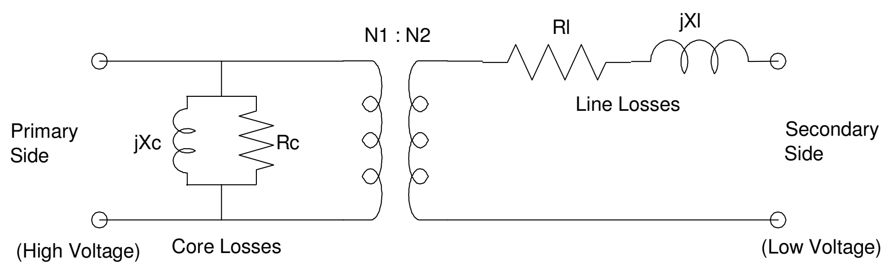
ECE 111: Homework 16

ECE 331 Energy Conversion
Due Monday, December 11th

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	40 W	0.015
Short-Circuit Test	V2 = 40V	12 W	0.985

Open Circuit Test

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

```
>> V = 13.2e3;
>> P = 40;
>> pf = 0.015;
>> I = P / ( V * pf )

I =    0.2020
```

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

$$\cos\theta = pf$$

```
>> q = acos(pf)

q =    1.5558   radians
```

The series model for the core is then:

```
>> Z = V/I * (cos(q) + j*sin(q))

Z =   9.8010e+002 +6.5333e+004i
```

The parallel model for the core is then:

```
>> Rc = 1/real(1/Z)
```

Rc = 4.3560e+006

```
>> Xc = - 1/imag(1/Z)
```

Xc = 6.5347e+004

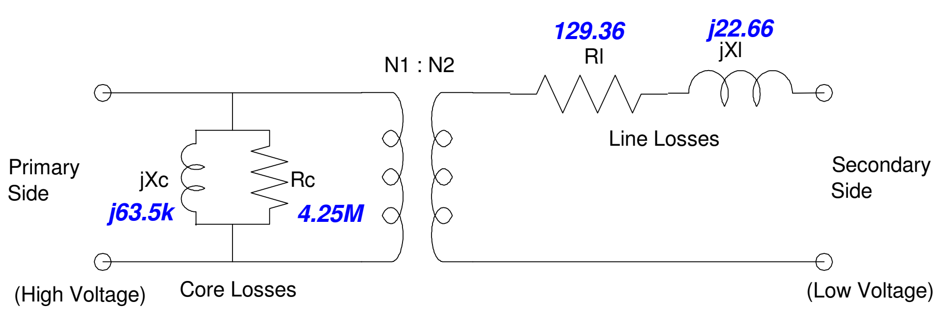
Line Model:

```
>> V = 40;
>> P = 12;
>> pf = 0.985;
>> I = P / ( V * pf )

I =     0.3046

>> q = acos(pf)

q =     0.1734    radians

>> Z = V/I * (cos(q) + j*sin(q))

Z =   1.2936e+002 +2.2662e+001i

>> RL = real(Z)
```

