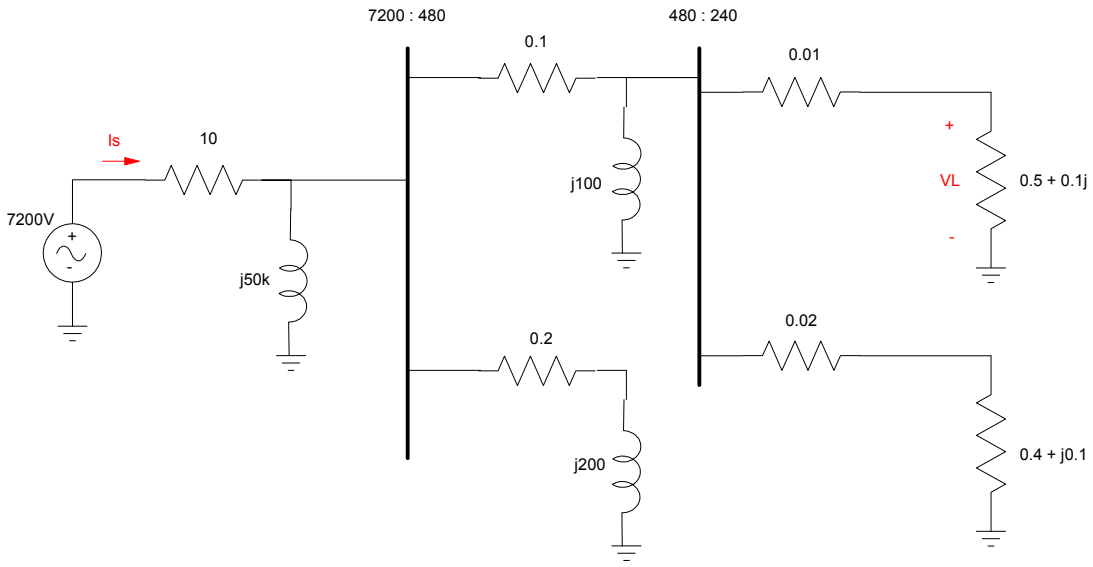
ECE 331 - Homework #6

Per-unit analysis. Life Cycle Costing
Due Monday, March 3, start of class

Per-Unit Analysis: Consider the following utility grid:



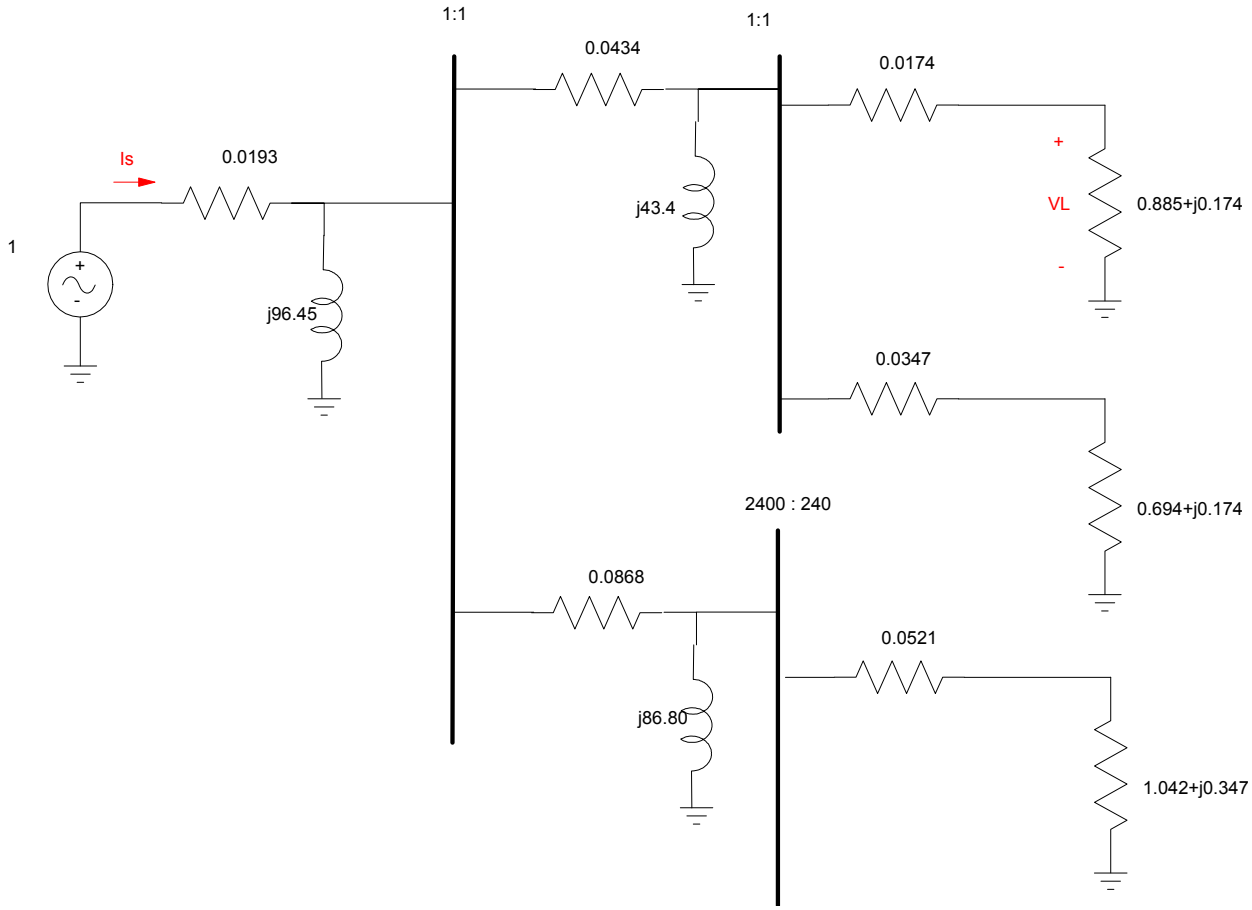
Problem 1:

Vo = 7200V	Vo = 480 V	Vo = 240 V
Po = 100kVA	Po = 100 kVA	Po = 100 kVA
Io = 13.888 A	Io = 208A	Io = 416.666A
Zo = 518.4 Ohms	Zo = 2.304 Ohms	Zo = 0.5760 Ohms

Scale the voltage and impedances by Zo in each region

Problem 2:

Redraw with per-unit values:



Voltage Node Equations

$$\left(\frac{1}{0.0193}+\frac{1}{j96.45}+\frac{1}{0.0434}+\frac{1}{0.0868+j86.8}\right)V_1-\left(\frac{1}{0.0193}\right)1V-\left(\frac{1}{0.0434}\right)V_2=0$$

$$\left(\frac{1}{0.0434}+\frac{1}{j43.4}+\frac{1}{0.0174+0.8681+j0.1736}\right)V_2-\left(\frac{1}{0.0434}\right)V_1=0$$

```
-->a11 = 1/0.0193+1/(j*96.45)+1/0.0434+1/(0.0868+j*86.8)
-->a12 = - 1/0.0434
-->a21 = -1/0.0434
-->a22 = 1/0.0434+1/(j*43.4)+1/(0.0174+0.868+j*0.1736)

-->A = [a11,a12;a21,a22]

    74.854958 - 0.0218888i   - 23.041475
  - 23.041475                  24.129096 - 0.2362909i

-->B = [1/0.0193;0]

    51.813472
    0.
```

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

    0.9802899 + 0.0044019i
    0.9359723 + 0.0133693i
```

Answer in per-units

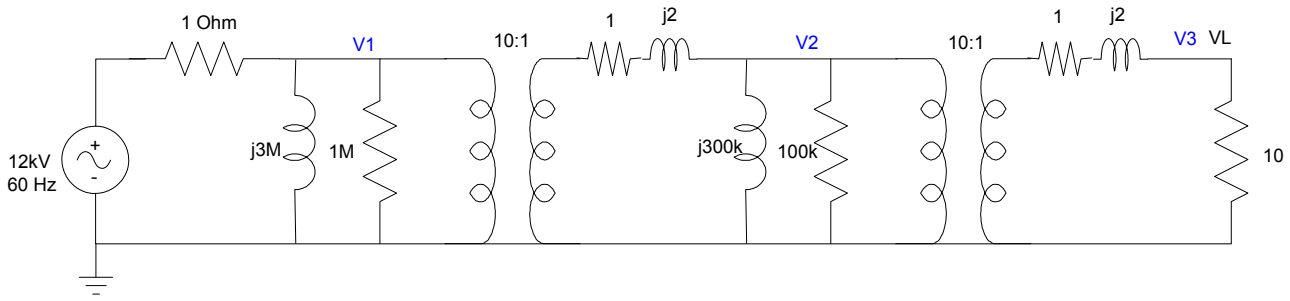
```
-->Is = (1 - V(1)) / 0.0193

