

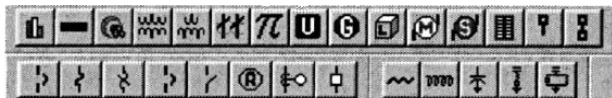
# ECE 470 POWER SYSTEMS I

## Lab # 7 - Load Flow Analysis

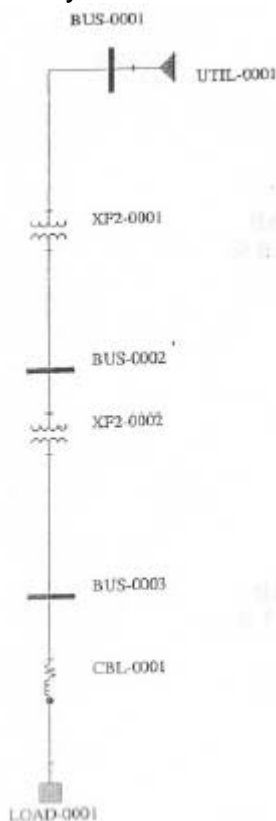
This Lab will require the Load Flow software in the **SKM Power Tools** package in the Power Lab. To run the software log on to the computer using your username and password. Then click on the **PTW32** icon.

In **Part 1** of the lab you will run a simple tutorial to get used to entering data. In **Part 2** you will perform an actual Load Flow.

Go to **Project** and click **Close**, then go back to **Project** and click **New**. In the Project Name Box type **Tutor40**. A new One-Line Diagram and Component Editor dialog box will appear. You will build the system using the one-line diagram by selecting components from the toolbar shown below.



When adding a component use the "push-pin" behavior of the mouse (not drag-drop) to place the component. Do this to build the system shown below. Remember to periodically hit the "save" icon.



When all components have been added to the one-line diagram, start entering the component values.

Go to the Component Editor dialog box and click on the **All** tab to display all components. Enter the nominal voltages at busses 1, 2 and 3. Bus 4 is connected to bus 3 by a cable, so bus 4 automatically has the same nominal voltage as bus 3.

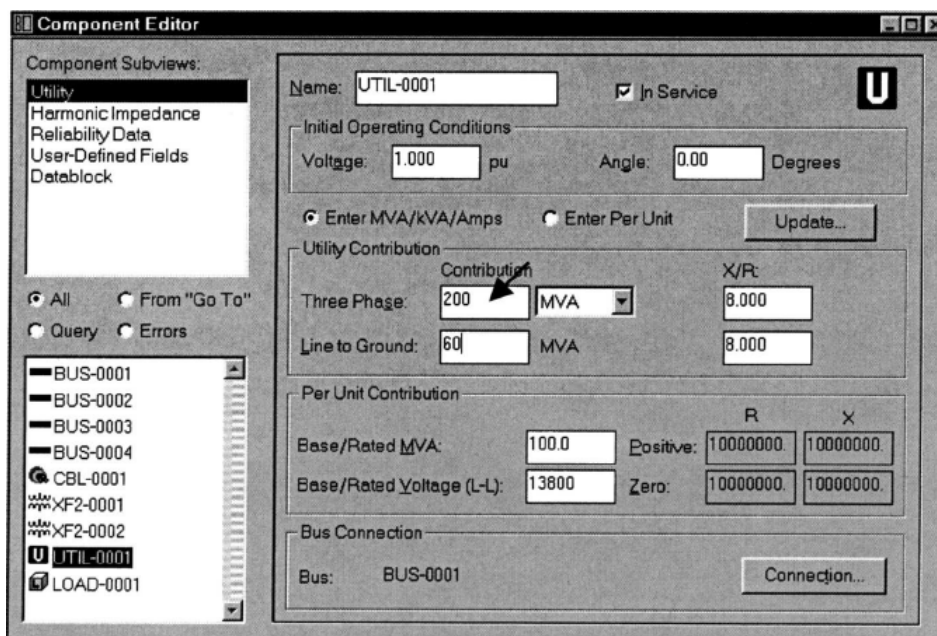
Go to cable CBL-0001 and you can either enter impedance values or go to the library and have standard values entered. Click on the library button and select Copper Magnetic THHN 60 Hz 3 Wire+Grnd, then click the **Apply** and **Close** buttons. Now select "2" in the "Cable Size" field and enter 100 in the "Length" field.

