ECONOMIC POWER FACTOR DETERMINATION OF ELECTRIC POWER SYSTEMS

by

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I. INTRODUCTION

Increased penetration of refrigerators, air conditioners, and other motor operated appliances, which are inductive loads, has resulted in a decrease in electric utility load power factor. Lower power factors allow lesser real power to be transmitted over transmission lines because of kilovoltamperes limitations. Higher current on the lines may result in excessive voltage drop and thus voltages at substation buses may have unacceptable values. Hence, on substations, especially those operating at low power factors, the voltage drop considerations frequently dictate amount of power which can be distributed[2]. Furthermore, heating of transformers limit their capacity and losses on the lines determine the required wire sizes. In general, increased current with low power factor increases the required investment.

Overall improvements in the electric power system operation will be achieved if means are introduced of reducing the system inductive reactance or phase angle between load current and voltage, consequently, supplying the power system with the reactive power needed. The required reactive power for an efficient electric system operation can be supplied by the source generators, but there are at least two disadvantages to the generation of reactive power at the source: 1. source generators usually have limitations in terms of the maximum and minimum reactive power that can be generated, and 2. larger sizes of generators, transmission lines, and transformers are needed to handle the increase in reactive power generation and transmission, which is economically unpreferrable.

Compensation of the inductance of transmission and distribution lines with series capacitance has very limited benefits. The most common approach is to install synchronous condensers or static capacitors in shunt at different points in the power system[2,5]. Whether this added investment is justified or not depends almost entirely on economic comparisons. Cost must be compared with that for adding more lines and transformer capacity. Development of lower cost static capacitors has made their use economically feasible. Generally, they are installed either at transmission buses, substation buses, or on feeders. Also, an important feature of capacitor banks is their transportability. The value of this equipment is demonstrated when it becomes necessary to relocate them as needed by the operating requirements of the electric power system. Shunt capacitor units draw a component of current over the line that leads voltage, and upon adding it to the component that is lagging behind, a resultant is obtained which will be more nearly in phase with the voltage[2,5].

Shunt capacitors applied on the load end of electric power system supplying a lagging power factor load have several effects[7]:

1. Decreases lagging part of power system current.
2. Improves load voltage.
3. Improves voltage regulation if switched capacitor banks are efficiently operated.
4. Decreases I^2R loss in the entire power system, which results from current reduction.
5. Decreases I^2X loss in the entire power system, which results from current reduction.
6. Improves source generators power factor.
7. Reduces loading of generators and power systems kVA load in order to relax an overloaded case or releases generation and transmission capacity for future expansion.
8. By decreasing source generators kVA loading extra active power load may be added at the source generators if turbine capacity is available.
9. Decreases kVA power demand if power is bought. In some conditions, improving the power factor to 100% is optimal.
10. Decreases power system apparatus investment per kilowatt of load supplied.

Since electric power losses are of great interest to power engineers and planners of an economic electric power system, and due to the increasing cost of fuel and installation of electric power plant, electric utility companies gain if energy losses can be decreased, and new plant construction is postponed.

Some of these goals may be met partially through the application of shunt capacitor banks.

Hopkins has suggested a method to determine the benefits of installation of shunt capacitors in electric power systems[4]. According to him, the items which are considered important in attribution to the economic benefits of installing shunt capacitors on electric power system load buses are due to release of generation capacity, transmission capacity, and reduction in energy losses. He added that applications based on optimizing these three benefits against the cost of shunt capacitor banks will give a solution which is very nearly optimum.

In this report, these three effects are considered in arriving at economic applications of shunt capacitors. Addition of shunt capacitors only at load buses will be considered. Load flow analysis is done for complete electric power systems that include generators, transformers, transmission lines, and substation buses to furnish optimal benefits and ratings of shunt capacitor banks needed to compensate for inductive substation buses. Load flow algorithm is created using Stott's decoupled method, which is used because of its fast convergence [6]. Economic power factors of several electric power systems are investigated using a computerized method based on Hopkins discussion.

II. METHODOLOGY

As stated earlier in this report the largest possible economic benefits in most cases are due to reductions in kW demand, kVA flow, and energy losses. The important aspect of the following procedure is finding the equations to account for total benefits and costs.

1. Benefits and Costs:

Benefits and costs can be categorized explicitly as follows[4]:

a. Demand Reduction:

The reduction in current magnitude in the system due to addition of shunt capacitors results in lower resistive losses. This in turn means that source generators produce lesser power in order to supply the same amount of power to the loads. This benefit is measured in terms of generation capacity released.

$$DkW \times RF \times \$/kW \times FCR = \$/Yr$$

where DkW = Reduction in generation from load flow .

RF = Responsibility factor, a correction factor.

$/kW = Cost of peaking generation.

FCR = Fixed charge rate.

$/Yr = Anual benefits or costs, whichever applies.

b. Energy Loss Reduction:

As seen earlier that addition of shunt capacitor units results in reduction of losses. This reduction has an added benefit in terms of energy savings. The reduction of energy loss is determined by calculating loss reduction in each line section, then summing them for all line sections.

$$DkW \times Hr/Yr \times LsF \times \$/kWh = \$/Yr$$

where Hr/Yr = Hours per year.

LsF = Loss factor, average power loss divided by load power loss at system peak over a specific time interval.

\$/kWh = Cost of energy.

c. Transmission Capacity Released:

Addition of shunt capacitor banks at load buses results in reduction of current magnitude on the transmission lines, which in turn reduces the kVA flow through the transmission lines. Thus, it is possible to transmit more power over the transmission lines at higher power factors. The benefits of extra transmission capacity available are measured in terms of released capacity. Transmission capacity released in per unit is the difference between apparent power in per unit before and after shunt capacitor banks are added.

DkVA X $/kVA X FCR = $/Yr

where DkVA = Reduction in kVA flows from load flow.

$/kVA = Cost of transmission equipment.

d. Capacitor Costs:

Capacitor costs are the cost of the required shunt capacitor banks and their installation.

DkVAR X $/kVAR X FCR = $/Yr

where DkVAR = Capacitor additions

$/kVAR = Cost of capacitors

Thus, total benefits due to installing shunt capacitors are:

Total benefits = benefits due to demand reduction +

benefits due to energy usage reduction +

benefits due to transmission capacity released.

Total costs = cost of capacitors added at the load buses.

Savings = total benefits - total costs.

2. Computer Program:

The computer program to determine the above mentioned quantities is coded in "C" language (Appendix B.) and executed on VAX 750.

The method to determine the most economic power factor proceeds as follows:

First, a base case load flow is run for the given system. Then, shunt capacitors are installed on every substation bus in order to correct the load power factor to 90% at those buses, if the power factor is less than 90%. Nothing is done for the buses whose power factor is higher than 90%. In the next step, load flow program is run to obtain and store total system kVA, total kW losses (transmission line losses), and capacitor ratings in kVARs. Then, capacitors are installed on every distribution substation load to improve the power factor to 91%, and again load flow run is required to record the above mentioned totals. If any bus has power factor higher than 91% then nothing is done for that bus. This procedure is repeated, and the power factor is increased each time by 1.0%, until the power factor equals unity. Then, total costs and benefits are determined for each step of power factor correction and the incremental benefits and costs of improving the power factor by an additional 1.0% are obtained. The economic power factor for a given electric power system is reached when incremental benefits and costs are equal.

III. SIMULATION AND RESULTS

Cost data that will be used to illustrate the determination of economic power factors for electric power systems are[4]:

FCR = 20.0%

Hr/Yr = 8760.0Hrs/Yr

LsF = 14.0%

RF = 1.0

\$/kVA = \$24.0/kVA

\$/kVAR = \$4.5/kVAR

\$/kW = \$200.0/kW

\$/kWh = \$0.025/kWh

To apply the method of determining economic power factors of electric power systems, the following systems are simulated since a solution to the basic run is available for most of them in order to validate the computer program code.

The electric power systems reactances are on a 100 MVA , 132 kV base.

1. Figure 1 shows a power system that will be investigated[1]. Per unit line impedances, and per unit values of real power (P), reactive power (Q), voltage magnitude (V), and voltage angle (θ) at each bus for the system are given in Table 1. The question mark (?) entry indicates an unknown quantity.

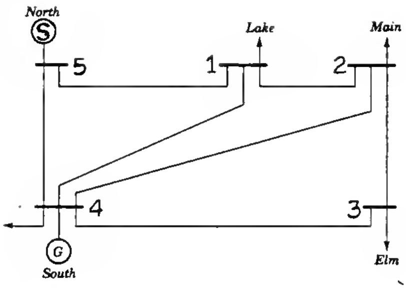

Figure 1: Power System # 1.

From-To	Series Impedance (p.u.)	Shunt Admittance (p.u.)
5-4	0.02 + j0.06	j0.03
5-1	0.08 + j0.24	j0.025
4-1	0.06 + j0.18	j0.02
4-2	0.06 + j0.18	j0.02
4-3	0.04 + j0.12	j0.015
1-2	0.01 + j0.03	j0.01
2-3	0.08 + j0.24	j0.025

No.	Bus Type	Voltage		Generator		Load	
		V(p.u.)	θ(deg.)	P(p.u.)	Q(p.u.)	P(p.u.)	Q(p.u.)
1	L	?	?	0.0	0.0	0.45	0.15
2	L	?	?	0.0	0.0	0.40	0.05
3	L	?	?	0.0	0.0	0.60	0.10
4	G	1.0	?	0.4	?	0.20	0.10
5	S	1.06	0.0	?	?	0.0	0.0

Table 1: Data for Power System # 1.

Appendix A.1 contains the output of load flow program for the original power factor, and the gradually corrected power factor until unity is reached.

Table 2 shows benefits of installing capacitors due to demand and energy reductions, and transmission capacity released. Table 2 also contains capacitor installation cost, and net savings. First column contains an index representing every consecutive power factor increment, and the entries in that row are incremental values compared to the previous values. Savings in p.u. are obtained by dividing the actual savings by the absolute savings determined in the first step of a power factor correction. Conversion to p.u. is done for the ease of plotting.

Plot of savings in p.u. v.s. power factor is shown in Figure 2. From Table 2 and Figure 2, savings are not seen when shunt capacitors are added, therefore the economic power factor is the original one, which is 94.9%.

	P.F. %	Reductions ($) Demand	Energy	Capacity	Benefits ($)	Capacitor costs ($)	Savings (p.u.)
1	95.0	64.9	49.7	-120.9	-6.3	188.3	-1.0
2	96.0	487.9	374.0	-1103.1	-241.2	1499.2	-8.94
3	97.0	482.0	369.5	-1510.3	-658.9	1662.2	-11.93
4	98.0	481.6	369.1	-2118.7	-1268.0	1926.4	-16.42
5	99.0	887.2	680.0	-1176.2	391.1	3758.4	-17.31
6	100.0	1343.5	1029.8	-3438.3	-1065.0	17965.5	-97.78

Table 2: Benefits, Costs & Savings of System # 1.

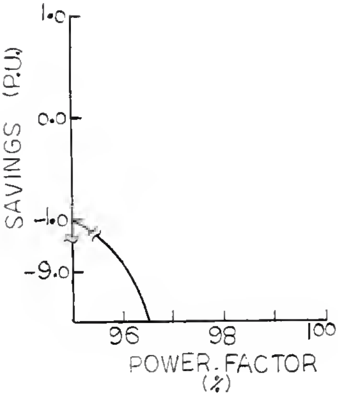

Figure 2: Savings v.s. Power Factor for System # 1.

Note that bus 1 is the only bus where power factor is corrected because the other load buses already have a power factor of 99%. It was found that the kVA flow decreased on the lines from 4 to 3, 5 to 4, and 5 to 1 and increased on the lines from 4 to 1, 4 to 2, 1 to 2 , and 2 to 3. Thus it appears that the load on bus 3 is getting power through a longer way instead of getting it directly. Thus, an increase in total kVA flow is seen, which is dominating the results.

2. The power system that will be considered next is shown in Fig. 3[5]. P.U. Line impedances and P.U. values of real power (P), reactive power (Q), voltage magnitude (V), and voltage phase (θ) at each bus are given in Table 3.

From-To	Series Impedance (p.u.)	Shunt Admittance (p.u.)
5-1	0.042 + j0.168	j0.041
5-3	0.031 + j0.126	j0.031
1-4	0.031 + j0.126	j0.031
4-2	0.084 + j0.336	j0.082
4-3	0.053 + j0.210	j0.051
2-3	0.063 + j0.252	j0.061

No.	Bus Type	Voltage		Generator		Load	
		V(p.u.)	θ(deg.)	P(p.u.)	Q(p.u.)	P(p.u.)	Q(p.u.)
1	L	?	?	0.0	0.0	1.15	0.6
2	L	?	?	0.0	0.0	0.7	0.3
3	L	?	?	0.0	0.0	0.85	0.4
4	G	1.02	?	1.8	?	0.7	0.4
5	S	1.04	0.0	?	?	0.65	0.3

Table 3: Data for Power System # 2.

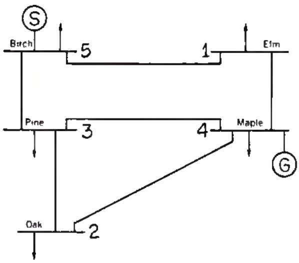

Figure 3: Power System # 2.

Load flow output for the system of Figure 3 is shown in Appendix A.9. Benefits, capacitor costs, and savings are shown in Table 4. A plot of savings in per unit v.s. power factor can be seen in Figure 4. The costs and benefits are equal at the economic power factor which is found to be 99.25%.

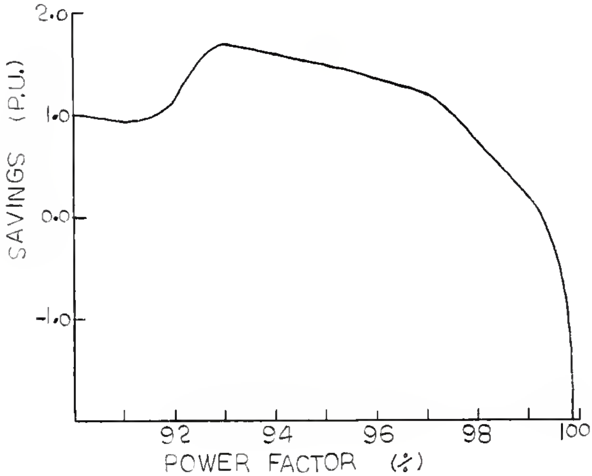

Figure 4: Savings v.s. Power Factor for System # 2.

	P.F. %	Reductions ($) Demand	Energy	Capacity	Benefits ($)	Capacitor costs ($)	Savings (p.u.)
1	90.0	4445.4	3407.4	10902.8	18755.6	3872.7	1.0
2	91.0	4319.9	3311.2	10378.3	18009.5	4116.9	0.93
3	92.0	5509.4	4222.9	13000.4	22732.7	5492.9	1.16
4	93.0	8089.5	6200.6	18627.0	32917.1	7477.8	1.71
5	94.0	7672.7	5881.1	18131.3	31685.1	7842.5	1.6
6	95.0	7263.8	5567.7	17633.5	30465.0	8327.0	1.49
7	96.0	6855.9	5255.1	17122.7	29233.7	8995.2	1.36
8	97.0	6436.8	4933.8	16569.9	27940.5	9973.5	1.21
9	98.0	5980.4	4584.0	12079.0	22644.2	11558.3	0.74
10	99.0	5407.5	4144.8	7845.7	17398.0	14717.6	0.18
11	100.0	3576.7	2741.5	-16979.2	-10661.0	34625.6	-3.04

Table 4: Benefits, Costs & Savings of System # 2.

3. In Figure 5, the desired power system is shown [3]. Values of real power (P), reactive power (Q), voltage magnitude (V), voltage angle (θ) at each bus, and line impedances are given in Table 5.

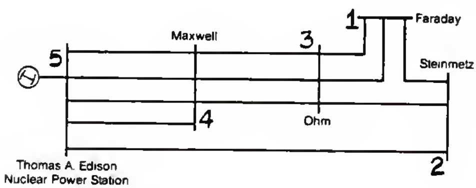

Figure 5: Power System # 3.

From-To	Series Impedance (p.u.)	Shunt Admittance (p.u.)
5-4	j0.005	j0.05
4-3	j0.010	j0.06
3-1	0.0005 + j0.010	j0.01
5-2	j0.090	j0.10
1-2	0.0050 + j0.010	j0.001

No.	Bus Type	Voltage		Generator		Load	
		V(p.u.)	Θ(deg.)	P(p.u.)	Q(p.u.)	P(p.u.)	Q(p.u.)
1	L	?	?	0.0	0.0	-2.52	-1.2205
2	L	?	?	0.0	0.0	1.0	0.05
3	L	?	?	0.0	0.0	2.2	0.7
4	L	?	?	0.0	0.0	5.0	3.0
5	S	1.0	0.0	?	?	0.0	0.0

Table 5: Data for Power System # 3.

Appendix A.22 contains load flow output for the above system. The economic power factor of the electric power system shown in Figure 5 can be determined from Table 6, which contains total benefits, capacitor installation costs, and savings, and Figure 6, which shows a graph of per unit savings v.s. power factor.

From Figure 6, it can be concluded that the economic power factor of this system is 95.15%, since savings are not attained at larger power factors.

	P.F. %	Reductions ($) Demand	Energy	Capacity	Benefits ($)	Capacitor costs ($)	Savings (p.u.)
1	90.0	182.4	139.8	110335.5	110657.7	52055.1	1.0
2	91.0	41.3	31.7	23465.6	23538.6	12918.9	0.18
3	92.0	41.0	31.4	22515.2	22587.6	13326.9	0.16
4	93.0	40.8	31.3	21546.2	21618.3	13847.8	0.13
5	94.0	40.9	31.4	20541.6	20613.9	14523.2	0.1
6	95.0	41.3	31.7	19474.8	19547.8	15420.3	0.07
7	96.0	82.7	63.4	2226.8	2372.9	21907.9	-0.33
8	97.0	95.6	73.3	-11893.1	-11724.2	26595.9	-0.65
9	98.0	90.5	69.4	-23977.2	-23817.4	30822.1	-0.93
10	99.0	84.0	64.4	-46503.6	-46355.1	39247.0	-1.46
11	100.0	232.5	178.2	-205273.4	-204862.7	96835.0	-5.15

Table 6: Benefits, Costs & Savings of System # 3.

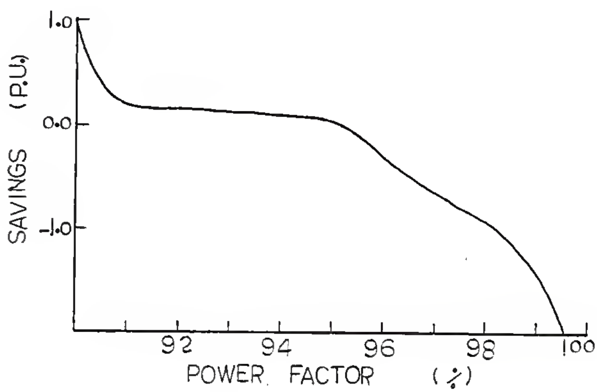

Figure 6: Savings v.s. Power Factor for System # 3.

4. Figure 7 shows the electric power system to be analyzed. Values of real power (P), reactive power (Q), voltage magnitude (V), voltage angle (θ) at each bus, and line impedances are given in Table 7.