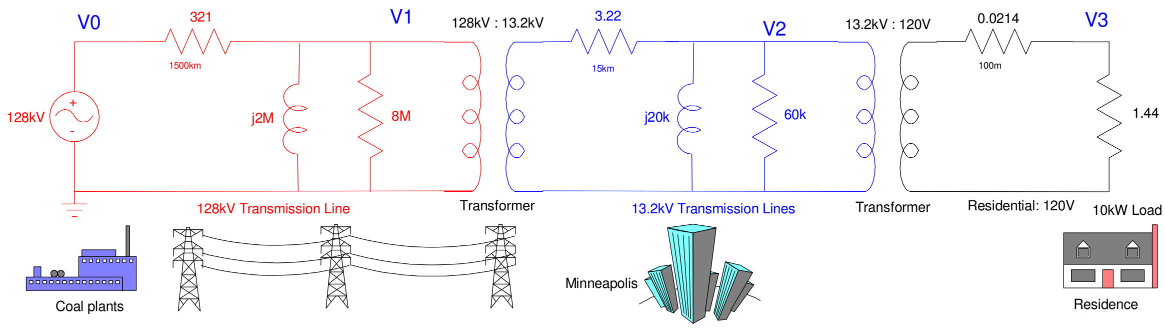
RL = 129.3633

```
>> XL = imag(Z)
```

XL = 22.6621

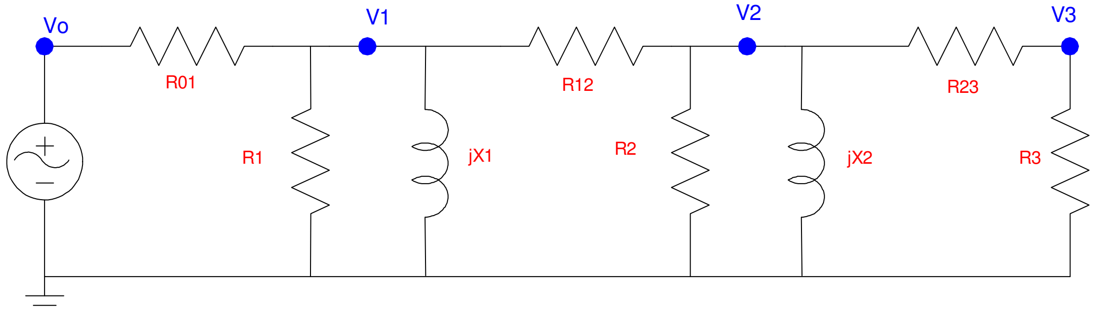


2) Convert the voltages and impeances to the 120V node (right side)




```
>> V0 = 128000 * (120/128000)

V0    120

>> R01 = 321 * (120/128000)^2

R01 =  2.8213e-004

>> R1 = 2e6 * (120/128000)^2

R1 =    1.7578

>> X1 = j*8e6 * (120/128000)^2

X1 =        0 + 7.0313i

>> R12 = 3.22 * (120/13200)^2

R12 =  2.6612e-004

>> R2 = 60e3 * (120/13200)^2

R2 =    4.9587

>> X2 = j*20e3 * (120/13200)^2

X2 =        0 + 1.6529i

>> R23 = 0.0214;
>> R3 = 1.44;
```

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



$$V_0 = 120$$

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

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

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

4) Determine the voltages at each node

Group terms

$$V_0 = 120$$

$$-\left(\frac{1}{R_{01}}\right)V_0 + \left(\frac{1}{R_{01}} + \frac{1}{R_1} + \frac{1}{jX_1} + \frac{1}{R_{12}}\right)V_1 - \left(\frac{1}{R_{12}}\right)V_2 = 0$$

$$-\left(\frac{1}{R_{12}}\right)V_1 + \left(\frac{1}{R_{12}} + \frac{1}{R_2} + \frac{1}{jX_2} + \frac{1}{R_{23}}\right)V_2 - \left(\frac{1}{R_{23}}\right)V_3 = 0$$

$$-\left(\frac{1}{R_{23}}\right)V_2 + \left(\frac{1}{R_{23}} + \frac{1}{R_3}\right)V_3 = 0$$

Place in matrix form

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

Solve in Matlab

```
>> a1 = [1,0,0,0];
>> a2 = [-1/R01,1/R01+1/R1+1/X1+1/R12,-1/R12,0];
>> a3 = [0,-1/R12,1/R12+1/R2+1/X2+1/R23,-1/R23];
>> a4 = [0,0,-1/R23,1/R23+1/R3];
>> A = [a1;a2;a3;a4]

   0.0010                  0                  0                   0
  -3.5445             7.3028 - 0.0001i  -3.7578                   0
        0            -3.7578              3.8047 - 0.0006i  -0.0467
        0                  0            -0.0467              0.0474


>> B = [120;0;0;0]

   120
     0
     0
     0
```

```
>> V = inv(A)*B
```

```
V0   120.00
V1   119.95 + 0.03i
V2   119.92 + 0.04i
V3   118.17 + 0.04i
```

If you prefer polar form:

```
>> abs(V)

  120.0000
  119.9508
  119.9225
  118.1664
```

The voltage at the customer has dropped to 118.16 Volts.