Select Transformer XF2-0001 and click on the library button. Select the Oil Air 60 Hz entry, then click the **Apply** and **Close** buttons. Select 1000 in the nominal kVA field.

Do the same for Transformer XF2-0002 but choose a Dry Type and enter 500 kVA.

Select LOAD-0001 and enter 95 Amps and 0.8 Lag.

Select Utility UTIL-0001 and enter the data shown below.



**Component Editor**

Component Subviews:  
Utility  
Harmonic Impedance  
Reliability Data  
User-Defined Fields  
Datablock

All  From "Go To"  
 Query  Errors

Component List:  
BUS-0001  
BUS-0002  
BUS-0003  
BUS-0004  
CBL-0001  
XF2-0001  
XF2-0002  
**UTIL-0001**  
LOAD-0001

Name: UTIL-0001  In Service

Initial Operating Conditions  
Voltage: 1.000 pu Angle: 0.00 Degrees

Enter MVA/kVA/Amps  Enter Per Unit

Utility Contribution

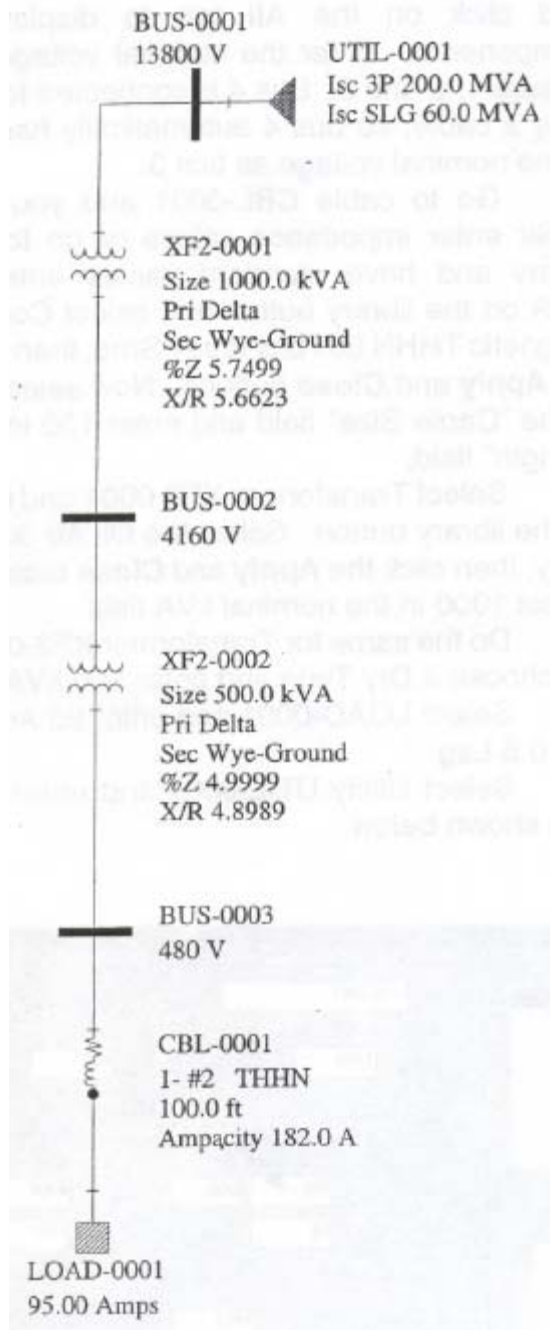
Contribution		X/R:
Three Phase:	200 MVA	8.000
Line to Ground:	60 MVA	8.000

