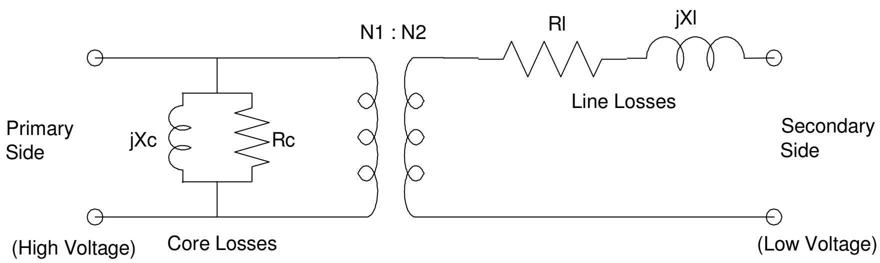
ECE 111: Homework 15

Week #15 - ECE 331 Energy Conversion. Due Tuesday, May 2nd

1) Determine the circuit model for a 13.2kV : 240V transformer is tested with the following test results:



Transformer Model

	V	Power	pf
Open-Circuit Test	V1 = 13.2kV	56 W	0.025
Short-Circuit Test	V2 = 40V	9 W	0.975

Open-Circuit Test:

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

$$56W = 13.2kV \cdot I \cdot 0.025$$

$$I = 0.1697A$$

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

$$Z = 77,785 \angle 88.5675^0$$

Convert to rectangular coordinates

$$Z = 1944.64 + j77,761.40$$

To find Rc and Xc, take the inverse

$$\frac{1}{Z} = \frac{1}{R_c} + \frac{1}{jX_c} = (3.2140e-7) - (j1.2852e-5)$$

$$R_c = \frac{1}{3.2140e-7} = 3.111M\Omega$$

$$jX_c = \frac{1}{-j1.2852e-5} = j77.81k\Omega$$

	V	Power	pf

Open-Circuit Test	V1 = 13.2kV	56 W	0.025
Short-Circuit Test	V2 = 40V	9 W	0.975

Short-Circuit Test

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

$$9W = 40V \cdot I \cdot 0.975$$

$$I = 0.2308A$$

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

$$Z = 173.333\angle 12.83^0$$

Convert to rectangular form

$$Z = 169.00 + j38.5155$$

This is the line model

$$R_L = 169.00\Omega$$

$$jX_L = j38.5155\Omega$$

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

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

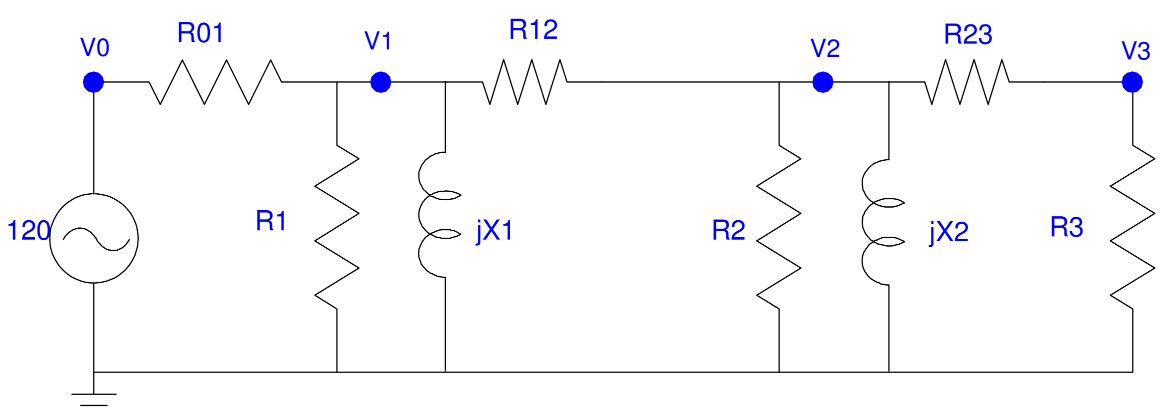
Matlab Code

```
V0 = 138000  * (120/138000)
R01 = 342    * (120/138000)^2
R1 = 3e6     * (120/138000)^2
X1 = j*600e3 * (120/138000)^2
R12 = 2.14   * (120/9600)^2
X2 = j*6e3   * (120/9600)^2
R2 = 20e3    * (120/9600)^2
R23 = 0.01704
R3 = 0.36
```