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

Compute the power dissipated in each resistor

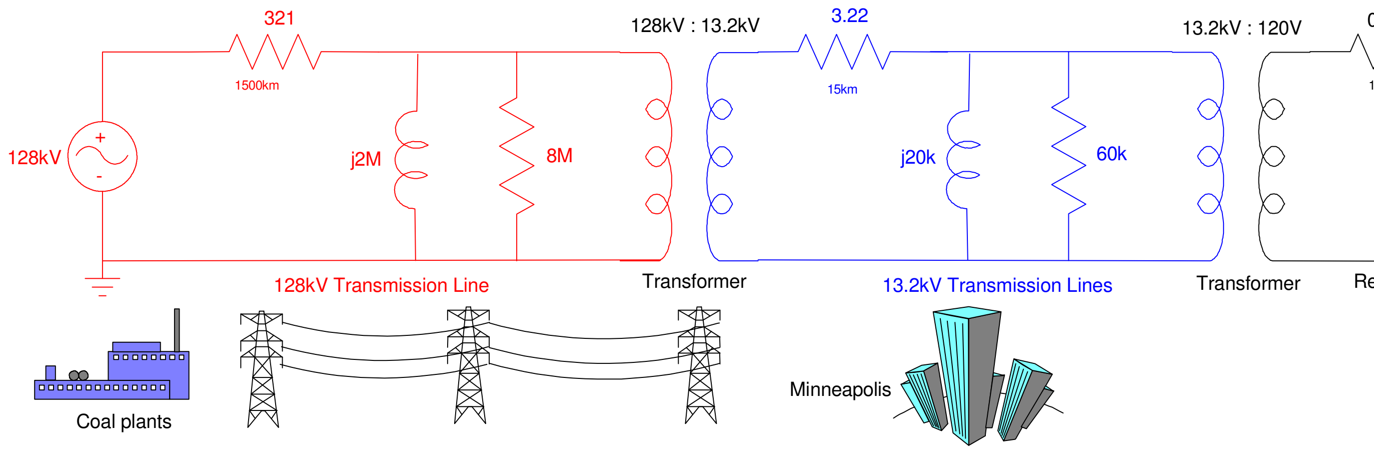
```
>> V0 = V(1);
>> V1 = V(2);
>> V2 = V(3);
>> V3 = V(4);
>> P01 = (abs(V0-V1))^2 / R01

P01 =   10.8551

>> P1 = (abs(V1))^2 / R1

P1 =  8.1853e+003

>> P12 = (abs(V1-V2))^2 / R12

P12 =    4.4047

>> P2 = (abs(V2))^2 / R2

P2 =  2.9002e+003

>> P23 = (abs(V2-V3))^2 / R23

P23 =  144.1043

>> P3 = (abs(V3))^2 / R3

P3 =  9.6967e+003
```

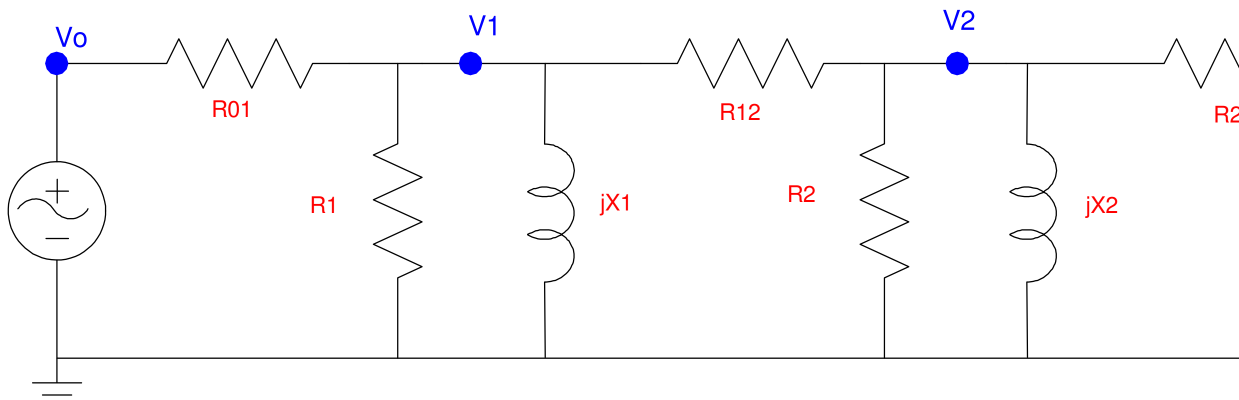
a) The efficency including everything (single customer)

```
>> eff = P3 / (P01 + P12 + P23 + P1 + P2 + P3)

eff =    0.4630
```

b) Efficiency ignoring the core losses (many customers)

```
>> eff = P3 / (P01 + P12 + P23 + P3)

eff =    0.9838

>>
```


321
1500km
128kV
j2M
8M
128kV : 13.2kV
3.22
15km
j20k
60k
13.2kV : 120V
Transformer
128kV Transmission Line
13.2kV Transmission Lines
Transformer
Coal plants
Minneapolis


Vo
V1
V2
R01
R12
R1
jX1
R2
jX2