Per Unit Contribution

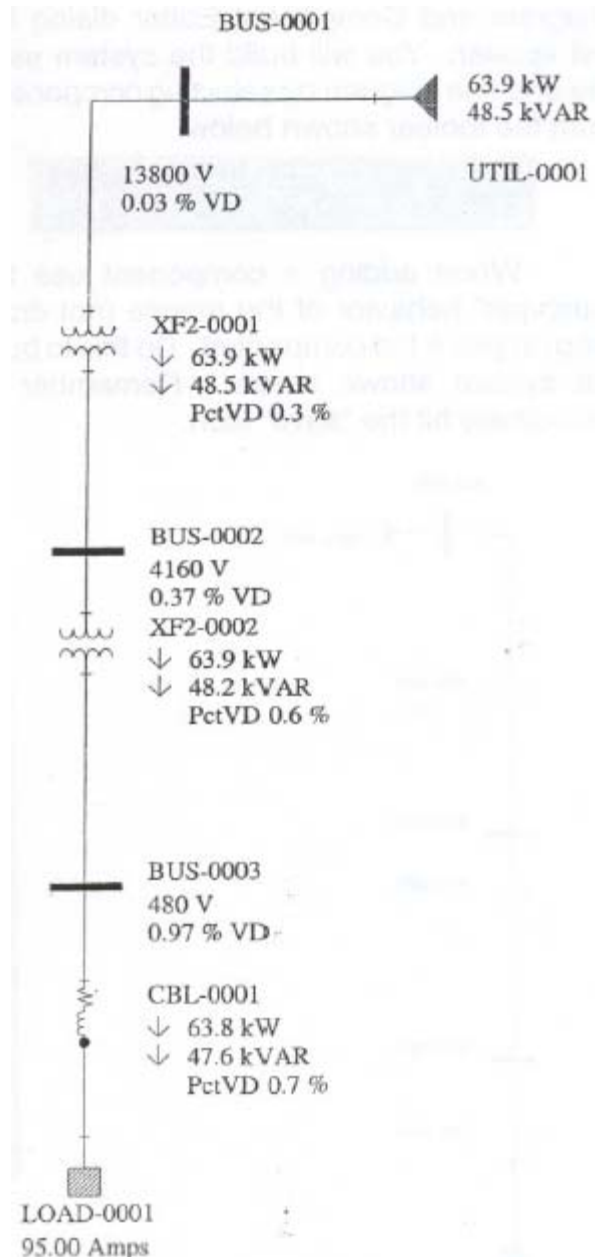
Base/Rated MVA:	R		X
	Positive:	Zero:	
100.0	10000000	10000000	10000000
Base/Rated Voltage (L-L): 13800	Zero:	10000000	10000000

Bus Connection  
Bus: BUS-0001

Use the datablock display to update the diagram. Click on the one-line diagram then select the **Run>Datablock Format** option. Select **Input Data** then click the **Apply** and **Close** buttons. The one-line diagram will display the input data next to each component.



You are now ready to run the Load Flow Study for this simple system. Click on the one-line diagram then select the **Run>Balanced System Studies** option. Check the **Load Flow** box and click **Run**. The **Study Messages** window will appear and when the study is complete, click **Close**. To review the results, select the **Document>Report** option and open Lf.rpt and the results will be displayed in tabular form. A summary of the results can be displayed on the one-line diagram by selecting **Run>Datablock Format** then selecting "Load Flow Power Data" then click the **Apply** and **Close** buttons. The one-line diagram will display a summary of the load flow data next to each component.



## Part 2 - Load Flow Study

The load flow study is taken from chapter 8 of "Elements of Power System Analysis" by W.D. Stevenson. The data is shown below for the system whose base values are 100 MVA and 138 kV.

The Charging MVAR in Table 1 accounts for the distributed capacitance of the transmission lines (whose SKM icon looks like a transmission tower). The data input to SKM asks for this in ohms and is converted as follows:

4.1 - 4645  $\Omega$ , 3.1 - 6143  $\Omega$ , 8.2 - 2322  $\Omega$ ,  
5.1 - 3734  $\Omega$ , 6.1 - 3122  $\Omega$ .

