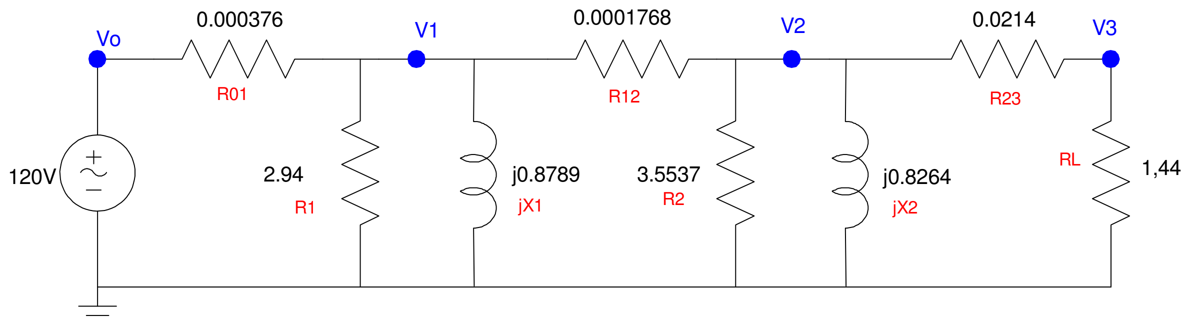
```
V0 = 128000 * (120/128000)
R01 = 428 * (120/128000)^2
R1 = 3.3e6 * (120/128000)^2
X1 = j*1e6 * (120/128000)^2
R12 = 2.14 * (120/13200)^2
X2 = j*10e3 * (120/13200)^2
R2 = 43e3 * (120/13200)^2
R23 = 0.0214
R3 = 1.44
```

Matlab Results

```
V0 =   120
R01 =  3.7617e-004
R1 =    2.9004
X1 =         0 + 0.8789i
R12 =  1.7686e-004
X2 =         0 + 0.8264i
R2 =    3.5537
R23 =    0.0214
R3 =    1.4400
```



3) Determine the voltages at each node



Writing the voltage node equations

$$V_0 = 120$$

$$\left(\frac{V_1 - V_0}{R_{01}}\right) + \left(\frac{V_1}{R_1}\right) + \left(\frac{V_1}{jX_1}\right) + \left(\frac{V_1 - V_2}{R_{12}}\right) = 0$$

$$\left(\frac{V_2 - V_1}{R_{12}}\right) + \left(\frac{V_2}{R_2}\right) + \left(\frac{V_2}{jX_2}\right) + \left(\frac{V_2 - V_3}{R_{23}}\right) = 0$$

$$\left(\frac{V_3 - V_2}{R_{23}}\right) + \left(\frac{V_3}{R_3}\right) = 0$$

Place in matrix form

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ \left(\frac{-1}{R_{01}}\right) & \left(\frac{1}{R_{01}} + \frac{1}{R_1} + \frac{1}{jX_1} + \frac{1}{R_{12}}\right) & \left(\frac{-1}{R_{12}}\right) & 0 \\ & \left(\frac{-1}{R_{12}}\right) & \left(\frac{1}{R_{12}} + \frac{1}{R_2} + \frac{1}{jX_2} + \frac{1}{R_{23}}\right) & \left(\frac{-1}{R_{23}}\right) \\ & & \left(\frac{-1}{R_{23}}\right) & \left(\frac{1}{R_{23}} + \frac{1}{R_3}\right) \end{bmatrix} \begin{bmatrix} V_0 \\ V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 120 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