From_To	Series Impedance (p.u.)	Shunt Admittance (p.u.)
9-8	0.0192 + j0.0575	j0.0264
9-1	0.0452 + j0.1852	j0.0204
8-2	0.057 + j0.1737	j0.0183
1-2	0.0132 + j0.0379	j0.0042
8-5	0.0472 + j0.1983	j0.0209
8-6	0.0581 + j0.1763	j0.0187
2-6	0.0119 + j0.0414	j0.0045
5-3	0.046 + j0.116	j0.0102
6-3	0.0267 + j0.082	j0.0085
6-7	0.012 + j0.042	j0.0045
7-4	0.0636 + j0.2	j0.0214
6-4	0.0169 + j0.0599	j0.0065

No.	Bus Type	Voltage		Generator		Load	
		V(p.u.)	θ(deg.)	P(p.u.)	Q(p.u.)	P(p.u.)	Q(p.u.)
1	L	?	?	0.0	0.0	0.024	0.012
2	L	?	?	0.0	0.0	0.515	0.158
3	L	?	?	0.0	0.0	0.228	0.109
4	L	?	?	0.0	0.0	0.181	0.05
5	L	?	?	0.0	0.0	0.942	0.19
6	L	?	?	0.0	0.0	0.434	0.0
7	L	?	?	0.0	0.0	0.3	0.3
8	G	1.05	?	0.4	?	0.217	0.127
9	S	1.0	0.0	?	?	0.0	0.0

Table 7: Data for Power System # 4.

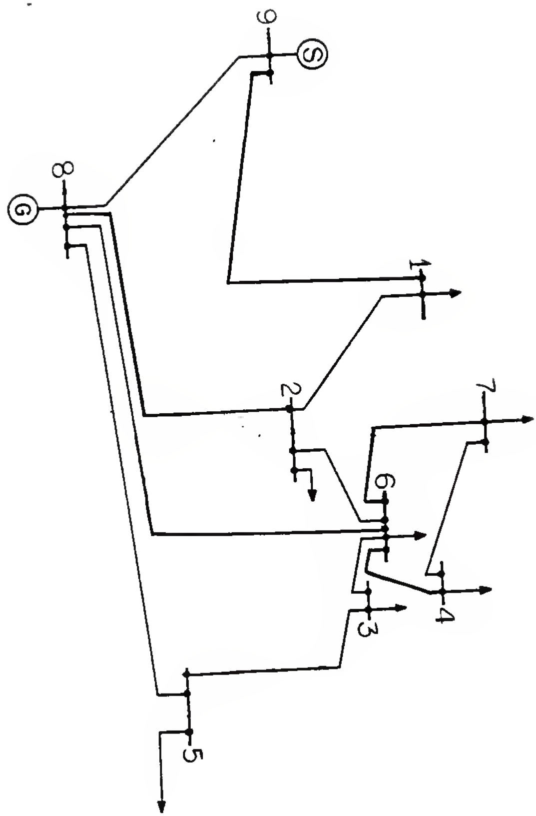

Figure 7: Power System # 4.

Load flow output is located in Appendix A.35. Table 8 shows benefits, capacitor cost, and savings. Savings in per unit v.s. power factor are plotted in Figure 8. It is clear that savings are resulted even at unity power factor, consequently, the economic power factor is 100.0%.

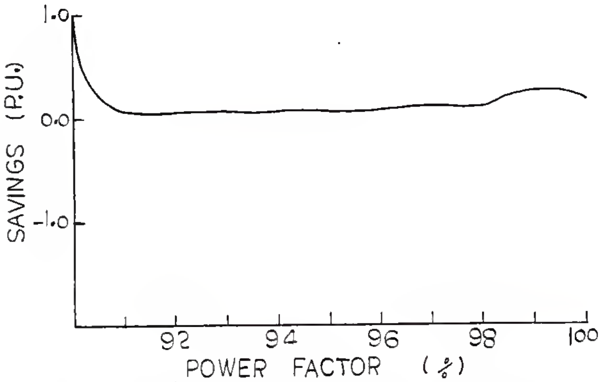

Figure 8: Savings v.s. Power Factor for System # 4.

	P.F. %	Reductions ($) Demand	Energy	Capacity	Benefits ($)	Capacitor costs ($)	Savings (p.u.)
1	90.0	25241.9	19347.9	84517.2	129107.1	13957.2	1.0
2	91.0	1974.3	1513.3	5232.4	8720.0	1298.0	0.06
3	92.0	2189.3	1678.1	5609.2	9476.6	1471.3	0.07
4	93.0	2202.4	1688.2	5554.1	9444.7	1528.8	0.07
5	94.0	2231.3	1710.3	5522.2	9463.7	1603.4	0.07
6	95.0	2281.9	1749.1	5520.2	9551.1	1702.4	0.07
7	96.0	3096.9	2373.8	6428.0	11898.7	2540.3	0.08
8	97.0	4783.8	3666.8	8271.0	16721.6	4358.7	0.11
9	98.0	5296.2	4059.5	7772.6	17128.3	5342.5	0.1
10	99.0	11660.6	8937.8	20527.6	41126.0	11822.3	0.25
11	100.0	16582.2	12710.3	19135.6	48428.1	28085.2	0.18

Table 8: Benefits, Costs & Savings of System # 4.

5. In Figure 9, the electric power system under consideration is shown. Values of real power (P), reactive power (Q), voltage magnitude (V), voltage angle (θ) at each bus, and line impedances are given in Table 9.

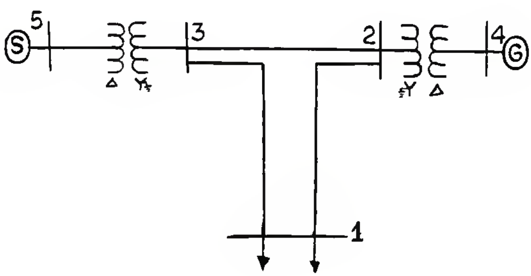

Figure 9: Power System # 5.

From-To	Series Impedance (p.u.)	Shunt Admittance (p.u.)
1-2	0.036 + j0.4	j0.43
1-3	0.018 + j0.2	j0.22
2-3	0.009 + j0.1	j0.11
5-3	0.006 + j0.08	0.0
4-2	0.003 + j0.04	0.0

No.	Bus Type	Voltage V(p.u.)	Voltage θ(deg.)	Generator P(p.u.)	Generator Q(p.u.)	Load P(p.u.)	Load Q(p.u.)
1	L	?	?	0.0	0.0	2.0	0.7
2	L	?	?	0.0	0.0	0.0	0.0
3	L	?	?	0.0	0.0	0.0	0.0
4	G	1.05	?	1.3	?	0.2	0.1
5	S	1.0	0.0	?	?	0.0	0.0

Table 9: Data for Power System # 5.

Load flow output can be found in Appendix A.51. Total benefits, capacitor costs, and savings are recorded in Table 10. Figure 10 contains a plot of savings in per unit v.s. power factor. It can be concluded from Figure 10 and Table 10 that the optimum power factor of the electric power system in Figure 9 is 97.65%, where total benefits and costs are equal.

	P.F. %	Reductions ($) Demand	Energy	Capacity	Benefits ($)	Capacitor costs ($)	Savings (p.u.)
1	95.0	6348.8	4866.4	8249.4	19464.6	3836.9	1.0
2	96.0	8991.1	6891.7	8621.6	24504.3	6663.1	1.14
3	97.0	7325.4	5614.9	1841.8	14782.2	7387.8	0.47
4	98.0	5694.0	4364.8	-7128.3	2930.9	8561.7	-0.36
5	99.0	3627.3	2780.4	-38119.7	-31712.0	10902.0	-2.73
6	100.0	-3485.8	-2671.9	-129174.4	-135332.1	25648.6	-10.3

Table 10: Benefits, Costs & Savings of System # 5.

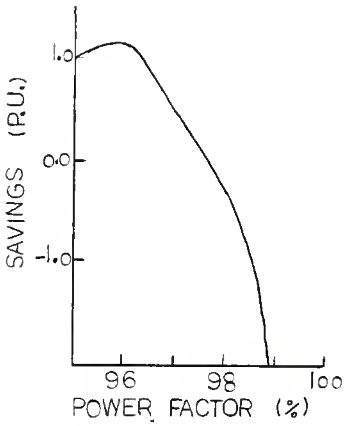

Figure 10: Savings v.s. Power Factor for System # 5.

6. The power system to be analyzed can be found in Figure 11[3]. Line impedences, real power (P), reactive power (Q), voltage magnitude (V), and voltage phase (θ) values at each bus are given in Table 11.

From-To	Series Impedance (p.u.)	Shunt Admittance (p.u.)
1-2	j0.01	0.0
1-3	0.01 + j0.01	0.0
6-1	j0.005	0.0
3-4	0.01 + j0.01	0.0
5-4	j0.01	0.0
6-5	j0.01	0.0
6-5	j0.01	0.0
6-5	j0.01	0.0

No.	Bus Type	Voltage V(p.u.)	Voltage θ(deg.)	Generator P(p.u.)	Generator Q(p.u.)	Load P(p.u.)	Load Q(p.u.)
1	L	?	?	0.0	0.0	0.75	0.12
2	L	?	?	0.0	0.0	0.1	0.01
3	L	?	?	0.0	0.0	0.05	0.01
4	L	?	?	0.0	0.0	0.1	0.1
5	L	?	?	0.0	0.0	1.0	0.8
6	S	1.0	0.0	?	?	0.0	0.0

Table 11: Data for Power System # 6.

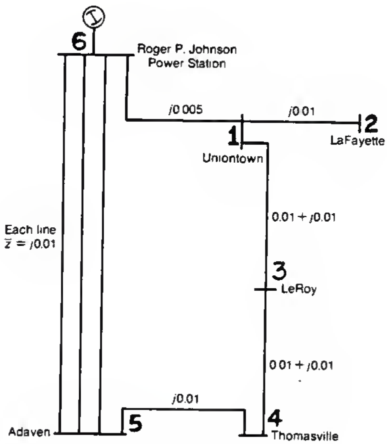

Figure 11: Power System # 6.

Output of load flow program of the above power system is located in Appendix A.59. The data required to find an economic power factor of this system is in Table 12. The corresponding plot is shown in Figure 12. Savings are diminished at 94.9% power factor, which is the optimum.

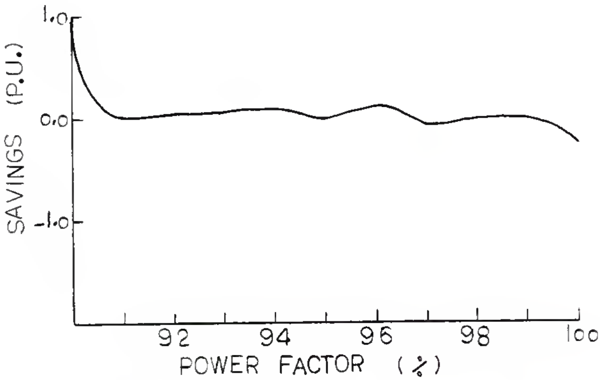

Figure 12: Savings v.s. Power Factor for System # 6.

	P.F. %	Reductions ($) Demand	Energy	Capacity	Benefits ($)	Capacitor costs ($)	Savings (p.u.)
1	90.0	377.9	289.7	120941.5	121609.0	33052.1	1.0
2	91.0	-21.7	-16.6	4958.4	4920.1	2842.2	0.02
3	92.0	17.2	13.2	7799.2	7829.7	2931.9	0.06
4	93.0	16.1	12.4	7616.1	7644.4	3046.5	0.05
5	94.0	55.0	42.2	11997.3	12094.4	3195.1	0.1
6	95.0	-26.2	-20.1	2316.9	2270.7	3392.5	-0.01
7	96.0	52.4	40.2	13749.0	13841.6	3664.7	0.12
8	97.0	-29.17	-22.4	-2142.5	-2194.0	4063.3	-0.07
9	98.0	8.6	6.6	4382.0	4397.2	4708.9	0.0
10	99.0	5.4	4.1	5502.7	5512.2	7436.6	-0.02
11	100.0	-48.5	-37.2	2234.4	2148.8	25266.2	-0.26

Table 12: Benefits, Costs & Savings of System # 6.

7. A diagram for a simple electric power system is shown in Fig. 13(3]. P.U. line impedances, and P.U. values of real power (P), reactive power (Q), voltage magnitude (V), and voltage phase (θ) at each bus are given in Table 13.

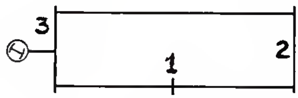

Figure 13: Power System # 7.

From-To	Series Impedance (p.u.)	Shunt Admittance (p.u.)
3-2	j0.05	0.0
3-1	0.01 + j0.01	0.0
1-2	j0.01	0.0

No.	Bus Type	Voltage		Generator		Load	
		V(p.u.)	θ(deg.)	P(p.u.)	Q(p.u.)	P(p.u.)	Q(p.u.)
1	L	?	?	0.0	0.0	0.96	-2.07
2	L	?	?	0.0	0.0	3.15	2.85
3	S	1.05	0.0	?	?	0.0	0.0

Table 13: Data for Power System # 7.

Appendix A.72 contains the output of load flow program for this system. Total benefits, costs, and savings are reported in Table 14. These per unit savings v.s. power factor are plotted in Figure 14. The economic power factor in this case is 92.0%, since the curve intersects the horizontal (zero) axis at this value.

	P.F. %	Reductions ($) Demand	Energy	Capacity	Benefits ($)	Capacitor costs ($)	Savgs. (p.u.)
1	90.0	-2962.5	-2270.7	384226.0	378992.8	119194.7	1.0
2	91.0	-2731.1	-2093.4	14487.0	9662.4	8138.9	0.01
3	92.0	-3140.4	-2407.1	13267.2	7719.7	8395.9	0.0
4	93.0	-3607.8	-2765.4	11960.5	5587.3	8724.1	-0.01
5	94.0	-4158.0	-3187.1	10521.9	3176.9	9149.6	-0.02
6	95.0	-4638.9	-3555.8	9232.2	1037.5	9714.8	-0.03
7	96.0	-5681.6	-4355.0	6927.8	-3108.9	10494.4	-0.05
8	97.0	-6871.5	-5267.0	4382.3	-7756.1	11635.7	-0.08
9	98.0	-8707.4	-6674.2	686.4	-14695.2	13484.7	-0.11
10	99.0	-12228.3	-9373.0	-6032.0	-27633.3	17170.6	-0.17
11	100.0	-33908.1	-25990.5	-45991.4	-105890.0	40396.6	-0.56

Table 14: Benefits, Costs & Savings of System # 7.

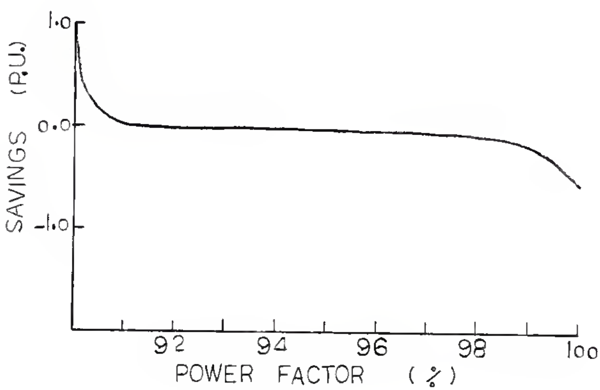

Figure 14: Savings v.s. Power Factor for System # 7.

Upon examining results of the above mentioned cases, it can be seen that the most economic power factor is generally not unity. However, the most economic power factor is a function of the cost data. Thus for a given system, the economic power factor may vary with time. Hence, while planning for installation of capacitors the planner should accurately take into account the cost of various items in this study.

IV. SUMMARY

A study on shunt capacitor banks application for power factor correction in electric power systems has been presented. Load flow program is developed to assist power engineers and planners for determining optimal shunt capacitor sizes for improvement of power system operation (Appendix B.). With the help of the several examples it has been shown that every system has its own optimal power factor. Thus, determination of the right capacitors size for power factor correction is an important study for power systems planners.

Installation of shunt capacitors also results in voltage improvement at load buses, which can be seen in the results of the above mentioned systems (Appendix A.). In this study, a value was not assigned to the benefits obtained by having proper voltage at the load buses. In fact, in some situations the optimal power factor may result in voltage at one or more buses lower than the acceptable minimum. In such cases, voltage becomes a dominant criteria instead of savings and it may become necessary to install more shunt capacitors for voltage correction. Detailed analysis of the voltage profile at the buses is not a part of this study, but it is a topic for further investigation.

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APPENDIX A.

The Simulated Electric Power Systems

Output Printout

Load Flow Output of System # 1

CASE: 1
The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 7
Number of loads = 3
Tolerance (eps) = 1.0e-03
Last iteration = 5

Load flow results

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.987	-4.64	0.00	0.00	0.00	0.45	0.15	0.95	0.00	0.00
2	11	0.984	-4.96	0.00	0.00	0.00	0.40	0.05	0.99	0.00	0.00
3	11	0.972	-5.76	0.00	0.00	0.00	0.60	0.10	0.99	0.00	0.00
4	12	1.000	-2.06	0.40	-0.62	0.54	0.20	0.10	0.89	0.00	0.00
5	13	1.060	0.00	1.31	0.91	0.82	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-4	0.89	0.74		0.02	0.01
1	4-5	-0.87	-0.73	1.16	0.02	0.01
2	5-1	0.42	0.17		0.02	-0.01
2	1-5	-0.40	-0.18	0.45	0.02	-0.01
3	4-1	0.24	-0.03		0.00	-0.03
3	1-4	-0.24	0.00	0.25	0.00	-0.03
4	4-2	0.28	-0.02		0.00	-0.03
4	2-4	-0.27	-0.01	0.28	0.00	-0.03
5	4-3	0.55	0.06		0.01	0.01
5	3-4	-0.53	-0.05	0.55	0.01	0.01
6	1-2	0.19	0.03		0.00	-0.02
6	2-1	-0.19	-0.05	0.20	0.00	-0.02
7	2-3	0.07	0.01		0.00	-0.05
7	3-2	-0.07	-0.05	0.08	0.00	-0.05

S_total = 296612.18 kVA, Total_p_loss = 6122.28 kW
C_total[1] = 0.00 kVAR

CASE: 2
The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 7
Number of loads = 3
Tolerance (eps) = 1.0e-03
Last iteration = 5

Load flow results

....