The loads are presented in Table 2 as  $P + jQ$ , but SKM wants them as  $P$  and pf, so you have to work out the pf.

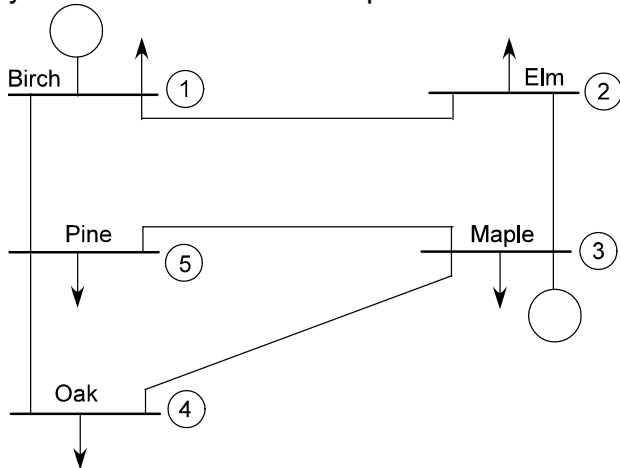


Table 1

Line bus to bus	R $\Omega$	X $\Omega$	Charging MVAR
1 - 2	8	32	4.1
1 - 5	6	24	3.1
2 - 3	6	24	3.1
3 - 4	16	64	8.2
3 - 5	10	40	5.1
4 - 5	12	48	6.1

Table 2

Bus	Generation		Load		V, per unit	Remarks
	P, MW	Q, Mvar	P, MW	Q, Mvar		
1	.....	.....	65	30	1.04 $\angle 0^\circ$	Swing bus
2	0	0	115	60	1.00 $\angle 0^\circ$	Load bus (inductive)
3	180	.....	70	40	1.02 $\angle 0^\circ$	Voltage magnitude constant
4	0	0	70	30	1.00 $\angle 0^\circ$	Load bus (inductive)
5	0	0	85	40	1.00 $\angle 0^\circ$	Load bus (inductive)

Each generator needs to have its rating input, use 500 MVA with a nominal pf of 0.9 lag. Additionally, generator 2 needs to have its MVAR limits input, use  $\pm 500$  MVAR but note that this has to be input as kVAR. Voltages are asked for in volts not kV. We do not want to include the voltage drop inside the generators, so go to ANSI Contribution and reduce the X" values from 0.15 to 0.001 pu. You are now ready to run the load flow.

The converged load flow is shown below in Table 3 and you should check your results against this. Use your results to determine the total system losses.

Table 3

REPORT OF POWER FLOW CALCULATIONS FOR AREA 1, BUS DATA							
BUS	NAME	VOLTS	ANGLE	X-GENERATION MW	X-MVAR	X-LOAD MW	X-LOAD MVAR
1	BIRCH	1.040	0.0	234.7	100.1	65.0	30.0
2	ELM	0.961	-6.3	0.0	0.0	115.0	60.0
3	MAPLE	1.020	-3.7	180.0	110.3R	70.0	40.0
4	OAK	0.920	-10.9	0.0	0.0	70.0	30.0
5	PINE	0.968	-6.2	0.0	0.0	85.0	40.0
AREA TOTALS				414.7	210.4	405.0	200.0

It can be seen that the voltage at bus 4 is 0.92 pu and is unacceptable for practical operation. Convert this to a PV bus with a specified voltage magnitude of 0.95 pu and re-run the study. Specify the MVAR rating (at 138 kV) of the capacitor bank needed for this correction. If the capacitors cost \$50/kVAR to purchase and install what would be the total cost. If this money is borrowed at 3%, how long will the reduction in losses take to pay for the bank? Assume the cost of losses is \$50/MWh.

An alternative to installing a capacitor bank is to build another line. Study the effect of adding an identical line in parallel with line 4 from bus 3 to bus 4. What will be the voltage at bus 4? What will be the system losses? If the line costs 10M\$ to build and this money is borrowed at 3%, how long will the reduction in losses take to pay for the line?