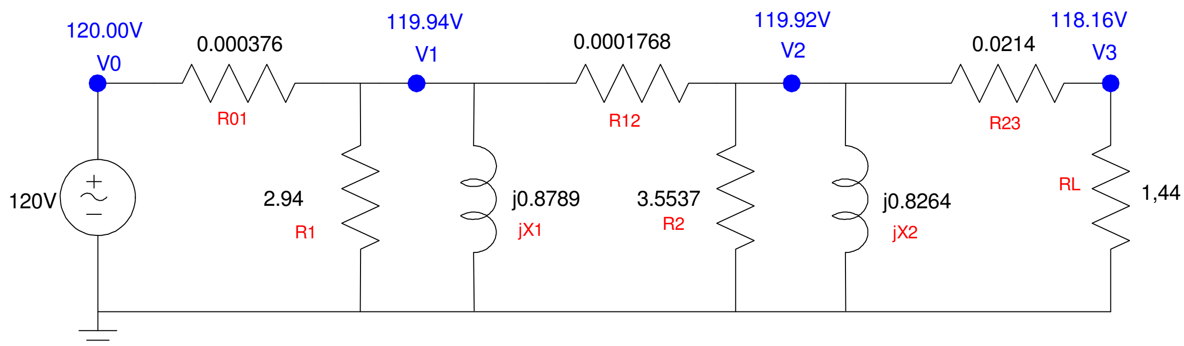
Solve in Matlab

```
a0 = [1,0,0,0];
a1 = [-1/R01,1/R01 + 1/R1 + 1/X1 + 1/R12, -1/R12, 0];
a2 = [0,-1/R12, 1/R12 + 1/R2 + 1/X2 + 1/R23, -1/R23];
a3 = [0,0,-1/R23, 1/R23 + 1/R3];
A = [a0;a1;a2;a3]
B = [120 ; 0 ; 0 ; 0]

V = inv(A)*B
```

V0 120.00 - 0.00i
V1 119.94 + 0.11i
V2 119.92 + 0.13i
V3 118.16 + 0.13i

```
abs(V)
```

V0 120.0000
V1 119.9408
V2 119.9203
V3 118.1643



4) Determine the efficiency of this system

- Ignoring the core losses
  - Assumes a large number of customers share these losses
- Including the core losses
  - Assumes a single customer

In Matlab

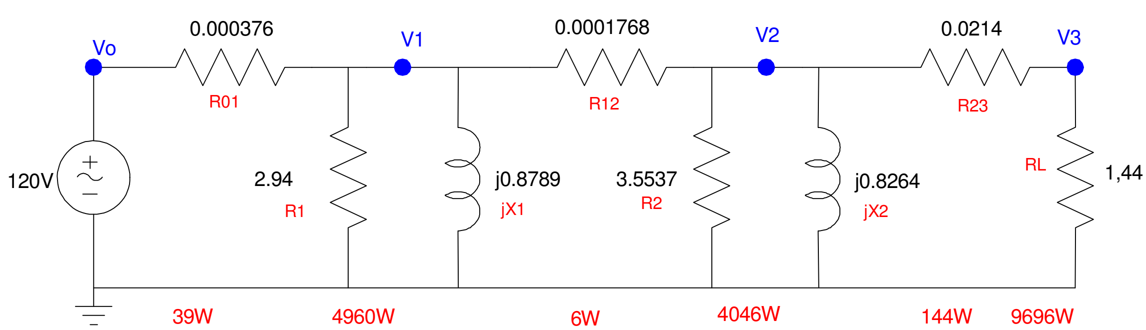
```
V1 = V(1);
V2 = V(2);
V3 = V(3);

P01 = ( abs(V0 - V1) )^2 / R01
P1 = abs(V1)^2 / R1
P12 = ( abs(V1 - V2) )^2 / R12
P2 = abs(V2)^2 / R2
P23 = ( abs(V2 - V3) )^2 / R23
P3 = abs(V3)^2 / R3

eff1 = P3 / (P3 + P1 + P2 + P01 + P12 + P23)

eff2 = P3 / (P3 + P01 + P12 + P23)
```