No.	b_type	Voltage mag	Voltage ang	Generator p	Generator q	Generator pf	Load p	Load q	Load pf	Mismatch d_p	Mismatch d_q
1	11	0.987	-4.64	0.00	0.00	0.00	0.45	0.15	0.95	0.00	0.00
2	11	0.984	-4.96	0.00	0.00	0.00	0.40	0.05	0.99	0.00	0.00
3	11	0.972	-5.77	0.00	0.00	0.00	0.60	0.10	0.99	0.00	0.00
4	12	1.000	-2.06	0.40	-0.62	0.54	0.20	0.10	0.89	0.00	0.00
5	13	1.060	0.00	1.31	0.91	0.82	0.00	0.00	0.00	0.00	0.00

No.	F-T	Line Flow P	Line Flow Q	Line Flow S	Line Loss P	Line Loss Q
1	5-4	0.89	0.74		0.02	0.01
1	4-5	-0.87	-0.73	1.16	0.02	0.01
2	5-1	0.42	0.17		0.02	-0.01
2	1-5	-0.40	-0.17	0.45	0.02	-0.01
3	4-1	0.24	-0.03		0.00	-0.03
3	1-4	-0.24	0.00	0.25	0.00	-0.03
4	4-2	0.28	-0.02		0.00	-0.03
4	2-4	-0.27	-0.01	0.28	0.00	-0.03
5	4-3	0.55	0.06		0.01	0.01
5	3-4	-0.53	-0.05	0.55	0.01	0.01
6	1-2	0.19	0.03		0.00	-0.02
6	2-1	-0.19	-0.05	0.20	0.00	-0.02
7	2-3	0.07	0.01		0.00	-0.05
7	3-2	-0.07	-0.05	0.08	0.00	-0.05

S_total = 296637.38 kVA, Total_p_loss = 6120.65 kW
C_total[2] = 209.22 kVAR

CASE: 3

The slack bus is number 5

Base KV = 132.0 kV

Base KVA = 1.0e+05 kVA

Number of buses = 5

Number of lines = 7

Number of loads = 3

Tolerance (eps) = 1.0e-03

Last iteration = 5

Load flow results

....

No.	b_type	Voltage mag	Voltage ang	Generator p	Generator q	Generator pf	Load p	Load q	Load pf	Mismatch d_p	Mismatch d_q
1	11	0.988	-4.66	0.00	0.00	0.00	0.45	0.13	0.96	0.00	0.00
2	11	0.985	-4.97	0.00	0.00	0.00	0.40	0.05	0.99	0.00	0.00
3	11	0.972	-5.77	0.00	0.00	0.00	0.60	0.10	0.99	0.00	0.00
4	12	1.000	-2.06	0.40	-0.63	0.54	0.20	0.10	0.89	0.00	0.00
5	13	1.060	0.00	1.31	0.90	0.82	0.00	0.00	0.00	0.00	0.00

No.	F-T	Line Flow P	Line Flow Q	Line Flow S	Line Loss P	Line Loss Q
1	5-4	0.89	0.74		0.02	0.01
1	4-5	-0.87	-0.73	1.16	0.02	0.01
2	5-1	0.42	0.16		0.02	-0.01
2	1-5	-0.40	-0.17	0.45	0.02	-0.01
3	4-1	0.24	-0.03		0.00	-0.03
3	1-4	-0.24	0.00	0.25	0.00	-0.03
4	4-2	0.28	-0.02		0.00	-0.03
4	2-4	-0.27	0.00	0.28	0.00	-0.03
5	4-3	0.55	0.05		0.01	0.01
5	3-4	-0.53	-0.05	0.55	0.01	0.01
6	1-2	0.19	0.04		0.00	-0.02
6	2-1	-0.19	-0.05	0.20	0.00	-0.02
7	2-3	0.07	0.01		0.00	-0.05
7	3-2	-0.07	-0.05	0.09	0.00	-0.05

S_total = 296867.27 kVA, Total_p_loss = 6108.45 kW

C_total[3] = 1665.78 kVAR

```
CASE: 4
 The slack bus is number    5
 Base KV          = 132.0 kV
 Base KVA         =   1.0e+05  kVA
 Number of buses =   5
 Number of lines =   7
 Number of loads =   3
 Tolerance (eps) =   1.0e-03
 Last iteration  =   5
     Load flow results
    ...................
```

No.	b_type	Voltage mag	Voltage ang	Generator p	Generator q	Generator pf	Load p	Load q	Load pf	Mismatch d_p	Mismatch d_q
1	11	0.990	-4.67	0.00	0.00	0.00	0.45	0.11	0.97	0.00	0.00
2	11	0.986	-4.98	0.00	0.00	0.00	0.40	0.05	0.99	0.00	0.00
3	11	0.972	-5.77	0.00	0.00	0.00	0.60	0.10	0.99	0.00	0.00
4	12	1.000	-2.06	0.40	-0.64	0.53	0.20	0.10	0.89	0.00	0.00
5	13	1.060	0.00	1.31	0.90	0.82	0.00	0.00	0.00	0.00	0.00

No.	F-T	Line Flow P	Line Flow Q	Line Flow S	Line Loss P	Line Loss Q
1	5-4	0.89	0.74		0.02	0.01
1	4-5	-0.87	-0.73	1.16	0.02	0.01
2	5-1	0.42	0.16		0.01	-0.01
2	1-5	-0.40	-0.17	0.45	0.01	-0.01
3	4-1	0.24	-0.04		0.00	-0.03
3	1-4	-0.24	0.01	0.25	0.00	-0.03
4	4-2	0.28	-0.03		0.00	-0.03
4	2-4	-0.27	0.00	0.28	0.00	-0.03
5	4-3	0.55	0.05		0.01	0.01
5	3-4	-0.53	-0.04	0.55	0.01	0.01
6	1-2	0.19	0.04		0.00	-0.02
6	2-1	-0.19	-0.06	0.20	0.00	-0.02
7	2-3	0.07	0.01		0.00	-0.05
7	3-2	-0.07	-0.06	0.09	0.00	-0.05

```
------------------------------------------------------
S_total = 297182.03 kVA, Total_p_loss =  6096.40 kW
C_total[4] =  1846.94 kVAR
======================================================================
```

CASE: 5

The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 7
Number of loads = 3
Tolerance (eps) = 1.0e-03
Last iteration = 5

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.991	-4.69	0.00	0.00	0.00	0.45	0.09	0.98	0.00	0.00
2	11	0.987	-5.00	0.00	0.00	0.00	0.40	0.05	0.99	0.00	0.00
3	11	0.973	-5.77	0.00	0.00	0.00	0.60	0.10	0.99	0.00	0.00
4	12	1.000	-2.06	0.40	-0.66	0.52	0.20	0.10	0.89	0.00	0.00
5	13	1.060	0.00	1.31	0.89	0.83	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-4	0.89	0.74		0.02	0.01
1	4-5	-0.87	-0.73	1.16	0.02	0.01
2	5-1	0.42	0.15		0.01	-0.01
2	1-5	-0.40	-0.16	0.45	0.01	-0.01
3	4-1	0.24	-0.05		0.00	-0.03
3	1-4	-0.24	0.02	0.25	0.00	-0.03
4	4-2	0.28	-0.03		0.00	-0.03
4	2-4	-0.27	0.01	0.28	0.00	-0.03
5	4-3	0.55	0.05		0.01	0.01
5	3-4	-0.53	-0.04	0.55	0.01	0.01
6	1-2	0.19	0.05		0.00	-0.02
6	2-1	-0.19	-0.07	0.21	0.00	-0.02
7	2-3	0.07	0.01		0.00	-0.05
7	3-2	-0.07	-0.06	0.09	0.00	-0.05

S_total = 297623.58 kVA, Total_p_loss = 6084.36 kW
C_total(5] = 2140.42 kVAR

==

```
CASE: 6
 The slack bus is number    5
 Base KV          = 132.0 kV
 Base KVA         =    1.0e+05  kVA
 Number of buses =    5
 Number of lines =    7
 Number of loads =    3
 Tolerance (eps) =    1.0e-03
 Last iteration  =    5
     Load flow results
     ...................
                 Voltage    Generator         Load        Mismatch
               ---------- -------------- ------------- -------------
No. b_type     mag   ang   p      q    pf    p     q    pf   d_p   d_q
 1   11      0.993 -4.72 0.00   0.00 0.00 0.45 0.06 0.99 0.00 0.00
 2   11      0.989 -5.02 0.00   0.00 0.00 0.40 0.05 0.99 0.00 0.00
 3   11      0.974 -5.80 0.00   0.00 0.00 0.60 0.09 0.99 0.00 0.00
 4   12      1.000 -2.06 0.40 -0.70 0.50 0.20 0.10 0.89 0.00 0.00
 5   13      1.060  0.00 1.31   0.88 0.83 0.00 0.00 0.00 0.00 0.00
                 Line Flow       Line Loss
             ---------------  ------------
No. F-T    P     Q      S     P     Q
 1  5-4  0.89  0.74         0.02  0.01
 1  4-5 -0.87 -0.73 1.16    0.02  0.01
 2  5-1  0.42  0.14         0.01 -0.01
 2  1-5 -0.40 -0.15 0.44    0.01 -0.01
 3  4-1  0.24 -0.06         0.00 -0.03
 3  1-4 -0.24  0.03 0.25    0.00 -0.03
 4  4-2  0.28 -0.04         0.00 -0.03
 4  2-4 -0.27  0.02 0.28    0.00 -0.03
 5  4-3  0.55  0.03         0.01  0.01
 5  3-4 -0.53 -0.03 0.55    0.01  0.01
 6  1-2  0.19  0.06         0.00 -0.02
 6  2-1 -0.19 -0.08 0.21    0.00 -0.02
 7  2-3  0.07  0.01         0.00 -0.05
 7  3-2 -0.07 -0.06 0.09    0.00 -0.05
----------------------------------------------------
S_total = 297868.94 kVA, Total_p_loss =  6062.17 kW
C_total[6] =  4175.95 kVAR
==================================================================
```

```
CASE: 7
 The slack bus is number    5
 Base KV          = 132.0 kV
 Base KVA         =   1.0e+05  kVA
 Number of buses =   5
 Number of lines =   7
 Number of loads =   3
 Tolerance (eps) =   1.0e-03
 Last iteration  =   5
     Load flow results
    ...................
             Voltage    Generator        Load       Mismatch
            --------- ------------- ------------ ------------
No. b_type    mag   ang   p     q    pf   p    q    pf  d_p  d_q
 1   11     1.001 -4.85 0.00  0.00 0.00 0.45 0.00 1.00 0.00 0.00
 2   11     0.997 -5.15 0.00  0.00 0.00 0.40 0.00 1.00 0.00 0.00
 3   11     0.984 -5.94 0.00  0.00 0.00 0.60 0.00 1.00 0.00 0.00
 4   12     1.000 -2.05 0.40 -0.86 0.42 0.20 0.10 0.89 0.00 0.00
 5   13     1.060  0.00 1.31  0.85 0.84 0.00 0.00 0.00 0.00 0.00
             Line Flow       Line Loss
          --------------   -----------
No. F-T    P     Q     S      P     Q
 1  5-4  0.89  0.74         0.02  0.01
 1  4-5 -0.87 -0.73 1.16    0.02  0.01
 2  5-1  0.42  0.11         0.01 -0.01
 2  1-5 -0.41 -0.12 0.43    0.01 -0.01
 3  4-1  0.24 -0.10         0.00 -0.03
 3  1-4 -0.24  0.07 0.26    0.00 -0.03
 4  4-2  0.28 -0.09         0.00 -0.03
 4  2-4 -0.27  0.06 0.29    0.00 -0.03
 5  4-3  0.55 -0.05         0.01  0.01
 5  3-4 -0.53  0.05 0.55    0.01  0.01
 6  1-2  0.20  0.05         0.00 -0.02
 6  2-1 -0.20 -0.07 0.21    0.00 -0.02
 7  2-3  0.07  0.01         0.00 -0.05
 7  3-2 -0.07 -0.05 0.09    0.00 -0.05
----------------------------------------------------
S_total = 298585.91 kVA, Total_p_loss =  6028.55 kW
C_total[7] = 19961.69 kVAR
=================================================================
```

No.	Dem.Red. ($)	Energy Red. ($)	Capacity Rel. ($)	T.Benefit ($)	Cap.Cost ($)	Savings (pu)
1	64.87	49.73	-120.93	-6.33	188.29	-1.000
2	488.01	374.06	-1103.48	-241.41	1499.21	-8.943
3	482.11	369.54	-1510.87	-659.23	1662.24	-11.928
4	481.72	369.24	-2119.41	-1268.46	1926.38	-16.415
5	887.35	680.15	-1177.72	389.78	3758.36	-17.308
6	1345.17	1031.07	-3441.48	-1065.25	17965.52	-97.780

Load Flow Output of System # 2

```
CASE: 1
 The slack bus is number    5
 Base KV          = 132.0 kV
 Base KVA         =   1.0e+05  kVA
 Number of buses =   5
 Number of lines =   6
 Number of loads =   3
 Tolerance (eps) =   1.0e-03
 Last iteration  =   4
     Load flow results
    ...................
             Voltage     Generator         Load        Mismatch
            ---------- ------------- ------------ ------------
No. b_type   mag    ang     p     q    pf    p     q    pf  d_p   d_q
 1   11     0.964   -6.32 0.00 0.00 0.00 1.15 0.60 0.89 0.00 0.00
 2   11     0.936 -10.91 0.00 0.00 0.00 0.70 0.30 0.92 0.00 0.00
 3   11     0.977   -6.21 0.00 0.00 0.00 0.85 0.40 0.90 0.00 0.00
 4   12     1.020   -3.66 1.80 0.91 0.89 0.70 0.40 0.87 0.00 0.00
 5   13     1.040    0.00 2.34 0.88 0.94 0.65 0.30 0.00 0.00 0.00
             Line Flow         Line Loss
          --------------    ------------
No. F-T     P     Q      S      P     Q
 1  5-1  0.74  0.28           0.03  0.02
 1  1-5 -0.71 -0.26 0.79      0.03  0.02
 2  5-3  0.95  0.30           0.03  0.06
 2  3-5 -0.93 -0.25 1.00      0.03  0.06
 3  1-4 -0.44 -0.34           0.01 -0.02
 3  4-1  0.45  0.32 0.55      0.01 -0.02
 4  4-2  0.40  0.09           0.02 -0.09
 4  2-4 -0.39 -0.19 0.43      0.02 -0.09
 5  4-3  0.25  0.10           0.00 -0.08
 5  3-4 -0.24 -0.18 0.31      0.00 -0.08
 6  2-3 -0.31 -0.11           0.01 -0.08
 6  3-2  0.32  0.03 0.33      0.01 -0.08
----------------------------------------------------
S_total = 341279.48 kVA, Total_p_loss =  9140.28 kW
C_total[1] =      0.00 kVAR
=================================================================
```

CASE: 2

The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 6
Number of loads = 3
Tolerance (eps) = 1.0e-03
Last iteration = 4

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.968	-6.34	0.00	0.00	0.00	1.15	0.56	0.90	0.00	0.00
2	11	0.936	-10.91	0.00	0.00	0.00	0.70	0.30	0.92	0.00	0.00
3	11	0.977	-6.20	0.00	0.00	0.00	0.85	0.40	0.90	0.00	0.00
4	12	1.020	-3.65	1.80	0.88	0.90	0.70	0.40	0.87	0.00	0.00
5	13	1.040	0.00	2.34	0.86	0.94	0.65	0.30	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-1	0.74	0.26		0.02	0.02
1	1-5	-0.71	-0.24	0.78	0.02	0.02
2	5-3	0.95	0.30		0.03	0.06
2	3-5	-0.92	-0.25	1.00	0.03	0.06
3	1-4	-0.44	-0.32		0.01	-0.02
3	4-1	0.45	0.29	0.54	0.01	-0.02
4	4-2	0.40	0.09		0.02	-0.09
4	2-4	-0.39	-0.19	0.43	0.02	-0.09
5	4-3	0.25	0.10		0.00	-0.08
5	3-4	-0.25	-0.18	0.31	0.00	-0.08
6	2-3	-0.31	-0.11		0.01	-0.08
6	3-2	0.32	0.03	0.33	0.01	-0.08

S_total = 339008.06 kVA, Total_p_loss = 9029.14 kW
C_total[2] = 4302.96 kVAR

==

CASE: 3
The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 6
Number of loads = 3
Tolerance (eps) = 1.0e-03
Last iteration = 4

Load flow results
....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.970	-6.35	0.00	0.00	0.00	1.15	0.52	0.91	0.00	0.00
2	11	0.937	-10.90	0.00	0.00	0.00	0.70	0.30	0.92	0.00	0.00
3	11	0.977	-6.21	0.00	0.00	0.00	0.85	0.39	0.91	0.00	0.00
4	12	1.020	-3.64	1.80	0.86	0.90	0.70	0.40	0.87	0.00	0.00
5	13	1.040	0.00	2.34	0.84	0.94	0.65	0.30	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-1	0.74	0.24		0.02	0.01
1	1-5	-0.71	-0.23	0.77	0.02	0.01
2	5-3	0.95	0.30		0.03	0.06
2	3-5	-0.92	-0.24	1.00	0.03	0.06
3	1-4	-0.44	-0.30		0.01	-0.03
3	4-1	0.45	0.27	0.53	0.01	-0.03
4	4-2	0.40	0.09		0.02	-0.09
4	2-4	-0.39	-0.18	0.43	0.02	-0.09
5	4-3	0.25	0.10		0.00	-0.08
5	3-4	-0.25	-0.18	0.30	0.00	-0.08
6	2-3	-0.31	-0.12		0.01	-0.08
6	3-2	0.32	0.03	0.33	0.01	-0.08

S_total = 336845.91 kVA, Total_p_loss = 8921.14 kW
C_total[3] = 4574.35 kVAR

CASE: 4

The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 6
Number of loads = 3
Tolerance (eps) = 1.0e-03
Last iteration = 4

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.973	-6.37	0.00	0.00	0.00	1.15	0.49	0.92	0.00	0.00
2	11	0.938	-10.89	0.00	0.00	0.00	0.70	0.30	0.92	0.00	0.00
3	11	0.979	-6.22	0.00	0.00	0.00	0.85	0.36	0.92	0.00	0.00
4	12	1.020	-3.62	1.80	0.82	0.91	0.70	0.40	0.87	0.00	0.00
5	13	1.040	0.00	2.34	0.80	0.95	0.65	0.30	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-1	0.74	0.23		0.02	0.01
1	1-5	-0.71	-0.21	0.77	0.02	0.01
2	5-3	0.95	0.28		0.03	0.05
2	3-5	-0.92	-0.23	0.99	0.03	0.05
3	1-4	-0.44	-0.28		0.01	-0.03
3	4-1	0.45	0.25	0.52	0.01	-0.03
4	4-2	0.40	0.09		0.02	-0.10
4	2-4	-0.39	-0.18	0.43	0.02	-0.10
5	4-3	0.25	0.09		0.00	-0.09
5	3-4	-0.25	-0.17	0.30	0.00	-0.09
6	2-3	-0.31	-0.12		0.01	-0.08
6	3-2	0.32	0.03	0.33	0.01	-0.08

S_total = 334137.50 kVA, Total_p_loss = 8783.41 kW
C_total[4] = 6103.17 kVAR

===

CASE: 5

The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 6
Number of loads = 3
Tolerance (eps) = 1.0e-03
Last iteration = 4