Results

```
V0 =   120
R01 =  2.5860e-004
R1 =    2.2684
X1 =        0 + 0.4537i
R12 =  3.3438e-004
X2 =        0 + 0.9375i
R2 =    3.1250
R23     0.0170
R3 =    0.3600
```

3) Write the voltage node equations for this circuit (with transformers removed)



4) Determine the voltages at each node

Matlab Code

```
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
```

Result:

```
V0   120.00
V1   119.89 + 0.10i
V2   119.78 + 0.14i
V3   114.36 + 0.14i
```

5) 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

Matlab Code

```
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 =     3.1237e-024
P1  =  6348.0
P12 =   64.1564
P2  =  4599.9
P23 =    0.9387
P3  =  39850
```

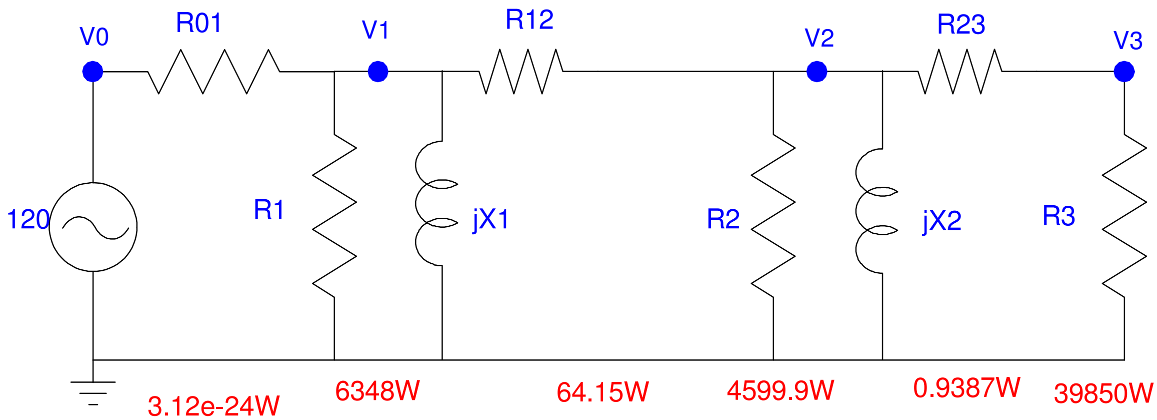
Total Efficiency (including everything)