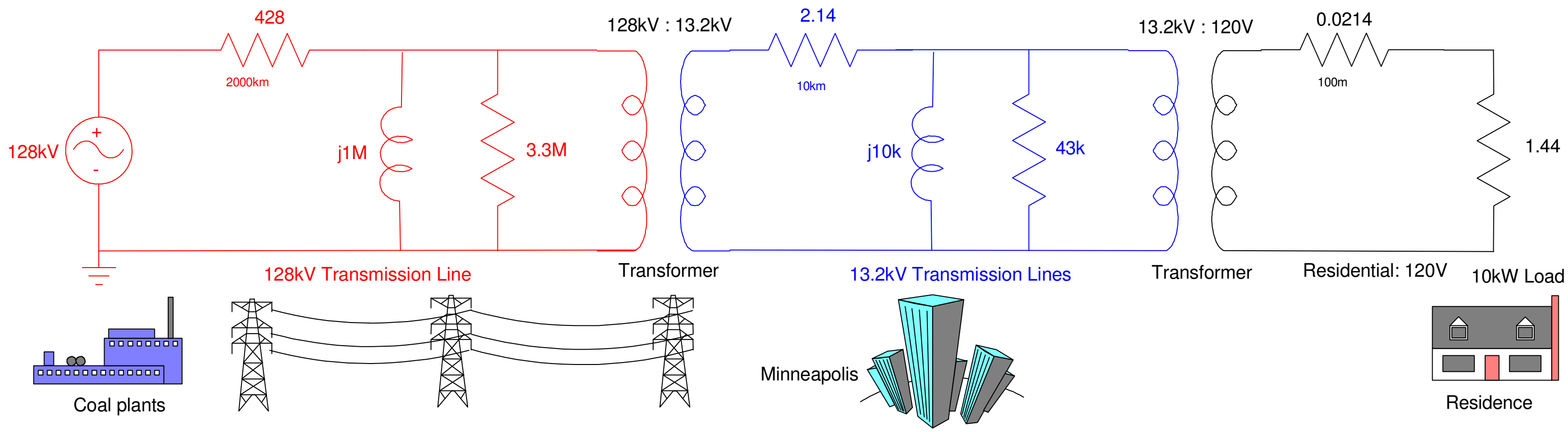
Result

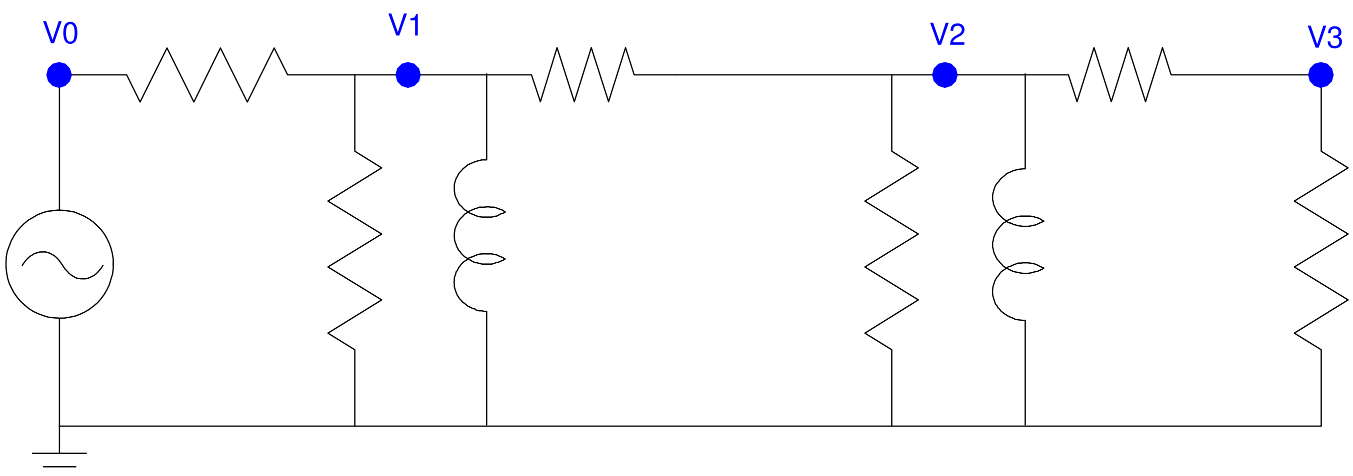
```
P01 =   39.1127
P1 =  4960.0
P12 =    6.0956
P2 =  4046.7
P23 =  144.0991
P3 =  9696.4
```

eff1 =   0.5132   Efficiency including all losses

eff2 =   0.9809   Efficiency ignoring core losses




428
2000km
128kV
+
-
j1M
3.3M
128kV : 13.2kV
2.14
10km
j10k
43k
13.2kV : 120V
0.0214
100m
1.44
128kV Transmission Line
Transformer
13.2kV Transmission Lines
Transformer
Residential: 120V
10kW Load
Coal plants
Minneapolis
Residence


V0
V1
V2
V3