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.976	-6.38	0.00	0.00	0.00	1.15	0.45	0.93	0.00	0.00
2	11	0.944	-10.89	0.00	0.00	0.00	0.70	0.28	0.93	0.00	0.00
3	11	0.983	-6.23	0.00	0.00	0.00	0.85	0.34	0.93	0.00	0.00
4	12	1.020	-3.60	1.80	0.77	0.92	0.70	0.40	0.87	0.00	0.00
5	13	1.040	0.00	2.34	0.76	0.95	0.65	0.30	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-1	0.73	0.21		0.02	0.01
1	1-5	-0.71	-0.20	0.76	0.02	0.01
2	5-3	0.95	0.25		0.03	0.05
2	3-5	-0.92	-0.20	0.99	0.03	0.05
3	1-4	-0.44	-0.26		0.01	-0.03
3	4-1	0.45	0.23	0.51	0.01	-0.03
4	4-2	0.40	0.07		0.01	-0.10
4	2-4	-0.39	-0.17	0.42	0.01	-0.10
5	4-3	0.25	0.07		0.00	-0.09
5	3-4	-0.25	-0.16	0.29	0.00	-0.09
6	2-3	-0.31	-0.11		0.01	-0.08
6	3-2	0.32	0.02	0.33	0.01	-0.08

S_total = 330256.87 kVA, Total_p_loss = 8581.17 kW
C_total[5] = 8308.69 kVAR

==

CASE: 6

The slack bus is number 5

Base KV = 132.0 kV

Base KVA = 1.0e+05 kVA

Number of buses = 5

Number of lines = 6

Number of loads = 3

Tolerance (eps) = 1.0e-03

Last iteration = 4

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.978	-6.39	0.00	0.00	0.00	1.15	0.42	0.94	0.00	0.00
2	11	0.949	-10.90	0.00	0.00	0.00	0.70	0.25	0.94	0.00	0.00
3	11	0.986	-6.25	0.00	0.00	0.00	0.85	0.31	0.94	0.00	0.00
4	12	1.020	-3.58	1.80	0.71	0.93	0.70	0.40	0.87	0.00	0.00
5	13	1.040	0.00	2.33	0.72	0.96	0.65	0.30	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-1	0.73	0.19		0.02	0.01
1	1-5	-0.71	-0.18	0.76	0.02	0.01
2	5-3	0.95	0.23		0.03	0.05
2	3-5	-0.92	-0.18	0.98	0.03	0.05
3	1-4	-0.44	-0.23		0.01	-0.03
3	4-1	0.45	0.20	0.50	0.01	-0.03
4	4-2	0.40	0.05		0.01	-0.10
4	2-4	-0.39	-0.15	0.42	0.01	-0.10
5	4-3	0.25	0.06		0.00	-0.09
5	3-4	-0.25	-0.14	0.29	0.00	-0.09
6	2-3	-0.31	-0.10		0.01	-0.09
6	3-2	0.32	0.01	0.33	0.01	-0.09

S_total = 326479.52 kVA, Total_p_loss = 8389.35 kW

C_total[6] = 8713.91 kVAR

==

```
CASE: 7
 The slack bus is number    5
 Base KV          = 132.0 kV
 Base KVA         =    1.0e+05  kVA
 Number of buses =    5
 Number of lines =    6
 Number of loads =    3
 Tolerance (eps) =    1.0e-03
 Last iteration  =    4
     Load flow results
    ...................
```

No.	b_type	Voltage mag	Voltage ang	Generator p	Generator q	Generator pf	Load p	Load q	Load pf	Mismatch d_p	Mismatch d_q
1	11	0.981	-6.41	0.00	0.00	0.00	1.15	0.38	0.95	0.00	0.00
2	11	0.955	-10.91	0.00	0.00	0.00	0.70	0.23	0.95	0.00	0.00
3	11	0.989	-6.27	0.00	0.00	0.00	0.85	0.28	0.95	0.00	0.00
4	12	1.020	-3.55	1.80	0.65	0.94	0.70	0.40	0.87	0.00	0.00
5	13	1.040	0.00	2.33	0.68	0.96	0.65	0.30	0.00	0.00	0.00

No.	F-T	Line Flow P	Line Flow Q	Line Flow S	Line Loss P	Line Loss Q
1	5-1	0.73	0.17		0.02	0.01
1	1-5	-0.71	-0.17	0.75	0.02	0.01
2	5-3	0.95	0.20		0.03	0.05
2	3-5	-0.92	-0.16	0.97	0.03	0.05
3	1-4	-0.44	-0.21		0.01	-0.03
3	4-1	0.45	0.18	0.49	0.01	-0.03
4	4-2	0.40	0.03		0.01	-0.10
4	2-4	-0.39	-0.14	0.41	0.01	-0.10
5	4-3	0.25	0.04		0.00	-0.09
5	3-4	-0.25	-0.13	0.28	0.00	-0.09
6	2-3	-0.31	-0.09		0.01	-0.09
6	3-2	0.32	0.00	0.33	0.01	-0.09

```
S_total = 322805.88 kVA, Total_p_loss =  8207.76 kW
C_total[7] =  9252.21 kVAR
==================================================================
```

CASE: 8
The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 6
Number of loads = 3
Tolerance (eps) = 1.0e-03
Last iteration = 4

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.985	-6.42	0.00	0.00	0.00	1.15	0.34	0.96	0.00	0.00
2	11	0.962	-10.93	0.00	0.00	0.00	0.70	0.20	0.96	0.00	0.00
3	11	0.992	-6.29	0.00	0.00	0.00	0.85	0.25	0.96	0.00	0.00
4	12	1.020	-3.53	1.80	0.59	0.95	0.70	0.40	0.87	0.00	0.00
5	13	1.040	0.00	2.33	0.63	0.97	0.65	0.30	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-1	0.73	0.15		0.02	0.01
1	1-5	-0.71	-0.15	0.75	0.02	0.01
2	5-3	0.95	0.17		0.03	0.05
2	3-5	-0.92	-0.13	0.96	0.03	0.05
3	1-4	-0.44	-0.19		0.01	-0.03
3	4-1	0.45	0.15	0.48	0.01	-0.03
4	4-2	0.40	0.02		0.01	-0.11
4	2-4	-0.39	-0.12	0.41	0.01	-0.11
5	4-3	0.25	0.02		0.00	-0.09
5	3-4	-0.25	-0.11	0.27	0.00	-0.09
6	2-3	-0.31	-0.08		0.01	-0.09
6	3-2	0.32	-0.01	0.32	0.01	-0.09

S_total = 319238.64 kVA, Total_p_loss = 8036.36 kW
C_total[8] = 9994.71 kVAR

===

```
CASE: 9
 The slack bus is number    5
 Base KV          = 132.0 kV
 Base KVA         =    1.0e+05  kVA
 Number of buses =    5
 Number of lines =    6
 Number of loads =    3
 Tolerance (eps) =    1.0e-03
 Last iteration  =    4
     Load flow results
    ...................
             Voltage     Generator        Load       Mismatch
            ---------- ------------- ------------ ------------
No. b_type   mag    ang    p     q    pf    p    q    pf   d_p  d_q
 1   11     0.988   -6.44 0.00 0.00 0.00 1.15 0.29 0.97 0.00 0.00
 2   11     0.969 -10.94 0.00 0.00 0.00 0.70 0.18 0.97 0.00 0.00
 3   11     0.996   -6.32 0.00 0.00 0.00 0.85 0.21 0.97 0.00 0.00
 4   12     1.020   -3.51 1.80 0.52 0.96 0.70 0.40 0.87 0.00 0.00
 5   13     1.040    0.00 2.33 0.58 0.97 0.65 0.30 0.00 0.00 0.00
             Line Flow        Line Loss
          --------------    -----------
No. F-T    P     Q      S      P     Q
 1  5-1  0.73  0.13          0.02  0.00
 1  1-5 -0.71 -0.13 0.74     0.02  0.00
 2  5-3  0.95  0.14          0.03  0.04
 2  3-5 -0.92 -0.10 0.96     0.03  0.04
 3  1-4 -0.44 -0.16          0.01 -0.04
 3  4-1  0.45  0.12 0.47     0.01 -0.04
 4  4-2  0.40 -0.01          0.01 -0.11
 4  2-4 -0.39 -0.10 0.40     0.01 -0.11
 5  4-3  0.25  0.00          0.00 -0.09
 5  3-4 -0.25 -0.09 0.27     0.00 -0.09
 6  2-3 -0.31 -0.07          0.01 -0.09
 6  3-2  0.32 -0.02 0.32     0.01 -0.09
----------------------------------------------------
S_total = 315786.58 kVA, Total_p_loss =  7875.44 kW
C_total[9] = 11081.62 kVAR
=================================================================
```

CASE: 10

The slack bus is number 5

Base KV = 132.0 kV

Base KVA = 1.0e+05 kVA

Number of buses = 5

Number of lines = 6

Number of loads = 3

Tolerance (eps) = 1.0e-03

Last iteration = 4

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.992	-6.47	0.00	0.00	0.00	1.15	0.23	0.98	0.00	0.00
2	11	0.977	-10.97	0.00	0.00	0.00	0.70	0.14	0.98	0.00	0.00
3	11	1.001	-6.34	0.00	0.00	0.00	0.85	0.17	0.98	0.00	0.00
4	12	1.020	-3.49	1.80	0.45	0.97	0.70	0.40	0.87	0.00	0.00
5	13	1.040	0.00	2.33	0.51	0.98	0.65	0.30	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-1	0.73	0.11		0.02	0.00
1	1-5	-0.71	-0.11	0.74	0.02	0.00
2	5-3	0.95	0.11		0.03	0.04
2	3-5	-0.92	-0.07	0.95	0.03	0.04
3	1-4	-0.44	-0.13		0.01	-0.04
3	4-1	0.45	0.09	0.46	0.01	-0.04
4	4-2	0.40	-0.03		0.01	-0.11
4	2-4	-0.39	-0.08	0.40	0.01	-0.11
5	4-3	0.25	-0.02		0.00	-0.09
5	3-4	-0.25	-0.07	0.26	0.00	-0.09
6	2-3	-0.31	-0.06		0.01	-0.09
6	3-2	0.32	-0.03	0.32	0.01	-0.09

S_total = 313269.96 kVA, Total_p_loss = 7725.93 kW

C_total[10] = 12842.54 kVAR

==

CASE: 11

The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 6
Number of loads = 3
Tolerance (eps) = 1.0e-03
Last iteration = 4

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.998	-6.50	0.00	0.00	0.00	1.15	0.16	0.99	0.00	0.00
2	11	0.987	-11.00	0.00	0.00	0.00	0.70	0.10	0.99	0.00	0.00
3	11	1.006	-6.38	0.00	0.00	0.00	0.85	0.12	0.99	0.00	0.00
4	12	1.020	-3.46	1.80	0.35	0.98	0.70	0.40	0.87	0.00	0.00
5	13	1.040	0.00	2.33	0.44	0.98	0.65	0.30	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-1	0.73	0.08		0.02	0.00
1	1-5	-0.71	-0.08	0.73	0.02	0.00
2	5-3	0.95	0.06		0.03	0.04
2	3-5	-0.92	-0.02	0.95	0.03	0.04
3	1-4	-0.44	-0.09		0.01	-0.04
3	4-1	0.45	0.05	0.45	0.01	-0.04
4	4-2	0.40	-0.06		0.01	-0.11
4	2-4	-0.39	-0.05	0.40	0.01	-0.11
5	4-3	0.25	-0.04		0.00	-0.09
5	3-4	-0.25	-0.05	0.26	0.00	-0.09
6	2-3	-0.31	-0.04		0.01	-0.10
6	3-2	0.32	-0.05	0.32	0.01	-0.10

S_total = 311635.45 kVA, Total_p_loss = 7590.74 kW
C_total[11] = 16352.92 kVAR

CASE: 12
The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 6
Number of loads = 3
Tolerance (eps) = 1.0e-03
Last iteration = 4

Load flow results
....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.010	-6.58	0.00	0.00	0.00	1.15	0.00	1.00	0.00	0.00
2	11	1.010	-11.08	0.00	0.00	0.00	0.70	0.00	1.00	0.00	0.00
3	11	1.019	-6.48	0.00	0.00	0.00	0.85	0.00	1.00	0.00	0.00
4	12	1.020	-3.41	1.80	0.12	1.00	0.70	0.40	0.87	0.00	0.00
5	13	1.040	0.00	2.33	0.26	0.99	0.65	0.30	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-1	0.73	0.00		0.02	0.00
1	1-5	-0.71	-0.01	0.73	0.02	0.00
2	5-3	0.95	-0.04		0.03	0.04
2	3-5	-0.92	0.08	0.95	0.03	0.04
3	1-4	-0.44	0.01		0.01	-0.04
3	4-1	0.45	-0.05	0.45	0.01	-0.04
4	4-2	0.40	-0.13		0.01	-0.12
4	2-4	-0.39	0.01	0.42	0.01	-0.12
5	4-3	0.25	-0.11		0.00	-0.09
5	3-4	-0.25	0.01	0.27	0.00	-0.09
6	2-3	-0.31	-0.01		0.01	-0.10
6	3-2	0.32	-0.09	0.33	0.01	-0.10

S_total = 315172.78 kVA, Total_p_loss = 7501.33 kW
C_total[12] = 38472.92 kVAR

===

No.	Dem.Red. ($)	Energy Red. ($)	Capacity Rel. ($)	T.Benefit ($)	Cap.Cost ($)	Savings (pu)
1	4445.39	3407.39	10902.84	18755.63	3872.66	1.000
2	4319.95	3311.24	10378.30	18009.49	4116.92	0.933
3	5509.36	4222.92	13000.39	22732.67	5492.86	1.158
4	8089.53	6200.62	18626.99	32917.14	7477.82	1.709
5	7672.67	5881.10	18131.31	31685.08	7842.52	1.602
6	7263.82	5567.72	17633.48	30465.02	8326.99	1.487
7	6855.92	5255.06	17122.74	29233.73	8995.24	1.360
8	6436.79	4933.80	16569.86	27940.45	9973.46	1.207
9	5980.39	4583.97	12079.80	22644.16	11558.29	0.745
10	5407.47	4144.83	7845.66	17397.96	14717.63	0.180
11	3576.70	2741.54	-16979.21	-10660.97	34625.62	-3.043

Load Flow Output of System # 3

CASE: 1

The slack bus is number 5

Base KV = 132.0 kV

Base KVA = 1.0e+05 kVA

Number of buses = 5

Number of lines = 5

Number of loads = 4

Tolerance (eps) = 1.0e-03

Last iteration = 6

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.007	-0.85	0.00	0.00	0.00	-2.52	-1.22	0.90	0.00	0.00
2	11	1.003	-1.28	0.00	0.00	0.00	1.00	0.05	1.00	0.00	0.00
3	11	0.993	-1.83	0.00	0.00	0.00	2.20	0.70	0.95	0.00	0.00
4	11	0.988	-1.58	0.00	0.00	0.00	5.00	3.00	0.86	0.00	0.00
5	13	1.000	0.00	5.69	2.33	0.93	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-4	5.44	2.46		0.00	0.08
1	4-5	-5.44	-2.38	5.97	0.00	0.08
2	4-3	0.44	-0.62		0.00	-0.11
2	3-4	-0.44	0.51	0.76	0.00	-0.11
3	3-1	-1.76	-1.21		0.00	0.03
3	1-3	1.77	1.23	2.15	0.00	0.03
4	5-2	0.25	-0.13		0.00	-0.19
4	2-5	-0.25	-0.06	0.28	0.00	-0.19
5	1-2	0.75	-0.01		0.00	0.00
5	2-1	-0.75	0.01	0.75	0.00	0.00

S_total = 991182.27 kVA, Total_p_loss = 510.06 kW

C_total[1] = 0.00 kVAR

===

CASE: 2

The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 5
Number of loads = 4
Tolerance (eps) = 1.0e-03
Last iteration = 6

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.009	-0.85	0.00	0.00	0.00	-2.52	-1.22	0.90	0.00	0.00
2	11	1.005	-1.28	0.00	0.00	0.00	1.00	0.05	1.00	0.00	0.00
3	11	0.996	-1.83	0.00	0.00	0.00	2.20	0.70	0.95	0.00	0.00
4	11	0.991	-1.57	0.00	0.00	0.00	5.00	2.42	0.90	0.00	0.00
5	13	1.000	0.00	5.69	1.74	0.96	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-4	5.44	1.89		0.00	0.07
1	4-5	-5.44	-1.82	5.76	0.00	0.07
2	4-3	0.44	-0.60		0.00	-0.11
2	3-4	-0.44	0.48	0.74	0.00	-0.11
3	3-1	-1.76	-1.18		0.00	0.03
3	1-3	1.77	1.21	2.14	0.00	0.03
4	5-2	0.25	-0.15		0.00	-0.20
4	2-5	-0.25	-0.04	0.29	0.00	-0.20
5	1-2	0.75	0.01		0.00	0.00
5	2-1	-0.75	-0.01	0.75	0.00	0.00

S_total = 968195.70 kVA, Total_p_loss = 505.50 kW
C_total[2] = 57838.95 kVAR

==

CASE: 3
The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 5
Number of loads = 4
Tolerance (eps) = 1.0e-03
Last iteration = 6

Load flow results
....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.009	-0.85	0.00	0.00	0.00	-2.52	-1.22	0.90	0.00	0.00
2	11	1.006	-1.27	0.00	0.00	0.00	1.00	0.05	1.00	0.00	0.00
3	11	0.997	-1.82	0.00	0.00	0.00	2.20	0.70	0.95	0.00	0.00
4	11	0.991	-1.57	0.00	0.00	0.00	5.00	2.28	0.91	0.00	0.00
5	13	1.000	0.00	5.69	1.59	0.96	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-4	5.44	1.75		0.00	0.06
1	4-5	-5.44	-1.69	5.71	0.00	0.06
2	4-3	0.44	-0.59		0.00	-0.11
2	3-4	-0.44	0.48	0.74	0.00	-0.11
3	3-1	-1.76	-1.18		0.00	0.02
3	1-3	1.77	1.20	2.14	0.00	0.02
4	5-2	0.25	-0.16		0.00	-0.20
4	2-5	-0.25	-0.04	0.30	0.00	-0.20
5	1-2	0.75	0.02		0.00	0.00
5	2-1	-0.75	-0.01	0.75	0.00	0.00

S_total = 963307.03 kVA, Total_p_loss = 504.46 kW
C_total[3] = 14354.32 kVAR

===

CASE: 4

The slack bus is number 5

Base KV = 132.0 kV

Base KVA = 1.0e+05 kVA

Number of buses = 5

Number of lines = 5

Number of loads = 4

Tolerance (eps) = 1.0e-03

Last iteration = 6

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.010	-0.85	0.00	0.00	0.00	-2.52	-1.22	0.90	0.00	0.00
2	11	1.006	-1.27	0.00	0.00	0.00	1.00	0.05	1.00	0.00	0.00
3	11	0.997	-1.82	0.00	0.00	0.00	2.20	0.70	0.95	0.00	0.00
4	11	0.992	-1.57	0.00	0.00	0.00	5.00	2.13	0.92	0.00	0.00
5	13	1.000	0.00	5.69	1.44	0.97	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-4	5.44	1.61		0.00	0.06
1	4-5	-5.44	-1.54	5.67	0.00	0.06
2	4-3	0.44	-0.59		0.00	-0.11
2	3-4	-0.44	0.47	0.73	0.00	-0.11
3	3-1	-1.76	-1.17		0.00	0.02
3	1-3	1.77	1.20	2.13	0.00	0.02
4	5-2	0.25	-0.17		0.00	-0.20
4	2-5	-0.25	-0.03	0.30	0.00	-0.20
5	1-2	0.75	0.02		0.00	0.00
5	2-1	-0.75	-0.02	0.75	0.00	0.00