    1.0212501 - 0.2280784i

-->VL = (0.8681+j*0.17361)/(0.8681+j*0.17361+0.0174)*V(2)

    0.9182117 + 0.0165887i
```

Answer in Amps and Volts

```
-->Is * 13.8888

    14.183938 - 3.1677348i

-->VL * 240

    220.37081 + 3.9812828i
```

	per-unit	Amps / Volts
Is	$1.04\angle -12.6^0$	$14.59\angle -12.6^0$
VL	$0.918\angle 1^0$	$220\angle 1^0$

Problem 3)



Vo = 12 kV	Vo = 1.2 kV	Vo = 120 V
Po = 100kVA	Po = 100 kVA	Po = 100 kVA
Io = 8.3333 A	Io = 83.333 A	Io = 833.33 A
Zo = 1440 Ohms	Zo = 14.40 Ohms	Zo = 0.1440 Ohms

Voltage Node equations:

$$\left(\frac{1}{0.00088}+\frac{1}{j2631}+\frac{1}{877}+\frac{1}{0.08772+j0.1754}\right)V_1-\left(\frac{1}{0.00088}\right)1\angle 0^0-\left(\frac{1}{0.08772+j0.1754}\right)V_2=0$$

$$\left(\frac{1}{0.08772+j0.1754}+\frac{1}{j26315}+\frac{1}{772}+\frac{1}{8.772+j17.54}\right)V_2-\left(\frac{1}{0.08772+j0.1754}\right)V_1-\left(\frac{1}{8.772+j17.54}\right)V_3=0$$

$$\left(\frac{1}{8.772+j17.54}+\frac{1}{87.72}\right)V_3-\left(\frac{1}{8.772+j17.54}\right)V_2=0$$

Solving in MATLAB (SciLab)

```
-->a11 = 1/0.00088+1/(j*2631)+1/877+1/(0.08772+j*0.1754)
-->a12 = -1/(0.08772+j*0.1754)
-->a13 = 0;

-->a21 = a12
-->a22 = 1/(0.08772+j*0.1754)+1/(j*26315)+1/772+1/(8.772+j*17.54)
-->a23 = -1/(8.772+j*17.54)

-->a31 = a13
-->a32 = a23
-->a33 = 1/(8.772+j*17.54)+1/87.72


-->A = [a11,a12,a13;a21,a22,a23;a31,a32,a33]
-->B = [1/0.00088;0;0]
```

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

    0.9999890 + 0.0000020i
    0.9986673 - 0.0018167i
    0.8785495 - 0.1613514i
```

Answer in per-unit

```
-->Is = (1 - V(1)) / 0.00088

    0.0124492 - 0.0022598i

-->VL = V(3)

    0.8785495 - 0.1613514i
```

Answer in Amps and Volts

```
-->Is * 8.33333

    0.1037430 - 0.0188314i

-->VL * 120

    105.42594 - 19.362168i

-->abs(VL)*120

    107.18918
```

Note: This is the same answer as we got before

Problem 4)

Transformer A is the better investment

	Problem 4: 2.61 % Interest					
	Transformer A			Transformer B		
Year	Cost	Discount	PV	Cost	Discount	PV
0	10,300	1	10,300	600	1	600
1	300	0.97	292.37	600	0.97	584.74
2	300	0.95	284.93	600	0.95	569.86
3	300	0.93	277.68	600	0.93	555.37
4	300	0.9	270.62	600	0.9	541.24
5	300	0.88	263.74	600	0.88	527.48
6	300	0.86	257.03	600	0.86	514.06
7	300	0.83	250.49	600	0.83	500.98
8	300	0.81	244.12	600	0.81	488.24
9	300	0.79	237.91	600	0.79	475.82
10	300	0.77	231.86	600	0.77	463.72
11	300	0.75	225.96	600	0.75	451.92
12	300	0.73	220.21	600	0.73	440.43
13	300	0.72	214.61	600	0.72	429.23
14	300	0.7	209.15	600	0.7	418.31
15	300	0.68	203.83	600	0.68	407.67
16	300	0.66	198.65	600	0.66	397.3
17	300	0.65	193.6	600	0.65	387.19
18	300	0.63	188.67	600	0.63	377.34
19	300	0.61	183.87	600	0.61	367.75
20	0	0.6	0	15,000	0.6	8,959.78
Total			**14,749.32**			**18,458.43**