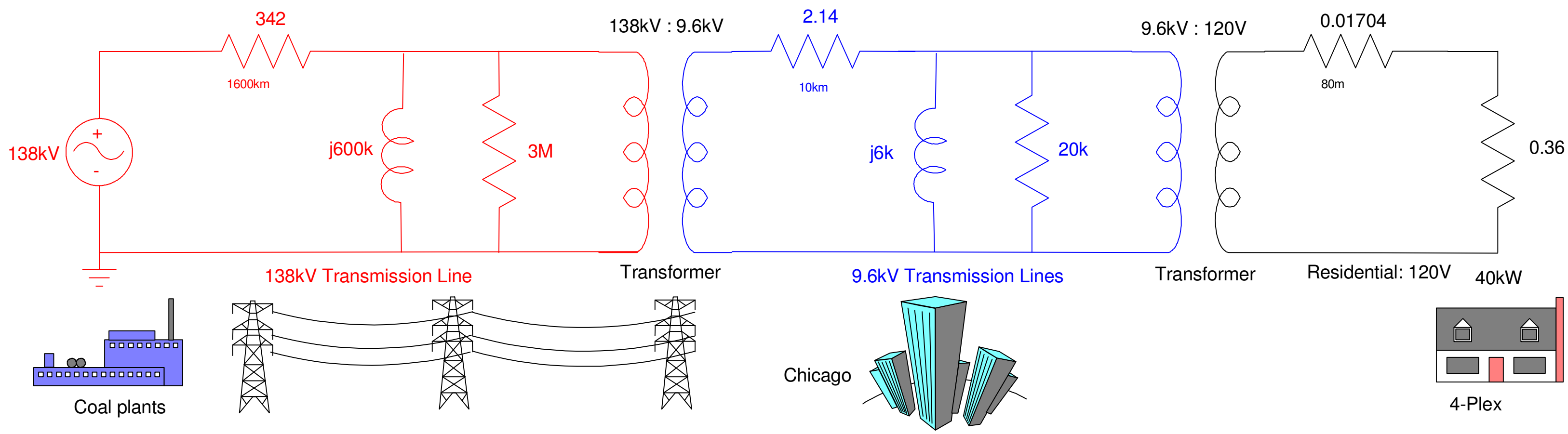
```
eff1 =    0.7835
```

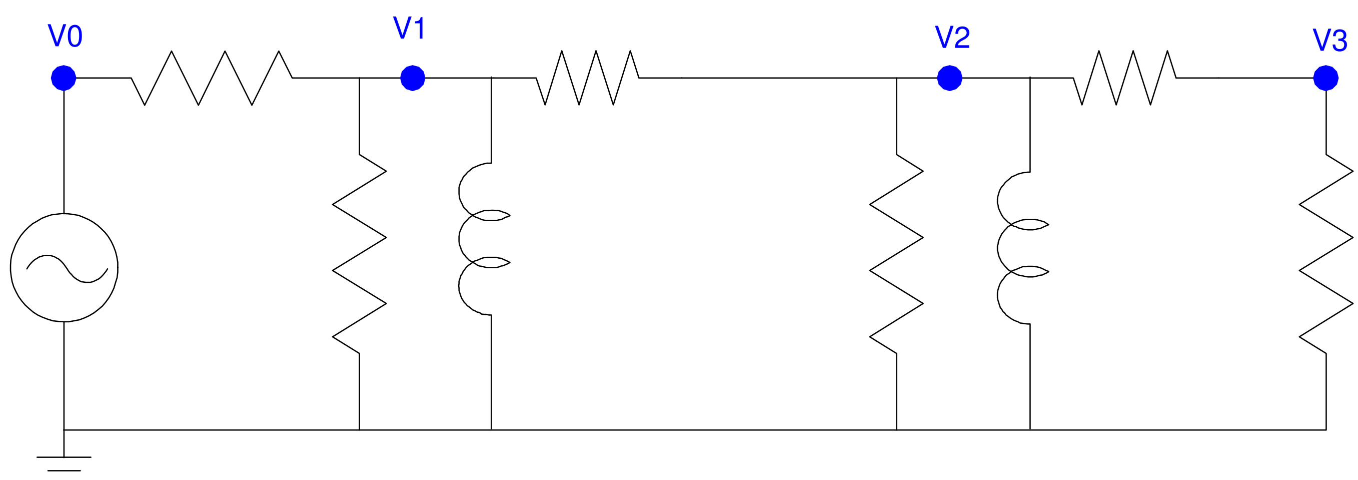
Efficience ignoring core losses

```
eff2 =    0.9984
```

```
P01 =     3.1237e-024
P1  =  6348.0
P12 =   64.1564
P2  =  4599.9
P23 =    0.9387
P3  =  39850
```




342
1600km
138kV
j600k
3M
138kV : 9.6kV
2.14
10km
j6k
20k
9.6kV : 120V
0.01704
80m
0.36
138kV Transmission Line
Transformer
9.6kV Transmission Lines
Transformer
Residential: 120V
40kW
Coal plants
Chicago
4-Plex


V0
V1
V2
V3