S_total = 958616.36 kVA, Total_p_loss = 503.44 kW

C_total[4] = 14807.62 kVAR

==

CASE: 5

The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 5
Number of loads = 4
Tolerance (eps) = 1.0e-03
Last iteration = 6

Load flow results
....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.011	-0.85	0.00	0.00	0.00	-2.52	-1.22	0.90	0.00	0.00
2	11	1.007	-1.27	0.00	0.00	0.00	1.00	0.05	1.00	0.00	0.00
3	11	0.998	-1.82	0.00	0.00	0.00	2.20	0.70	0.95	0.00	0.00
4	11	0.993	-1.57	0.00	0.00	0.00	5.00	1.98	0.93	0.00	0.00
5	13	1.000	0.00	5.69	1.28	0.98	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-4	5.44	1.46		0.00	0.06
1	4-5	-5.44	-1.40	5.63	0.00	0.06
2	4-3	0.44	-0.58		0.00	-0.11
2	3-4	-0.44	0.47	0.73	0.00	-0.11
3	3-1	-1.76	-1.17		0.00	0.02
3	1-3	1.77	1.19	2.13	0.00	0.02
4	5-2	0.25	-0.17		0.00	-0.20
4	2-5	-0.25	-0.02	0.30	0.00	-0.20
5	1-2	0.75	0.03		0.00	0.00
5	2-1	-0.75	-0.03	0.76	0.00	0.00

S_total = 954127.57 kVA, Total_p_loss = 502.42 kW
C_total[5] = 15386.46 kVAR

===

CASE: 6

The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 5
Number of loads = 4
Tolerance (eps) = 1.0e-03
Last iteration = 6

Load flow results
....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.011	-0.85	0.00	0.00	0.00	-2.52	-1.22	0.90	0.00	0.00
2	11	1.007	-1.27	0.00	0.00	0.00	1.00	0.05	1.00	0.00	0.00
3	11	0.999	-1.82	0.00	0.00	0.00	2.20	0.70	0.95	0.00	0.00
4	11	0.994	-1.57	0.00	0.00	0.00	5.00	1.81	0.94	0.00	0.00
5	13	1.000	0.00	5.69	1.12	0.98	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-4	5.44	1.30		0.00	0.06
1	4-5	-5.44	-1.24	5.59	0.00	0.06
2	4-3	0.44	-0.57		0.00	-0.11
2	3-4	-0.44	0.46	0.72	0.00	-0.11
3	3-1	-1.76	-1.16		0.00	0.02
3	1-3	1.76	1.18	2.13	0.00	0.02
4	5-2	0.25	-0.18		0.00	-0.20
4	2-5	-0.25	-0.02	0.31	0.00	-0.20
5	1-2	0.76	0.04		0.00	0.00
5	2-1	-0.75	-0.03	0.76	0.00	0.00

S_total = 949848.07 kVA, Total_p_loss = 501.40 kW
C_total[6] = 16136.88 kVAR

CASE: 7

The slack bus is number 5

Base KV = 132.0 kV

Base KVA = 1.0e+05 kVA

Number of buses = 5

Number of lines = 5

Number of loads = 4

Tolerance (eps) = 1.0e-03

Last iteration = 6

Load flow results

....

No.	b_type	Voltage mag	Voltage ang	Generator p	Generator q	Generator pf	Load p	Load q	Load pf	Mismatch d_p	Mismatch d_q
1	11	1.012	-0.85	0.00	0.00	0.00	-2.52	-1.22	0.90	0.00	0.00
2	11	1.008	-1.27	0.00	0.00	0.00	1.00	0.05	1.00	0.00	0.00
3	11	1.000	-1.82	0.00	0.00	0.00	2.20	0.70	0.95	0.00	0.00
4	11	0.994	-1.57	0.00	0.00	0.00	5.00	1.64	0.95	0.00	0.00
5	13	1.000	0.00	5.69	0.95	0.99	0.00	0.00	0.00	0.00	0.00

No.	F-T	Line Flow P	Line Flow Q	Line Flow S	Line Loss P	Line Loss Q
1	5-4	5.44	1.13		0.00	0.06
1	4-5	-5.44	-1.08	5.55	0.00	0.06
2	4-3	0.44	-0.57		0.00	-0.11
2	3-4	-0.44	0.45	0.72	0.00	-0.11
3	3-1	-1.76	-1.15		0.00	0.02
3	1-3	1.76	1.18	2.12	0.00	0.02
4	5-2	0.25	-0.19		0.00	-0.20
4	2-5	-0.25	-0.01	0.31	0.00	-0.20
5	1-2	0.76	0.04		0.00	0.00
5	2-1	-0.75	-0.04	0.76	0.00	0.00

S_total = 945790.82 kVA, Total_p_loss = 500.36 kW

C_total[7] = 17133.71 kVAR

```
CASE: 8
 The slack bus is number    5
 Base KV          = 132.0 kV
 Base KVA         =   1.0e+05  kVA
 Number of buses =   5
 Number of lines =   5
 Number of loads =   4
 Tolerance (eps) =   1.0e-03
 Last iteration  =   6
     Load flow results
    ....................
                Voltage    Generator         Load        Mismatch
              ---------- -------------- ------------- -------------
No. b_type    mag    ang   p     q    pf     p      q    pf   d_p  d_q
 1    11     1.013 -0.85 0.00 0.00 0.00 -2.52 -1.22 0.90 0.00 0.00
 2    11     1.009 -1.26 0.00 0.00 0.00  1.00  0.05 1.00 0.00 0.00
 3    11     1.001 -1.82 0.00 0.00 0.00  2.20  0.64 0.96 0.00 0.00
 4    11     0.996 -1.56 0.00 0.00 0.00  5.00  1.46 0.96 0.00 0.00
 5    13     1.000  0.00 5.68 0.70 0.99  0.00  0.00 0.00 0.00 0.00
                Line Flow        Line Loss
            ---------------   ------------
No. F-T     P     Q      S       P     Q
 1  5-4  5.44  0.90          0.00  0.05
 1  4-5 -5.44 -0.85 5.51     0.00  0.05
 2  4-3  0.44 -0.61          0.00 -0.11
 2  3-4 -0.44  0.50 0.75     0.00 -0.11
 3  3-1 -1.76 -1.14          0.00  0.02
 3  1-3  1.76  1.16 2.11     0.00  0.02
 4  5-2  0.25 -0.20          0.00 -0.20
 4  2-5 -0.25  0.00 0.32     0.00 -0.20
 5  1-2  0.76  0.06          0.00  0.00
 5  2-1 -0.75 -0.05 0.76     0.00  0.00
----------------------------------------------------
S_total = 945326.91 kVA, Total_p_loss =   498.29 kW
C_total[8] = 24342.05 kVAR
==================================================================
```

CASE: 9
The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 5
Number of loads = 4
Tolerance (eps) = 1.0e-03
Last iteration = 6

Load flow results

....

No.	b_type	Voltage mag	Voltage ang	Generator p	Generator q	Generator pf	Load p	Load q	Load pf	Mismatch d_p	Mismatch d_q
1	11	1.015	-0.85	0.00	0.00	0.00	-2.52	-1.22	0.90	0.00	0.00
2	11	1.011	-1.26	0.00	0.00	0.00	1.00	0.05	1.00	0.00	0.00
3	11	1.003	-1.81	0.00	0.00	0.00	2.20	0.55	0.97	0.00	0.00
4	11	0.997	-1.56	0.00	0.00	0.00	5.00	1.25	0.97	0.00	0.00
5	13	1.000	0.00	5.68	0.40	1.00	0.00	0.00	0.00	0.00	0.00

No.	F-T	Line Flow P	Line Flow Q	Line Flow S	Line Loss P	Line Loss Q
1	5-4	5.44	0.62		0.00	0.05
1	4-5	-5.44	-0.57	5.47	0.00	0.05
2	4-3	0.44	-0.68		0.00	-0.11
2	3-4	-0.44	0.57	0.81	0.00	-0.11
3	3-1	-1.76	-1.12		0.00	0.02
3	1-3	1.76	1.14	2.10	0.00	0.02
4	5-2	0.25	-0.22		0.00	-0.20
4	2-5	-0.25	0.02	0.33	0.00	-0.20
5	1-2	0.76	0.08		0.00	0.00
5	2-1	-0.75	-0.07	0.76	0.00	0.00

S_total = 947804.64 kVA, Total_p_loss = 495.90 kW
C_total[9] = 29550.99 kVAR

==

CASE: 10

The slack bus is number 5

Base KV = 132.0 kV

Base KVA = 1.0e+05 kVA

Number of buses = 5

Number of lines = 5

Number of loads = 4

Tolerance (eps) = 1.0e-03

Last iteration = 6

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.018	-0.86	0.00	0.00	0.00	-2.52	-1.22	0.90	0.00	0.00
2	11	1.013	-1.25	0.00	0.00	0.00	1.00	0.05	1.00	0.00	0.00
3	11	1.006	-1.81	0.00	0.00	0.00	2.20	0.45	0.98	0.00	0.00
4	11	0.999	-1.56	0.00	0.00	0.00	5.00	1.02	0.98	0.00	0.00
5	13	1.000	0.00	5.68	0.06	1.00	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-4	5.44	0.30		0.00	0.05
1	4-5	-5.44	-0.25	5.45	0.00	0.05
2	4-3	0.44	-0.77		0.00	-0.11
2	3-4	-0.44	0.65	0.88	0.00	-0.11
3	3-1	-1.76	-1.10		0.00	0.02
3	1-3	1.76	1.12	2.09	0.00	0.02
4	5-2	0.25	-0.24		0.00	-0.20
4	2-5	-0.25	0.05	0.34	0.00	-0.20
5	1-2	0.76	0.10		0.00	0.00
5	2-1	-0.75	-0.10	0.76	0.00	0.00

S_total = 952799.89 kVA, Total_p_loss = 493.64 kW

C_total[10] = 34246.77 kVAR

CASE: 11

```
 The slack bus is number    5
 Base KV          = 132.0 kV
 Base KVA         =   1.0e+05  kVA
 Number of buses =   5
 Number of lines =   5
 Number of loads =   4
 Tolerance (eps) =   1.0e-03
 Last iteration  =   6
```

Load flow results

....

No.	b_type	Voltage mag	Voltage ang	Generator p	Generator q	Generator pf	Load p	Load q	Load pf	Mismatch d_p	Mismatch d_q
1	11	1.020	-0.86	0.00	0.00	0.00	-2.52	-1.22	0.90	0.00	0.00
2	11	1.015	-1.24	0.00	0.00	0.00	1.00	0.05	1.00	0.00	0.00
3	11	1.009	-1.81	0.00	0.00	0.00	2.20	0.31	0.99	0.00	0.00
4	11	1.001	-1.56	0.00	0.00	0.00	5.00	0.71	0.99	0.00	0.00
5	13	1.000	0.00	5.68	-0.38	1.00	0.00	0.00	0.00	0.00	0.00

No.	F-T	Line Flow P	Line Flow Q	Line Flow S	Line Loss P	Line Loss Q
1	5-4	5.44	-0.11		0.00	0.05
1	4-5	-5.44	0.16	5.44	0.00	0.05
2	4-3	0.44	-0.87		0.00	-0.11
2	3-4	-0.44	0.76	0.98	0.00	-0.11
3	3-1	-1.76	-1.07		0.00	0.02
3	1-3	1.76	1.09	2.07	0.00	0.02
4	5-2	0.24	-0.27		0.00	-0.20
4	2-5	-0.24	0.07	0.36	0.00	-0.20
5	1-2	0.76	0.13		0.00	0.00
5	2-1	-0.76	-0.12	0.77	0.00	0.00

S_total = 962488.13 kVA, Total_p_loss =   491.54 kW

C_total[11] = 43607.79 kVAR

===

CASE: 12
The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 5
Number of loads = 4
Tolerance (eps) = 1.0e-03
Last iteration = 6

Load flow results

....

		Voltage		Generator			Load		Mismatch		
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.028	-0.86	0.00	0.00	0.00	-2.52	-1.22	0.90	0.00	0.00
2	11	1.022	-1.23	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00
3	11	1.016	-1.80	0.00	0.00	0.00	2.20	0.00	1.00	0.00	0.00
4	11	1.006	-1.55	0.00	0.00	0.00	5.00	0.00	1.00	0.00	0.00
5	13	1.000	0.00	5.68	-1.45	0.97	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	5-4	5.44	-1.10		0.00	0.05
1	4-5	-5.44	1.15	5.56	0.00	0.05
2	4-3	0.44	-1.15		0.00	-0.11
2	3-4	-0.44	1.04	1.23	0.00	-0.11
3	3-1	-1.76	-1.04		0.00	0.02
3	1-3	1.76	1.06	2.06	0.00	0.02
4	5-2	0.24	-0.35		0.00	-0.19
4	2-5	-0.24	0.15	0.42	0.00	-0.19
5	1-2	0.76	0.16		0.00	0.00
5	2-1	-0.76	-0.15	0.77	0.00	0.00

S_total = 1005253.43 kVA, Total_p_loss = 485.73 kW
C_total[12] = 107594.44 kVAR

==

No.	Dem.Red. ($)	Energy Red. ($)	Capacity Rel. ($)	T.Benefit ($)	Cap.Cost ($)	Savings (pu)
1	182.38	139.80	110335.53	110657.71	52055.05	1.000
2	41.31	31.66	23465.63	23538.60	12918.89	0.181
3	40.98	31.41	22515.19	22587.57	13326.86	0.158
4	40.83	31.29	21546.19	21618.31	13847.82	0.133
5	40.91	31.36	20541.62	20613.89	14523.19	0.104
6	41.31	31.66	19474.81	19547.78	15420.34	0.070
7	82.74	63.42	2226.76	2372.91	21907.85	-0.333
8	95.63	73.30	-11893.14	-11724.21	26595.89	-0.654
9	90.49	69.36	-23977.20	-23817.35	30822.10	-0.932
10	84.04	64.42	-46503.55	-46355.09	39247.01	-1.461
11	232.51	178.22	-205273.41	-204862.69	96835.00	-5.148

Load Flow Output of System # 4

CASE: 1
The slack bus is number 9
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 9
Number of lines = 12
Number of loads = 7
Tolerance (eps) = 1.0e-03
Last iteration = 5

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.999	-7.77	0.00	0.00	0.00	0.02	0.01	0.89	0.00	0.00
2	11	0.986	-9.39	0.00	0.00	0.00	0.52	0.16	0.96	0.00	0.00
3	11	0.957	-12.86	0.00	0.00	0.00	0.23	0.11	0.90	0.00	0.00
4	11	0.965	-11.65	0.00	0.00	0.00	0.18	0.05	0.96	0.00	0.00
5	11	0.956	-14.09	0.00	0.00	0.00	0.94	0.19	0.98	0.00	0.00
6	11	0.972	-11.02	0.00	0.00	0.00	0.43	0.00	1.00	0.00	0.00
7	11	0.957	-11.60	0.00	0.00	0.00	0.30	0.30	0.71	0.00	0.00
8	12	1.050	-5.66	0.40	1.42	0.27	0.22	0.13	0.86	0.00	0.00
9	13	1.060	0.00	2.62	-0.18	1.00	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	9-8	1.80	-0.35		0.06	0.11
1	8-9	-1.75	0.47	1.84	0.06	0.11
2	9-1	0.82	0.18		0.03	0.07
2	1-9	-0.79	-0.10	0.84	0.03	0.07
3	8-2	0.47	0.23		0.01	0.01
3	2-8	-0.45	-0.22	0.52	0.01	0.01
4	1-2	0.77	0.09		0.01	0.01
4	2-1	-0.76	-0.08	0.77	0.01	0.01
5	8-5	0.83	0.33		0.03	0.10
5	5-8	-0.79	-0.23	0.89	0.03	0.10
6	8-6	0.63	0.26		0.03	0.04
6	6-8	-0.61	-0.22	0.69	0.03	0.04
7	2-6	0.70	0.14		0.01	0.01
7	6-2	-0.69	-0.13	0.71	0.01	0.01
8	5-3	-0.15	0.04		0.00	-0.02
8	3-5	0.15	-0.06	0.16	0.00	-0.02

9	6-3	0.38	0.05		0.00	0.00
9	3-6	-0.38	-0.05	0.39	0.00	0.00
10	6-7	0.30	0.25		0.00	0.00
10	7-6	-0.29	-0.25	0.38	0.00	0.00
11	7-4	-0.01	-0.05		0.00	-0.04
11	4-7	0.01	0.01	0.05	0.00	-0.04
12	6-4	0.19	0.05		0.00	-0.01
12	4-6	-0.19	-0.06	0.20	0.00	-0.01

S_total = 744502.90 kVA, Total_p_loss = 18299.58 kW
C_total[1] = 0.00 kVAR

CASE: 2
The slack bus is number 9
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 9
Number of lines = 12
Number of loads = 7
Tolerance (eps) = 1.0e-03
Last iteration = 5

Load flow results

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.006	-7.83	0.00	0.00	0.00	0.02	0.01	0.90	0.00	0.00
2	11	0.994	-9.46	0.00	0.00	0.00	0.52	0.16	0.96	0.00	0.00
3	11	0.966	-12.89	0.00	0.00	0.00	0.23	0.11	0.90	0.00	0.00
4	11	0.978	-11.75	0.00	0.00	0.00	0.18	0.05	0.96	0.00	0.00
5	11	0.962	-14.05	0.00	0.00	0.00	0.94	0.19	0.98	0.00	0.00
6	11	0.983	-11.12	0.00	0.00	0.00	0.43	0.00	1.00	0.00	0.00
7	11	0.975	-11.78	0.00	0.00	0.00	0.30	0.15	0.90	0.00	0.00
8	12	1.050	-5.64	0.40	1.27	0.30	0.22	0.13	0.86	0.00	0.00
9	13	1.060	0.00	2.62	-0.21	1.00	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	9-8	1.79	-0.35		0.06	0.11
1	8-9	-1.74	0.46	1.83	0.06	0.11
2	9-1	0.82	0.14		0.03	0.07
2	1-9	-0.80	-0.07	0.84	0.03	0.07
3	8-2	0.47	0.18		0.01	0.00
3	2-8	-0.45	-0.18	0.50	0.01	0.00

4	1-2	0.77	0.06		0.01	0.01
4	2-1	-0.76	-0.04	0.77	0.01	0.01
5	8-5	0.82	0.30		0.03	0.10
5	5-8	-0.79	-0.21	0.88	0.03	0.10
6	8-6	0.63	0.20		0.02	0.03
6	6-8	-0.61	-0.16	0.66	0.02	0.03
7	2-6	0.70	0.06		0.01	0.01
7	6-2	-0.70	-0.05	0.70	0.01	0.01
8	5-3	-0.15	0.02		0.00	-0.02
8	3-5	0.15	-0.03	0.16	0.00	-0.02
9	6-3	0.39	0.07		0.00	0.00
9	3-6	-0.38	-0.08	0.39	0.00	0.00
10	6-7	0.30	0.11		0.00	0.00
10	7-6	-0.29	-0.11	0.31	0.00	0.00
11	7-4	-0.01	-0.03		0.00	-0.04
11	4-7	0.01	-0.01	0.03	0.00	-0.04
12	6-4	0.19	0.03		0.00	-0.01
12	4-6	-0.19	-0.04	0.19	0.00	-0.01