Problem 5

Transformer B is the better investment

	Problem 5: 11 % Interest					
	Transformer A			Transformer B		
Year	Cost	Discount	PV	Cost	Discount	PV
0	10,300	1	10,300	600	1	600
1	300	0.9	270.27	600	0.9	540.54
2	300	0.81	243.49	600	0.81	486.97
3	300	0.73	219.36	600	0.73	438.71
4	300	0.66	197.62	600	0.66	395.24
5	300	0.59	178.04	600	0.59	356.07
6	300	0.53	160.39	600	0.53	320.78
7	300	0.48	144.5	600	0.48	289
8	300	0.43	130.18	600	0.43	260.36
9	300	0.39	117.28	600	0.39	234.55
10	300	0.35	105.66	600	0.35	211.31
11	300	0.32	95.18	600	0.32	190.37
12	300	0.29	85.75	600	0.29	171.5
13	300	0.26	77.25	600	0.26	154.51
14	300	0.23	69.6	600	0.23	139.2
15	300	0.21	62.7	600	0.21	125.4
16	300	0.19	56.49	600	0.19	112.98
17	300	0.17	50.89	600	0.17	101.78
18	300	0.15	45.85	600	0.15	91.69
19	300	0.14	41.3	600	0.14	82.61
20	0	0.12	0	15,000	0.12	1,860.51
Total			**12,651.79**			**7,164.09**

Problem 6

They're almost the same, but Transformer B is slightly better

	Problem 6: 2.61 % Interest, 9 cent / kWh electricity					
	Transformer A			Transformer B		
Year	Cost	Discount	PV	Cost	Discount	PV
0	10,300	1	10,300	5,600	1	5,600
1	300	0.97	292.37	600	0.97	584.74
2	300	0.95	284.93	600	0.95	569.86
3	300	0.93	277.68	600	0.93	555.37
4	300	0.9	270.62	600	0.9	541.24
5	300	0.88	263.74	600	0.88	527.48
6	300	0.86	257.03	600	0.86	514.06
7	300	0.83	250.49	600	0.83	500.98
8	300	0.81	244.12	600	0.81	488.24
9	300	0.79	237.91	600	0.79	475.82
10	300	0.77	231.86	600	0.77	463.72
11	300	0.75	225.96	600	0.75	451.92
12	300	0.73	220.21	600	0.73	440.43
13	300	0.72	214.61	600	0.72	429.23
14	300	0.7	209.15	600	0.7	418.31
15	300	0.68	203.83	600	0.68	407.67
16	300	0.66	198.65	600	0.66	397.3
17	300	0.65	193.6	600	0.65	387.19
18	300	0.63	188.67	600	0.63	377.34
19	300	0.61	183.87	600	0.61	367.75
20	0	0.6	0	0	0.6	0
Total			14,749.32			14,498.65

Problem 7

Transformer A is better

	Problem 7: 2.61 % Interest, 18 cent / kWh electricity					
	Transformer A			Transformer B		
Year	Cost	Discount	PV	Cost	Discount	PV
0	10,600	1	10,600	6,200	1	6,200
1	600	0.97	584.74	1,200	0.97	1,169.48
2	600	0.95	569.86	1,200	0.95	1,139.73
3	600	0.93	555.37	1,200	0.93	1,110.74
4	600	0.9	541.24	1,200	0.9	1,082.49
5	600	0.88	527.48	1,200	0.88	1,054.95
6	600	0.86	514.06	1,200	0.86	1,028.12
7	600	0.83	500.98	1,200	0.83	1,001.97
8	600	0.81	488.24	1,200	0.81	976.48
9	600	0.79	475.82	1,200	0.79	951.64
10	600	0.77	463.72	1,200	0.77	927.44
11	600	0.75	451.92	1,200	0.75	903.85
12	600	0.73	440.43	1,200	0.73	880.86
13	600	0.72	429.23	1,200	0.72	858.45
14	600	0.7	418.31	1,200	0.7	836.61
15	600	0.68	407.67	1,200	0.68	815.33
16	600	0.66	397.3	1,200	0.66	794.6
17	600	0.65	387.19	1,200	0.65	774.38
18	600	0.63	377.34	1,200	0.63	754.69
19	600	0.61	367.75	1,200	0.61	735.49
20	0	0.6	0	0	0.6	0
Total			**19,498.65**			**23,997.29**