S_total = 726895.15 kVA, Total_p_loss = 17668.53 kW
C_total[2] = 15507.96 kVAR

===

CASE: 3
The slack bus is number 9
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 9
Number of lines = 12
Number of loads = 7
Tolerance (eps) = 1.0e-03
Last iteration = 5

Load flow results
....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.006	-7.83	0.00	0.00	0.00	0.02	0.01	0.91	0.00	0.00
2	11	0.994	-9.46	0.00	0.00	0.00	0.52	0.16	0.96	0.00	0.00
3	11	0.967	-12.90	0.00	0.00	0.00	0.23	0.10	0.91	0.00	0.00
4	11	0.979	-11.76	0.00	0.00	0.00	0.18	0.05	0.96	0.00	0.00
5	11	0.962	-14.05	0.00	0.00	0.00	0.94	0.19	0.98	0.00	0.00
6	11	0.984	-11.12	0.00	0.00	0.00	0.43	0.00	1.00	0.00	0.00
7	11	0.976	-11.79	0.00	0.00	0.00	0.30	0.14	0.91	0.00	0.00
8	12	1.050	-5.63	0.40	1.26	0.30	0.22	0.13	0.86	0.00	0.00
9	13	1.060	0.00	2.62	-0.21	1.00	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	9-8	1.79	-0.35		0.06	0.11
1	8-9	-1.74	0.46	1.83	0.06	0.11
2	9-1	0.82	0.14		0.03	0.07
2	1-9	-0.80	-0.06	0.84	0.03	0.07
3	8-2	0.47	0.18		0.01	0.00
3	2-8	-0.45	-0.17	0.50	0.01	0.00
4	1-2	0.77	0.05		0.01	0.01
4	2-1	-0.76	-0.04	0.77	0.01	0.01
5	8-5	0.82	0.30		0.03	0.10
5	5-8	-0.79	-0.20	0.88	0.03	0.10
6	8-6	0.63	0.19		0.02	0.03
6	6-8	-0.61	-0.16	0.66	0.02	0.03
7	2-6	0.70	0.06		0.01	0.01
7	6-2	-0.70	-0.04	0.70	0.01	0.01
8	5-3	-0.15	0.01		0.00	-0.02
8	3-5	0.15	-0.03	0.16	0.00	-0.02
9	6-3	0.39	0.07		0.00	0.00
9	3-6	-0.38	-0.08	0.39	0.00	0.00
10	6-7	0.30	0.10		0.00	0.00
10	7-6	-0.29	-0.11	0.31	0.00	0.00
11	7-4	-0.01	-0.03		0.00	-0.04
11	4-7	0.01	-0.01	0.03	0.00	-0.04
12	6-4	0.19	0.03		0.00	-0.01
12	4-6	-0.19	-0.04	0.19	0.00	-0.01

```
S_total = 725805.06 kVA, Total_p_loss = 17619.18 kW
C_total[3] =  1442.17 kVAR
===================================================================

CASE: 4
 The slack bus is number     9
 Base KV            = 132.0 kV
 Base KVA           =    1.0e+05  kVA
 Number of buses =    9
 Number of lines =   12
 Number of loads =    7
 Tolerance (eps) =    1.0e-03
 Last iteration  =    5
     Load flow results
    ...................
```

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.007	-7.84	0.00	0.00	0.00	0.02	0.01	0.92	0.00	0.00
2	11	0.995	-9.47	0.00	0.00	0.00	0.52	0.16	0.96	0.00	0.00
3	11	0.968	-12.91	0.00	0.00	0.00	0.23	0.10	0.92	0.00	0.00
4	11	0.980	-11.76	0.00	0.00	0.00	0.18	0.05	0.96	0.00	0.00
5	11	0.963	-14.05	0.00	0.00	0.00	0.94	0.19	0.98	0.00	0.00
6	11	0.985	-11.13	0.00	0.00	0.00	0.43	0.00	1.00	0.00	0.00
7	11	0.977	-11.80	0.00	0.00	0.00	0.30	0.13	0.92	0.00	0.00
8	12	1.050	-5.63	0.40	1.24	0.31	0.22	0.13	0.86	0.00	0.00
9	13	1.060	0.00	2.62	-0.22	1.00	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	9-8	1.79	-0.35		0.06	0.11
1	8-9	-1.74	0.46	1.83	0.06	0.11
2	9-1	0.82	0.13		0.03	0.07
2	1-9	-0.80	-0.06	0.83	0.03	0.07
3	8-2	0.47	0.17		0.01	0.00
3	2-8	-0.45	-0.17	0.50	0.01	0.00
4	1-2	0.77	0.05		0.01	0.01
4	2-1	-0.76	-0.04	0.77	0.01	0.01
5	8-5	0.82	0.30		0.03	0.10
5	5-8	-0.79	-0.20	0.87	0.03	0.10
6	8-6	0.63	0.19		0.02	0.03
6	6-8	-0.61	-0.15	0.66	0.02	0.03
7	2-6	0.70	0.05		0.01	0.01
7	6-2	-0.70	-0.04	0.70	0.01	0.01
8	5-3	-0.15	0.01		0.00	-0.02
8	3-5	0.15	-0.02	0.16	0.00	-0.02
9	6-3	0.39	0.07		0.00	0.00
9	3-6	-0.38	-0.07	0.39	0.00	0.00
10	6-7	0.30	0.09		0.00	0.00
10	7-6	-0.29	-0.10	0.31	0.00	0.00
11	7-4	-0.01	-0.03		0.00	-0.04
11	4-7	0.01	-0.01	0.03	0.00	-0.04
12	6-4	0.19	0.03		0.00	-0.01
12	4-6	-0.19	-0.04	0.19	0.00	-0.01

S_total = 724636.49 kVA, Total_p_loss = 17564.44 kW
C_total[4] = 1634.76 kVAR

==

CASE: 5

The slack bus is number 9
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 9
Number of lines = 12
Number of loads = 7
Tolerance (eps) = 1.0e-03
Last iteration = 5

Load flow results
....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	g	pf	p	q	pf	d_p	d_g
1	11	1.008	-7.85	0.00	0.00	0.00	0.02	0.01	0.93	0.00	0.00
2	11	0.996	-9.48	0.00	0.00	0.00	0.52	0.16	0.96	0.00	0.00
3	11	0.970	-12.92	0.00	0.00	0.00	0.23	0.09	0.93	0.00	0.00
4	11	0.981	-11.77	0.00	0.00	0.00	0.18	0.05	0.96	0.00	0.00
5	11	0.964	-14.05	0.00	0.00	0.00	0.94	0.19	0.98	0.00	0.00
6	11	0.986	-11.14	0.00	0.00	0.00	0.43	0.00	1.00	0.00	0.00
7	11	0.979	-11.81	0.00	0.00	0.00	0.30	0.12	0.93	0.00	0.00
8	12	1.050	-5.63	0.40	1.23	0.31	0.22	0.13	0.86	0.00	0.00
9	13	1.060	0.00	2.62	-0.22	1.00	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	9-8	1.79	-0.35		0.06	0.11
1	8-9	-1.73	0.46	1.83	0.06	0.11
2	9-1	0.82	0.13		0.03	0.07
2	1-9	-0.80	-0.06	0.83	0.03	0.07
3	8-2	0.47	0.17		0.01	0.00
3	2-8	-0.45	-0.17	0.49	0.01	0.00
4	1-2	0.77	0.05		0.01	0.01
4	2-1	-0.76	-0.03	0.77	0.01	0.01
5	8-5	0.82	0.29		0.03	0.10
5	5-8	-0.79	-0.19	0.87	0.03	0.10
6	8-6	0.63	0.18		0.02	0.03
6	6-8	-0.61	-0.15	0.66	0.02	0.03
7	2-6	0.70	0.04		0.01	0.01
7	6-2	-0.70	-0.03	0.70	0.01	0.01
8	5-3	-0.15	0.00		0.00	-0.02
8	3-5	0.15	-0.02	0.16	0.00	-0.02
9	6-3	0.39	0.07		0.00	0.00
9	3-6	-0.38	-0.07	0.39	0.00	0.00

```
10  6-7  0.30  0.09            0.00  0.00
10  7-6 -0.29 -0.09 0.31       0.00  0.00
11  7-4 -0.01 -0.03            0.00 -0.04
11  4-7  0.01 -0.01 0.03       0.00 -0.04
12  6-4  0.19  0.03            0.00 -0.01
12  4-6 -0.19 -0.04 0.19       0.00 -0.01
---------------------------------------------------
S_total = 723479.39 kVA, Total_p_loss = 17509.38 kW
C_total[5] =  1698.67 kVAR
======================================================================

CASE: 6
 The slack bus is number    9
 Base KV           = 132.0 kV
 Base KVA          =    1.0e+05  kVA
 Number of buses =    9
 Number of lines =   12
 Number of loads =    7
 Tolerance (eps) =    1.0e-03
 Last iteration  =    5
     Load flow results
    ...................
                 Voltage     Generator         Load        Mismatch
                ---------- ------------- ------------- -------------
No. b_type     mag     ang    p     q    pf    p    q    pf   d_p  d_q
 1   11      1.008   -7.85 0.00  0.00 0.00 0.02 0.01 0.94 0.00 0.00
 2   11      0.997   -9.49 0.00  0.00 0.00 0.52 0.16 0.96 0.00 0.00
 3   11      0.971  -12.93 0.00  0.00 0.00 0.23 0.08 0.94 0.00 0.00
 4   11      0.982  -11.78 0.00  0.00 0.00 0.18 0.05 0.96 0.00 0.00
 5   11      0.965  -14.05 0.00  0.00 0.00 0.94 0.19 0.98 0.00 0.00
 6   11      0.987  -11.15 0.00  0.00 0.00 0.43 0.00 1.00 0.00 0.00
 7   11      0.980  -11.83 0.00  0.00 0.00 0.30 0.11 0.94 0.00 0.00
 8   12      1.050   -5.63 0.40  1.21 0.31 0.22 0.13 0.86 0.00 0.00
 9   13      1.060    0.00 2.62 -0.22 1.00 0.00 0.00 0.00 0.00 0.00
                 Line Flow        Line Loss
              --------------   ------------
No. F-T    P     Q      S       P     Q
 1  9-8  1.79 -0.35            0.06  0.11
 1  8-9 -1.73  0.46 1.82       0.06  0.11
 2  9-1  0.82  0.13            0.03  0.07
 2  1-9 -0.80 -0.05 0.83       0.03  0.07
 3  8-2  0.47  0.16            0.01  0.00
 3  2-8 -0.45 -0.16 0.49       0.01  0.00
 4  1-2  0.77  0.04            0.01  0.01
 4  2-1 -0.76 -0.03 0.77       0.01  0.01
```

5	8-5	0.82	0.29		0.03	0.10
5	5-8	-0.79	-0.19	0.87	0.03	0.10
6	8-6	0.63	0.17		0.02	0.03
6	6-8	-0.61	-0.14	0.65	0.02	0.03
7	2-6	0.70	0.03		0.01	0.01
7	6-2	-0.70	-0.02	0.70	0.01	0.01
8	5-3	-0.15	0.00		0.00	-0.02
8	3-5	0.15	-0.02	0.16	0.00	-0.02
9	6-3	0.39	0.06		0.00	0.00
9	3-6	-0.38	-0.07	0.39	0.00	0.00
10	6-7	0.30	0.08		0.00	0.00
10	7-6	-0.29	-0.08	0.30	0.00	0.00
11	7-4	-0.01	-0.03		0.00	-0.04
11	4-7	0.01	-0.01	0.03	0.00	-0.04
12	6-4	0.19	0.03		0.00	-0.01
12	4-6	-0.19	-0.04	0.19	0.00	-0.01

S_total = 722328.94 kVA, Total_p_loss = 17453.60 kW
C_total[6] = 1781.51 kVAR

===

CASE: 7
The slack bus is number 9
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 9
Number of lines = 12
Number of loads = 7
Tolerance (eps) = 1.0e-03
Last iteration = 5

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.009	-7.86	0.00	0.00	0.00	0.02	0.01	0.95	0.00	0.00
2	11	0.998	-9.49	0.00	0.00	0.00	0.52	0.16	0.96	0.00	0.00
3	11	0.973	-12.94	0.00	0.00	0.00	0.23	0.07	0.95	0.00	0.00
4	11	0.983	-11.79	0.00	0.00	0.00	0.18	0.05	0.96	0.00	0.00
5	11	0.966	-14.04	0.00	0.00	0.00	0.94	0.19	0.98	0.00	0.00
6	11	0.988	-11.16	0.00	0.00	0.00	0.43	0.00	1.00	0.00	0.00
7	11	0.982	-11.84	0.00	0.00	0.00	0.30	0.10	0.95	0.00	0.00
8	12	1.050	-5.62	0.40	1.19	0.32	0.22	0.13	0.86	0.00	0.00
9	13	1.060	0.00	2.61	-0.23	1.00	0.00	0.00	0.00	0.00	0.00

No.	F-T	Line Flow P	Line Flow Q	Line Flow S	Line Loss P	Line Loss Q
1	9-8	1.79	-0.35		0.06	0.11
1	8-9	-1.73	0.46	1.82	0.06	0.11
2	9-1	0.83	0.12		0.03	0.07
2	1-9	-0.80	-0.05	0.83	0.03	0.07
3	8-2	0.47	0.16		0.01	0.00
3	2-8	-0.45	-0.16	0.49	0.01	0.00
4	1-2	0.77	0.04		0.01	0.01
4	2-1	-0.77	-0.03	0.77	0.01	0.01
5	8-5	0.82	0.28		0.03	0.10
5	5-8	-0.79	-0.19	0.87	0.03	0.10
6	8-6	0.63	0.17		0.02	0.03
6	6-8	-0.61	-0.14	0.65	0.02	0.03
7	2-6	0.70	0.03		0.01	0.01
7	6-2	-0.70	-0.02	0.70	0.01	0.01
8	5-3	-0.15	0.00		0.00	-0.02
8	3-5	0.15	-0.01	0.16	0.00	-0.02
9	6-3	0.39	0.06		0.00	0.00
9	3-6	-0.38	-0.06	0.39	0.00	0.00
10	6-7	0.30	0.07		0.00	0.00
10	7-6	-0.29	-0.07	0.30	0.00	0.00
11	7-4	-0.01	-0.03		0.00	-0.04
11	4-7	0.01	-0.01	0.03	0.00	-0.04
12	6-4	0.19	0.02		0.00	-0.01
12	4-6	-0.19	-0.04	0.19	0.00	-0.01

```
S_total = 721178.91 kVA, Total_p_loss = 17396.55 kW
C_total[7] =  1891.56 kVAR
=================================================================

CASE: 8
 The slack bus is number    9
 Base KV          = 132.0 kV
 Base KVA         =    1.0e+05  kVA
 Number of buses =    9
 Number of lines =   12
 Number of loads =    7
 Tolerance (eps) =    1.0e-03
 Last iteration  =    5
     Load flow results
    ...................
```

No.	b_type	Voltage mag	Voltage ang	Generator p	Generator q	Generator pf	Load p	Load q	Load pf	Mismatch d_p	Mismatch d_q
1	11	1.010	-7.87	0.00	0.00	0.00	0.02	0.01	0.96	0.00	0.00
2	11	0.999	-9.51	0.00	0.00	0.00	0.52	0.15	0.96	0.00	0.00
3	11	0.975	-12.96	0.00	0.00	0.00	0.23	0.07	0.96	0.00	0.00
4	11	0.985	-11.81	0.00	0.00	0.00	0.18	0.05	0.96	0.00	0.00
5	11	0.967	-14.04	0.00	0.00	0.00	0.94	0.19	0.98	0.00	0.00
6	11	0.990	-11.17	0.00	0.00	0.00	0.43	0.00	1.00	0.00	0.00
7	11	0.984	-11.86	0.00	0.00	0.00	0.30	0.09	0.96	0.00	0.00
8	12	1.050	-5.62	0.40	1.17	0.32	0.22	0.13	0.86	0.00	0.00
9	13	1.060	0.00	2.61	-0.23	1.00	0.00	0.00	0.00	0.00	0.00

No.	F-T	Line Flow P	Line Flow Q	Line Flow S	Line Loss P	Line Loss Q
1	9-8	1.79	-0.35		0.06	0.11
1	8-9	-1.73	0.46	1.82	0.06	0.11
2	9-1	0.83	0.11		0.03	0.07
2	1-9	-0.80	-0.04	0.83	0.03	0.07
3	8-2	0.46	0.15		0.01	0.00
3	2-8	-0.45	-0.15	0.49	0.01	0.00
4	1-2	0.77	0.04		0.01	0.01
4	2-1	-0.77	-0.02	0.77	0.01	0.01
5	8-5	0.82	0.28		0.03	0.09
5	5-8	-0.79	-0.18	0.87	0.03	0.09
6	8-6	0.63	0.16		0.02	0.03
6	6-8	-0.61	-0.13	0.65	0.02	0.03
7	2-6	0.70	0.02		0.01	0.01
7	6-2	-0.70	-0.01	0.70	0.01	0.01
8	5-3	-0.15	-0.01		0.00	-0.02
8	3-5	0.15	-0.01	0.15	0.00	-0.02
9	6-3	0.39	0.06		0.00	0.00
9	3-6	-0.38	-0.06	0.39	0.00	0.00
10	6-7	0.30	0.06		0.00	0.00
10	7-6	-0.29	-0.06	0.30	0.00	0.00
11	7-4	-0.01	-0.02		0.00	-0.04
11	4-7	0.01	-0.02	0.03	0.00	-0.04
12	6-4	0.19	0.02		0.00	-0.01
12	4-6	-0.19	-0.03	0.19	0.00	-0.01

S_total = 719839.74 kVA, Total_p_loss = 17319.13 kW
C_total[8] = 2822.53 kVAR

CASE: 9

The slack bus is number 9
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 9
Number of lines = 12
Number of loads = 7
Tolerance (eps) = 1.0e-03
Last iteration = 5

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.012	-7.90	0.00	0.00	0.00	0.02	0.01	0.97	0.00	0.00
2	11	1.002	-9.53	0.00	0.00	0.00	0.52	0.13	0.97	0.00	0.00
3	11	0.978	-12.97	0.00	0.00	0.00	0.23	0.06	0.97	0.00	0.00
4	11	0.988	-11.83	0.00	0.00	0.00	0.18	0.05	0.97	0.00	0.00
5	11	0.969	-14.03	0.00	0.00	0.00	0.94	0.19	0.98	0.00	0.00
6	11	0.993	-11.20	0.00	0.00	0.00	0.43	0.00	1.00	0.00	0.00
7	11	0.987	-11.89	0.00	0.00	0.00	0.30	0.08	0.97	0.00	0.00
8	12	1.050	-5.61	0.40	1.13	0.33	0.22	0.13	0.86	0.00	0.00
9	13	1.060	0.00	2.61	-0.25	1.00	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	9-8	1.79	-0.35		0.06	0.11
1	8-9	-1.73	0.46	1.82	0.06	0.11
2	9-1	0.83	0.10		0.03	0.07
2	1-9	-0.80	-0.03	0.83	0.03	0.07
3	8-2	0.46	0.13		0.01	0.00
3	2-8	-0.45	-0.13	0.48	0.01	0.00
4	1-2	0.77	0.03		0.01	0.01
4	2-1	-0.77	-0.01	0.77	0.01	0.01
5	8-5	0.82	0.27		0.03	0.09
5	5-8	-0.79	-0.17	0.86	0.03	0.09
6	8-6	0.63	0.14		0.02	0.03
6	6-8	-0.61	-0.11	0.64	0.02	0.03
7	2-6	0.70	0.02		0.01	0.01
7	6-2	-0.70	-0.01	0.70	0.01	0.01
8	5-3	-0.15	-0.02		0.00	-0.02
8	3-5	0.16	0.00	0.16	0.00	-0.02
9	6-3	0.39	0.06		0.00	0.00
9	3-6	-0.38	-0.06	0.39	0.00	0.00
10	6-7	0.30	0.05		0.00	-0.01
10	7-6	-0.29	-0.05	0.30	0.00	-0.01

11	7-4	-0.01	-0.02		0.00	-0.04
11	4-7	0.01	-0.02	0.02	0.00	-0.04
12	6-4	0.19	0.02		0.00	-0.01
12	4-6	-0.19	-0.03	0.19	0.00	-0.01

S_total = 718116.62 kVA, Total_p_loss = 17199.54 kW
C_total[9] = 4843.01 kVAR

CASE: 10

The slack bus is number 9
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 9
Number of lines = 12
Number of loads = 7
Tolerance (eps) = 1.0e-03
Last iteration = 5

Load flow results

		Voltage		Generator			Load		Mismatch		
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.015	-7.92	0.00	0.00	0.00	0.02	0.00	0.98	0.00	0.00
2	11	1.005	-9.56	0.00	0.00	0.00	0.52	0.10	0.98	0.00	0.00
3	11	0.981	-12.99	0.00	0.00	0.00	0.23	0.05	0.98	0.00	0.00
4	11	0.992	-11.86	0.00	0.00	0.00	0.18	0.04	0.98	0.00	0.00
5	11	0.971	-14.02	0.00	0.00	0.00	0.94	0.19	0.98	0.00	0.00
6	11	0.996	-11.22	0.00	0.00	0.00	0.43	0.00	1.00	0.00	0.00
7	11	0.991	-11.92	0.00	0.00	0.00	0.30	0.06	0.98	0.00	0.00
8	12	1.050	-5.60	0.40	1.07	0.35	0.22	0.13	0.86	0.00	0.00
9	13	1.060	0.00	2.61	-0.26	1.00	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	9-8	1.78	-0.35		0.06	0.11
1	8-9	-1.73	0.46	1.82	0.06	0.11
2	9-1	0.83	0.09		0.03	0.07
2	1-9	-0.80	-0.02	0.83	0.03	0.07
3	8-2	0.46	0.12		0.01	0.00
3	2-8	-0.45	-0.12	0.48	0.01	0.00
4	1-2	0.78	0.01		0.01	0.01
4	2-1	-0.77	0.00	0.78	0.01	0.01
5	8-5	0.82	0.25		0.03	0.09
5	5-8	-0.79	-0.16	0.86	0.03	0.09

6	8-6	0.63	0.12		0.02	0.03
6	6-8	-0.61	-0.09	0.64	0.02	0.03
7	2-6	0.70	0.01		0.01	0.01
7	6-2	-0.70	0.00	0.71	0.01	0.01
8	5-3	-0.16	-0.03		0.00	-0.02
8	3-5	0.16	0.01	0.16	0.00	-0.02
9	6-3	0.39	0.05		0.00	0.00
9	3-6	-0.38	-0.06	0.39	0.00	0.00
10	6-7	0.30	0.03		0.00	-0.01
10	7-6	-0.29	-0.04	0.30	0.00	-0.01
11	7-4	-0.01	-0.02		0.00	-0.04
11	4-7	0.01	-0.02	0.02	0.00	-0.04
12	6-4	0.19	0.01		0.00	-0.01
12	4-6	-0.19	-0.02	0.19	0.00	-0.01

S_total = 716497.33 kVA, Total_p_loss = 17067.13 kW
C_total[10] = 5936.11 kVAR

===

CASE: 11

The slack bus is number 9
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 9
Number of lines = 12
Number of loads = 7
Tolerance (eps) = 1.0e-03
Last iteration = 5

Load flow results
....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.020	-7.96	0.00	0.00	0.00	0.02	0.00	0.99	0.00	0.00
2	11	1.010	-9.61	0.00	0.00	0.00	0.52	0.07	0.99	0.00	0.00
3	11	0.990	-13.04	0.00	0.00	0.00	0.23	0.03	0.99	0.00	0.00
4	11	0.999	-11.90	0.00	0.00	0.00	0.18	0.03	0.99	0.00	0.00
5	11	0.981	-14.06	0.00	0.00	0.00	0.94	0.13	0.99	0.00	0.00
6	11	1.003	-11.26	0.00	0.00	0.00	0.43	0.00	1.00	0.00	0.00
7	11	0.998	-11.96	0.00	0.00	0.00	0.30	0.04	0.99	0.00	0.00
8	12	1.050	-5.59	0.40	0.95	0.39	0.22	0.13	0.86	0.00	0.00
9	13	1.060	0.00	2.61	-0.28	0.99	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	9-8	1.78	-0.35		0.06	0.11
1	8-9	-1.72	0.46	1.81	0.06	0.11
2	9-1	0.83	0.06		0.03	0.07
2	1-9	-0.80	0.01	0.83	0.03	0.07
3	8-2	0.46	0.08		0.01	0.00
3	2-8	-0.45	-0.09	0.47	0.01	0.00
4	1-2	0.78	-0.01		0.01	0.01
4	2-1	-0.77	0.02	0.78	0.01	0.01
5	8-5	0.82	0.20		0.03	0.09
5	5-8	-0.79	-0.12	0.84	0.03	0.09
6	8-6	0.63	0.09		0.02	0.02
6	6-8	-0.60	-0.06	0.63	0.02	0.02
7	2-6	0.71	-0.01		0.01	0.01
7	6-2	-0.70	0.02	0.71	0.01	0.01
8	5-3	-0.15	-0.02		0.00	-0.02
8	3-5	0.15	0.00	0.15	0.00	-0.02
9	6-3	0.39	0.03		0.00	0.00
9	3-6	-0.38	-0.03	0.39	0.00	0.00
10	6-7	0.30	0.01		0.00	-0.01
10	7-6	-0.29	-0.02	0.30	0.00	-0.01
11	7-4	-0.01	-0.02		0.00	-0.04
11	4-7	0.01	-0.02	0.02	0.00	-0.04
12	6-4	0.19	0.00		0.00	-0.01
12	4-6	-0.19	-0.01	0.19	0.00	-0.01

S_total = 712220.75 kVA, Total_p_loss = 16775.62 kW
C_total[11] = 13135.91 kVAR

CASE: 12

The slack bus is number 9
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 9
Number of lines = 12
Number of loads = 7
Tolerance (eps) = 1.0e-03
Last iteration = 5

Load flow results

No.	b_type	Voltage mag	ang	Generator p	q	pf	Load p	q	pf	Mismatch d_p	d_q
1	11	1.030	-8.06	0.00	0.00	0.00	0.02	0.00	1.00	0.00	0.00
2	11	1.023	-9.72	0.00	0.00	0.00	0.52	0.00	1.00	0.00	0.00
3	11	1.009	-13.15	0.00	0.00	0.00	0.23	0.00	1.00	0.00	0.00
4	11	1.015	-12.01	0.00	0.00	0.00	0.18	0.00	1.00	0.00	0.00
5	11	1.004	-14.17	0.00	0.00	0.00	0.94	0.00	1.00	0.00	0.00
6	11	1.017	-11.36	0.00	0.00	0.00	0.43	0.00	1.00	0.00	0.00
7	11	1.015	-12.07	0.00	0.00	0.00	0.30	0.00	1.00	0.00	0.00
8	12	1.050	-5.56	0.40	0.68	0.51	0.22	0.13	0.86	0.00	0.00
9	13	1.060	0.00	2.60	-0.34	0.99	0.00	0.00	0.00	0.00	0.00

No.	F-T	Line Flow P	Q	S	Line Loss P	Q
1	9-8	1.77	-0.35		0.06	0.11
1	8-9	-1.72	0.45	1.80	0.06	0.11
2	9-1	0.83	0.00		0.03	0.07
2	1-9	-0.81	0.07	0.83	0.03	0.07
3	8-2	0.46	0.01		0.01	-0.01
3	2-8	-0.45	-0.02	0.46	0.01	-0.01
4	1-2	0.78	-0.07		0.01	0.01
4	2-1	-0.77	0.08	0.78	0.01	0.01
5	8-5	0.82	0.09		0.03	0.08
5	5-8	-0.79	-0.01	0.83	0.03	0.08
6	8-6	0.62	0.00		0.02	0.02
6	6-8	-0.60	0.02	0.62	0.02	0.02
7	2-6	0.71	-0.06		0.01	0.01
7	6-2	-0.70	0.07	0.71	0.01	0.01
8	5-3	-0.15	0.01		0.00	-0.02
8	3-5	0.15	-0.02	0.15	0.00	-0.02
9	6-3	0.38	-0.03		0.00	-0.01
9	3-6	-0.38	0.02	0.38	0.00	-0.01
10	6-7	0.30	-0.03		0.00	-0.01
10	7-6	-0.29	0.02	0.30	0.00	-0.01
11	7-4	-0.01	-0.02		0.00	-0.04
11	4-7	0.01	-0.02	0.02	0.00	-0.04
12	6-4	0.19	-0.03		0.00	-0.01
12	4-6	-0.19	0.02	0.19	0.00	-0.01

S_total = 708234.17 kVA, Total_p_loss = 16361.06 kW
C_total[12] = 31205.81 kVAR

No.	Dem.Red. ($)	Energy Red. ($)	Capacity Rel. ($)	T.Benefit ($)	Cap.Cost ($)	Savings (pu)
1	25241.93	19347.94	84517.24	129107.11	13957.17	1.000
2	1974.27	1513.28	5232.41	8719.96	1297.96	0.064
3	2189.31	1678.10	5609.16	9476.57	1471.29	0.070
4	2202.44	1688.17	5554.05	9444.66	1528.80	0.069
5	2231.26	1710.26	5522.16	9463.68	1603.36	0.068
6	2281.87	1749.05	5520.15	9551.07	1702.41	0.068
7	3096.89	2373.77	6428.03	11898.69	2540.28	0.081
8	4783.82	3666.80	8270.96	16721.58	4358.70	0.107
9	5296.18	4059.52	7772.57	17128.27	5342.50	0.102
10	11660.58	8937.83	20527.62	41126.03	11822.32	0.254
11	16582.24	12710.28	19135.55	48428.07	28085.23	0.177

Load Flow Output of System # 5

CASE: 1
The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 5
Number of loads = 3
Tolerance (eps) = 1.0e-03
Last iteration = 7

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.936	-19.97	0.00	0.00	0.00	2.00	0.70	0.94	0.00	0.00
2	11	1.043	-2.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	11	1.009	-4.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	12	1.050	-0.45	1.30	0.21	0.99	0.20	0.10	0.89	0.00	0.00
5	13	1.000	0.00	0.97	-0.15	0.99	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	1-2	-0.73	-0.45		0.02	-0.60
1	2-1	0.75	-0.15	0.86	0.02	-0.60
2	1-3	-1.27	-0.25		0.03	-0.05
2	3-1	1.30	0.20	1.32	0.03	-0.05
3	2-3	0.34	0.21		0.00	-0.21
3	3-2	-0.34	-0.42	0.54	0.00	-0.21
4	5-3	0.97	-0.15		0.01	0.08
4	3-5	-0.96	0.22	0.99	0.01	0.08
5	4-2	1.10	0.11		0.00	0.04
5	2-4	-1.10	-0.07	1.11	0.00	0.04

S_total = 481334.79 kVA, Total_p_loss = 6625.82 kW
C_total[1] = 0.00 kVAR

===

```
CASE: 2
 The slack bus is number    5
 Base KV          = 132.0 kV
 Base KVA         =   1.0e+05  kVA
 Number of buses =   5
 Number of lines =   5
 Number of loads =   3
 Tolerance (eps) =   1.0e-03
 Last iteration  =   7
     Load flow results
    ...................
              Voltage    Generator        Load       Mismatch
             ---------- -------------- ------------- ------------
No. b_type   mag   ang    p     q   pf    p    q    pf  d_p  d_q
 1   11     0.948 -19.76 0.00  0.00 0.00 2.00 0.66 0.95 0.00 0.00
 2   11     1.045  -2.73 0.00  0.00 0.00 0.00 0.00 0.00 0.00 0.00
 3   11     1.012  -4.44 0.00  0.00 0.00 0.00 0.00 0.00 0.00 0.00
 4   12     1.050  -0.44 1.30  0.17 0.99 0.20 0.10 0.89 0.00 0.00
 5   13     1.000   0.00 0.96 -0.18 0.98 0.00 0.00 0.00 0.00 0.00
              Line Flow       Line Loss
           ---------------   ------------
No. F-T    P     Q      S      P    Q
 1  1-2  -0.73 -0.44         0.02 -0.62
 1  2-1   0.75 -0.18 0.85    0.02 -0.62
 2  1-3  -1.27 -0.22         0.03 -0.06
 2  3-1   1.30  0.15 1.31    0.03 -0.06
 3  2-3   0.34  0.20         0.00 -0.21
 3  3-2  -0.34 -0.41 0.54    0.00 -0.21
 4  5-3   0.96 -0.18         0.01  0.08
 4  3-5  -0.96  0.26 0.99    0.01 0.08
 5  4-2   1.10  0.07         0.00 0.04
 5  2-4  -1.10 -0.02 1.10    0.00 0.04
---------------------------------------------------
S_total = 479616.17 kVA, Total_p_loss =  6467.10 kW
C_total[2] =  4263.18 kVAR
=================================================================
```

CASE: 3
The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 5
Number of loads = 3
Tolerance (eps) = 1.0e-03
Last iteration = 6

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.968	-19.42	0.00	0.00	0.00	2.00	0.58	0.96	0.00	0.00
2	11	1.048	-2.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	11	1.017	-4.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	12	1.050	-0.42	1.30	0.10	1.00	0.20	0.10	0.89	0.00	0.00
5	13	1.000	0.00	0.96	-0.24	0.97	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	1-2	-0.73	-0.42		0.02	-0.65
1	2-1	0.75	-0.22	0.84	0.02	-0.65
2	1-3	-1.27	-0.16		0.03	-0.09
2	3-1	1.30	0.07	1.30	0.03	-0.09
3	2-3	0.35	0.18		0.00	-0.22
3	3-2	-0.34	-0.39	0.52	0.00	-0.22
4	5-3	0.96	-0.24		0.01	0.08
4	3-5	-0.96	0.32	1.01	0.01	0.08
5	4-2	1.10	0.00		0.00	0.04
5	2-4	-1.10	0.05	1.10	0.00	0.04

S_total = 477820.01 kVA, Total_p_loss = 6242.33 kW
C_total[3] = 7403.49 kVAR

==

CASE: 4
The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 5
Number of loads = 3
Tolerance (eps) = 1.0e-03
Last iteration = 6

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.989	-19.09	0.00	0.00	0.00	2.00	0.50	0.97	0.00	0.00
2	11	1.051	-2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	11	1.022	-4.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	12	1.050	-0.40	1.30	0.03	1.00	0.20	0.10	0.89	0.00	0.00
5	13	1.000	0.00	0.96	-0.31	0.95	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	1-2	-0.73	-0.40		0.02	-0.68
1	2-1	0.75	-0.27	0.83	0.02	-0.68
2	1-3	-1.27	-0.10		0.03	-0.11
2	3-1	1.30	-0.01	1.30	0.03	-0.11
3	2-3	0.35	0.16		0.00	-0.22
3	3-2	-0.34	-0.37	0.51	0.00	-0.22
4	5-3	0.96	-0.31		0.01	0.08
4	3-5	-0.95	0.39	1.03	0.01	0.08
5	4-2	1.10	-0.07		0.00	0.04
5	2-4	-1.10	0.12	1.10	0.00	0.04

S_total = 477436.30 kVA, Total_p_loss = 6059.19 kW
C_total[4] = 8208.61 kVAR

==

```
CASE: 5
 The slack bus is number    5
 Base KV          = 132.0 kV
 Base KVA         =   1.0e+05  kVA
 Number of buses =   5
 Number of lines =   5
 Number of loads =   3
 Tolerance (eps) =   1.0e-03
 Last iteration  =   5
     Load flow results
    ...................
               Voltage    Generator        Load       Mismatch
               ---------- -------------- ------------- ------------
No. b_type    mag    ang    p     q    pf    p    q    pf   d_p   d_q
 1   11      1.011 -18.75 0.00  0.00 0.00 2.00 0.41 0.98 0.00 0.00
 2   11      1.054  -2.69 0.00  0.00 0.00 0.00 0.00 0.00 0.00 0.00
 3   11      1.027  -4.41 0.00  0.00 0.00 0.00 0.00 0.00 0.00 0.00
 4   12      1.050  -0.39 1.30 -0.05 1.00 0.20 0.10 0.89 0.00 0.00
 5   13      1.000   0.00 0.96 -0.37 0.93 0.00 0.00 0.00 0.00 0.00
               Line Flow       Line Loss
             --------------- ------------
No. F-T     P     Q     S      P     Q
 1  1-2  -0.73 -0.38         0.02 -0.71
 1  2-1   0.75 -0.33 0.82    0.02 -0.71
 2  1-3  -1.27 -0.03         0.03 -0.13
 2  3-1   1.30 -0.11 1.30    0.03 -0.13
 3  2-3   0.35  0.13         0.00 -0.22
 3  3-2  -0.35 -0.35 0.49    0.00 -0.22
 4  5-3   0.96 -0.37         0.01  0.08
 4  3-5  -0.95  0.46 1.06    0.01  0.08
 5  4-2   1.10 -0.15         0.00  0.04
 5  2-4  -1.10  0.20 1.11    0.00  0.04
-------------------------------------------------------
S_total = 478921.36 kVA, Total_p_loss =  5916.83 kW
C_total[5] =  9512.99 kVAR
=================================================================
```

CASE: 6

The slack bus is number 5

Base KV = 132.0 kV

Base KVA = 1.0e+05 kVA

Number of buses = 5

Number of lines = 5

Number of loads = 3

Tolerance (eps) = 1.0e-03

Last iteration = 4

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.038	-18.38	0.00	0.00	0.00	2.00	0.28	0.99	0.00	0.00
2	11	1.057	-2.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	11	1.034	-4.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	12	1.050	-0.38	1.30	-0.15	0.99	0.20	0.10	0.89	0.00	0.00
5	13	1.000	0.00	0.96	-0.45	0.90	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	1-2	-0.73	-0.34		0.02	-0.74
1	2-1	0.75	-0.40	0.85	0.02	-0.74
2	1-3	-1.27	0.06		0.03	-0.16
2	3-1	1.30	-0.22	1.32	0.03	-0.16
3	2-3	0.35	0.10		0.00	-0.23
3	3-2	-0.35	-0.33	0.48	0.00	-0.23
4	5-3	0.96	-0.45		0.01	0.09
4	3-5	-0.95	0.54	1.10	0.01	0.09
5	4-2	1.10	-0.25		0.00	0.05
5	2-4	-1.10	0.29	1.14	0.00	0.05

S_total = 486862.96 kVA, Total_p_loss = 5826.15 kW

C_total[6] = 12113.28 kVAR

CASE: 7
The slack bus is number 5
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 5
Number of lines = 5
Number of loads = 3
Tolerance (eps) = 1.0e-03
Last iteration = 5
Load flow results
....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.095	-17.68	0.00	0.00	0.00	2.00	0.00	1.00	0.00	0.00
2	11	1.065	-2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	11	1.047	-4.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	12	1.050	-0.37	1.30	-0.35	0.97	0.20	0.10	0.89	0.00	0.00
5	13	1.000	0.00	0.96	-0.62	0.84	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	1-2	-0.73	-0.27		0.02	-0.80
1	2-1	0.75	-0.54	0.92	0.02	-0.80
2	1-3	-1.27	0.27		0.03	-0.19
2	3-1	1.30	-0.46	1.38	0.03	-0.19
3	2-3	0.35	0.04		0.00	-0.23
3	3-2	-0.35	-0.27	0.44	0.00	-0.23
4	5-3	0.96	-0.62		0.01	0.10
4	3-5	-0.95	0.73	1.20	0.01	0.10
5	4-2	1.10	-0.45		0.00	0.05
5	2-4	-1.10	0.50	1.20	0.00	0.05

S_total = 513774.30 kVA, Total_p_loss = 5913.29 kW
C_total[7] = 28498.46 kVAR

==

No.	Dem.Red. ($)	Energy Red. ($)	Capacity Rel. ($)	T.Benefit ($)	Cap.Cost ($)	Savings (pu)
1	6348.81	4866.36	8249.39	19464.57	3836.86	1.000
2	8991.07	6891.66	8621.57	24504.30	6663.14	1.142
3	7325.41	5614.93	1841.81	14782.15	7387.75	0.473
4	5694.40	4364.75	-7128.29	2930.86	8561.69	-0.360
5	3627.33	2780.35	-38119.70	-31712.03	10901.95	-2.727
6	-3485.81	-2671.87	-129174.41	-135332.09	25648.61	-10.301

Load Flow Output of System # 6

CASE: 1
The slack bus is number 6
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 6
Number of lines = 8
Number of loads = 5
Tolerance (eps) = 1.0e-02
Last iteration = 370

Load flow results

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.999	-0.27	0.00	0.00	0.00	0.75	0.12	0.99	-0.01	0.00
2	11	0.999	-0.32	0.00	0.00	0.00	0.10	0.01	1.00	0.00	0.00
3	11	0.998	-0.27	0.00	0.00	0.00	0.05	0.01	0.98	0.01	0.01
4	11	0.997	-0.25	0.00	0.00	0.00	0.10	0.10	0.71	-0.01	0.00
5	11	0.997	-0.21	0.00	0.00	0.00	1.00	0.80	0.78	0.00	0.00
6	13	1.000	0.00	2.00	1.05	0.89	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	1-2	0.10	0.01		0.00	0.00
1	2-1	-0.10	-0.01	0.10	0.00	0.00
2	1-3	0.07	0.07		0.00	0.00
2	3-1	-0.07	-0.07	0.10	0.00	0.00
3	1-6	-0.92	-0.20		0.00	0.00
3	6-1	0.92	0.20	0.95	0.00	0.00
4	3-4	0.03	0.06		0.00	0.00
4	4-3	-0.03	-0.06	0.06	0.00	0.00
5	4-5	-0.08	-0.04		0.00	0.00
5	5-4	0.08	0.04	0.09	0.00	0.00
6	5-6	-0.36	-0.28		0.00	0.00
6	6-5	0.36	0.28	0.46	0.00	0.00
7	5-6	-0.36	-0.28		0.00	0.00
7	6-5	0.36	0.28	0.46	0.00	0.00
8	5-6	-0.36	-0.28		0.00	0.00
8	6-5	0.36	0.28	0.46	0.00	0.00

S_total = 266558.14 kVA, Total_p_loss = 13.65 kW
C_total[1] = 0.00 kVAR

CASE: 2

The slack bus is number 6
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 6
Number of lines = 8
Number of loads = 5
Tolerance (eps) = 1.0e-02
Last iteration = 528

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.999	-0.26	0.00	0.00	0.00	0.75	0.12	0.99	0.00	0.00
2	11	0.999	-0.32	0.00	0.00	0.00	0.10	0.01	1.00	0.00	0.00
3	11	0.998	-0.27	0.00	0.00	0.00	0.05	0.01	0.98	0.01	0.01
4	11	0.998	-0.26	0.00	0.00	0.00	0.10	0.05	0.90	0.00	0.00
5	11	0.998	-0.21	0.00	0.00	0.00	1.00	0.48	0.90	0.00	0.00
6	13	1.000	0.00	2.00	0.68	0.95	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	1-2	0.10	0.01		0.00	0.00
1	2-1	-0.10	-0.01	0.10	0.00	0.00
2	1-3	0.05	0.03		0.00	0.00
2	3-1	-0.05	-0.03	0.06	0.00	0.00
3	1-6	-0.91	-0.16		0.00	0.00
3	6-1	0.91	0.17	0.92	0.00	0.00
4	3-4	0.01	0.02		0.00	0.00
4	4-3	-0.01	-0.02	0.02	0.00	0.00
5	4-5	-0.09	-0.03		0.00	0.00
5	5-4	0.09	0.03	0.10	0.00	0.00
6	5-6	-0.36	-0.17		0.00	0.00
6	6-5	0.36	0.17	0.40	0.00	0.00
7	5-6	-0.36	-0.17		0.00	0.00
7	6-5	0.36	0.17	0.40	0.00	0.00
8	5-6	-0.36	-0.17		0.00	0.00
8	6-5	0.36	0.17	0.40	0.00	0.00

S_total = 241362.00 kVA, Total_p_loss = 4.20 kW
C_total[2] = 36724.57 kVAR

CASE: 3
The slack bus is number 6
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 6
Number of lines = 8
Number of loads = 5
Tolerance (eps) = 1.0e-02
Last iteration = 545
Load flow results
....

No.	b_type	Voltage mag	Voltage ang	Generator p	Generator q	Generator pf	Load p	Load q	Load pf	Mismatch d_p	Mismatch d_q
1	11	0.999	-0.26	0.00	0.00	0.00	0.75	0.12	0.99	0.01	0.00
2	11	0.999	-0.32	0.00	0.00	0.00	0.10	0.01	1.00	0.00	0.00
3	11	0.998	-0.28	0.00	0.00	0.00	0.05	0.01	0.98	-0.01	-0.01
4	11	0.998	-0.26	0.00	0.00	0.00	0.10	0.05	0.91	0.01	0.00
5	11	0.998	-0.21	0.00	0.00	0.00	1.00	0.46	0.91	0.00	0.00
6	13	1.000	0.00	2.00	0.65	0.95	0.00	0.00	0.00	0.00	0.00

No.	F-T	Line Flow P	Line Flow Q	Line Flow S	Line Loss P	Line Loss Q
1	1-2	0.10	0.01		0.00	0.00
1	2-1	-0.10	-0.01	0.10	0.00	0.00
2	1-3	0.06	0.03		0.00	0.00
2	3-1	-0.06	-0.03	0.07	0.00	0.00
3	1-6	-0.90	-0.16		0.00	0.00
3	6-1	0.90	0.16	0.92	0.00	0.00
4	3-4	0.00	0.02		0.00	0.00
4	4-3	0.00	-0.02	0.02	0.00	0.00
5	4-5	-0.10	-0.03		0.00	0.00
5	5-4	0.10	0.03	0.10	0.00	0.00
6	5-6	-0.37	-0.16		0.00	0.00
6	6-5	0.37	0.16	0.40	0.00	0.00
7	5-6	-0.37	-0.16		0.00	0.00
7	6-5	0.37	0.16	0.40	0.00	0.00
8	5-6	-0.37	-0.16		0.00	0.00
8	6-5	0.37	0.16	0.40	0.00	0.00

S_total = 240329.00 kVA, Total_p_loss = 4.74 kW
C_total[3) = 3157.95 kVAR

CASE: 4
The slack bus is number 6
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 6
Number of lines = 8
Number of loads = 5
Tolerance (eps) = 1.0e-02
Last iteration = 565
Load flow results
....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.999	-0.26	0.00	0.00	0.00	0.75	0.12	0.99	0.01	0.00
2	11	0.999	-0.32	0.00	0.00	0.00	0.10	0.01	1.00	0.00	0.00
3	11	0.998	-0.28	0.00	0.00	0.00	0.05	0.01	0.98	-0.01	-0.01
4	11	0.998	-0.27	0.00	0.00	0.00	0.10	0.04	0.92	0.01	0.00
5	11	0.998	-0.21	0.00	0.00	0.00	1.00	0.43	0.92	0.00	0.00
6	13	1.000	0.00	2.00	0.62	0.96	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	1-2	0.10	0.01		0.00	0.00
1	2-1	-0.10	-0.01	0.10	0.00	0.00
2	1-3	0.06	0.03		0.00	0.00
2	3-1	-0.06	-0.03	0.06	0.00	0.00
3	1-6	-0.90	-0.16		0.00	0.00
3	6-1	0.90	0.16	0.92	0.00	0.00
4	3-4	0.00	0.02		0.00	0.00
4	4-3	0.00	-0.02	0.02	0.00	0.00
5	4-5	-0.10	-0.03		0.00	0.00
5	5-4	0.10	0.03	0.10	0.00	0.00
6	5-6	-0.37	-0.15		0.00	0.00
6	6-5	0.37	0.15	0.40	0.00	0.00
7	5-6	-0.37	-0.15		0.00	0.00
7	6-5	0.37	0.15	0.40	0.00	0.00
8	5-6	-0.37	-0.15		0.00	0.00
8	6-5	0.37	0.15	0.40	0.00	0.00

S_total = 238704.16 kVA, Total_p_loss = 4.31 kW
C_total[4] = 3257.68 kVAR

===

CASE: 5
The slack bus is number 6
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 6
Number of lines = 8
Number of loads = 5
Tolerance (eps) = 1.0e-02
Last iteration = 587

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.999	-0.26	0.00	0.00	0.00	0.75	0.12	0.99	0.01	0.00
2	11	0.999	-0.32	0.00	0.00	0.00	0.10	0.01	1.00	0.00	0.00
3	11	0.998	-0.28	0.00	0.00	0.00	0.05	0.01	0.98	-0.01	-0.01
4	11	0.998	-0.27	0.00	0.00	0.00	0.10	0.04	0.93	0.01	0.00
5	11	0.999	-0.21	0.00	0.00	0.00	1.00	0.40	0.93	0.00	0.00
6	13	1.000	0.00	2.00	0.58	0.96	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	1-2	0.10	0.01		0.00	0.00
1	2-1	-0.10	-0.01	0.10	0.00	0.00
2	1-3	0.06	0.02		0.00	0.00
2	3-1	-0.06	-0.02	0.06	0.00	0.00
3	1-6	-0.90	-0.15		0.00	0.00
3	6-1	0.90	0.16	0.91	0.00	0.00
4	3-4	0.00	0.01		0.00	0.00
4	4-3	0.00	-0.01	0.01	0.00	0.00
5	4-5	-0.10	-0.03		0.00	0.00
5	5-4	0.10	0.03	0.10	0.00	0.00
6	5-6	-0.37	-0.14		0.00	0.00
6	6-5	0.37	0.14	0.39	0.00	0.00
7	5-6	-0.37	-0.14		0.00	0.00
7	6-5	0.37	0.14	0.39	0.00	0.00
8	5-6	-0.37	-0.14		0.00	0.00
8	6-5	0.37	0.14	0.39	0.00	0.00

S_total = 237117.48 kVA, Total_p_loss = 3.91 kW
C_total[5] = 3385.02 kVAR

==

CASE: 6

The slack bus is number 6

Base KV = 132.0 kV

Base KVA = 1.0e+05 kVA

Number of buses = 6

Number of lines = 8

Number of loads = 5

Tolerance (eps) = 1.0e-02

Last iteration = 612

Load flow results

....

No.	b_type	Voltage mag	Voltage ang	Generator p	Generator q	Generator pf	Load p	Load q	Load pf	Mismatch d_p	Mismatch d_q
1	11	0.999	-0.26	0.00	0.00	0.00	0.75	0.12	0.99	-0.01	0.00
2	11	0.999	-0.32	0.00	0.00	0.00	0.10	0.01	1.00	0.00	0.00
3	11	0.999	-0.27	0.00	0.00	0.00	0.05	0.01	0.98	0.01	0.01
4	11	0.998	-0.27	0.00	0.00	0.00	0.10	0.04	0.94	-0.01	0.00
5	11	0.999	-0.21	0.00	0.00	0.00	1.00	0.36	0.94	0.00	0.00
6	13	1.000	0.00	2.00	0.55	0.96	0.00	0.00	0.00	0.00	0.00

No.	F-T	Line Flow P	Line Flow Q	Line Flow S	Line Loss P	Line Loss Q
1	1-2	0.10	0.01		0.00	0.00
1	2-1	-0.10	-0.01	0.10	0.00	0.00
2	1-3	0.04	0.02		0.00	0.00
2	3-1	-0.04	-0.02	0.05	0.00	0.00
3	1-6	-0.90	-0.15		0.00	0.00
3	6-1	0.90	0.15	0.91	0.00	0.00
4	3-4	0.00	0.01		0.00	0.00
4	4-3	0.00	-0.01	0.01	0.00	0.00
5	4-5	-0.10	-0.03		0.00	0.00
5	5-4	0.10	0.03	0.10	0.00	0.00
6	5-6	-0.37	-0.13		0.00	0.00
6	6-5	0.37	0.13	0.39	0.00	0.00
7	5-6	-0.37	-0.13		0.00	0.00
7	6-5	0.37	0.13	0.39	0.00	0.00
8	5-6	-0.37	-0.13		0.00	0.00
8	6-5	0.37	0.13	0.39	0.00	0.00

S_total = 234618.04 kVA, Total_p_loss = 2.54 kW

C_total[6] = 3550.11 kVAR

CASE: 7

The slack bus is number 6

Base KV = 132.0 kV

Base KVA = 1.0e+05 kVA

Number of buses = 6

Number of lines = 8

Number of loads = 5

Tolerance (eps) = 1.0e-02

Last iteration = 641

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.999	-0.26	0.00	0.00	0.00	0.75	0.12	0.99	0.01	0.00
2	11	0.999	-0.31	0.00	0.00	0.00	0.10	0.01	1.00	0.00	0.00
3	11	0.999	-0.28	0.00	0.00	0.00	0.05	0.01	0.98	-0.01	-0.01
4	11	0.999	-0.27	0.00	0.00	0.00	0.10	0.03	0.95	0.01	0.00
5	11	0.999	-0.21	0.00	0.00	0.00	1.00	0.33	0.95	0.00	0.00
6	13	1.000	0.00	2.00	0.51	0.97	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	1-2	0.10	0.01		0.00	0.00
1	2-1	-0.10	-0.01	0.10	0.00	0.00
2	1-3	0.05	0.02		0.00	0.00
2	3-1	-0.05	-0.02	0.06	0.00	0.00
3	1-6	-0.90	-0.15		0.00	0.00
3	6-1	0.90	0.15	0.91	0.00	0.00
4	3-4	-0.01	0.01		0.00	0.00
4	4-3	0.01	-0.01	0.01	0.00	0.00
5	4-5	-0.10	-0.03		0.00	0.00
5	5-4	0.10	0.03	0.11	0.00	0.00
6	5-6	-0.37	-0.12		0.00	0.00
6	6-5	0.37	0.12	0.39	0.00	0.00
7	5-6	-0.37	-0.12		0.00	0.00
7	6-5	0.37	0.12	0.39	0.00	0.00
8	5-6	-0.37	-0.12		0.00	0.00
8	6-5	0.37	0.12	0.39	0.00	0.00

S_total = 234135.35 kVA, Total_p_loss = 3.19 kW

C_total[7] = 3769.42 kVAR

===

CASE: 8

The slack bus is number 6
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 6
Number of lines = 8
Number of loads = 5
Tolerance (eps) = 1.0e-02
Last iteration = 676

Load flow results

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.999	-0.26	0.00	0.00	0.00	0.75	0.12	0.99	-0.01	0.00
2	11	0.999	-0.31	0.00	0.00	0.00	0.10	0.01	1.00	0.00	0.00
3	11	0.999	-0.27	0.00	0.00	0.00	0.05	0.01	0.98	0.01	0.01
4	11	0.999	-0.27	0.00	0.00	0.00	0.10	0.03	0.96	-0.01	0.00
5	11	0.999	-0.21	0.00	0.00	0.00	1.00	0.29	0.96	0.00	0.00
6	13	1.000	0.00	2.00	0.47	0.97	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	1-2	0.10	0.01		0.00	0.00
1	2-1	-0.10	-0.01	0.10	0.00	0.00
2	1-3	0.04	0.01		0.00	0.00
2	3-1	-0.04	-0.01	0.04	0.00	0.00
3	1-6	-0.90	-0.14		0.00	0.00
3	6-1	0.90	0.15	0.91	0.00	0.00
4	3-4	-0.00	0.00		0.00	0.00
4	4-3	0.00	0.00	0.00	0.00	0.00
5	4-5	-0.10	-0.03		0.00	0.00
5	5-4	-0.10	0.03	0.11	0.00	0.00
6	5-6	-0.3	-0.11		0.00	0.00
6	6-5	0.37	0.11	0.38	0.00	0.00
7	5-6	-0.37	-0.11		0.00	0.00
7	6-5	0.37	0.11	0.38	0.00	0.00
8	5-6	-0.37	-0.11		0.00	0.00
8	6-5	0.37	0.11	0.38	0.00	0.00

S_total = 231270.97 kVA, Total_p_loss = 1.88 kW
C_total[8] = 4071.92 kVAR

CASE: 9

The slack bus is number 6
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 6
Number of lines = 8
Number of loads = 5
Tolerance (eps) = 1.0e-02
Last iteration = 719

Load flow results
....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.999	-0.26	0.00	0.00	0.00	0.75	0.12	0.99	0.01	0.00
2	11	0.999	-0.31	0.00	0.00	0.00	0.10	0.01	1.00	0.00	0.00
3	11	0.999	-0.28	0.00	0.00	0.00	0.05	0.01	0.98	-0.01	-0.01
4	11	0.999	-0.27	0.00	0.00	0.00	0.10	0.03	0.97	0.01	0.00
5	11	0.999	-0.21	0.00	0.00	0.00	1.00	0.25	0.97	0.00	0.00
6	13	1.000	0.00	2.00	0.42	0.98	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	1-2	0.10	0.01		0.00	0.00
1	2-1	-0.10	-0.01	0.10	0.00	0.00
2	1-3	0.05	0.01		0.00	0.00
2	3-1	-0.05	-0.01	0.05	0.00	0.00
3	1-6	-0.89	-0.14		0.00	0.00
3	6-1	0.89	0.14	0.91	0.00	0.00
4	3-4	-0.01	0.00		0.00	0.00
4	4-3	0.01	0.00	0.01	0.00	0.00
5	4-5	-0.11	-0.03		0.00	0.00
5	5-4	0.11	0.03	0.11	0.00	0.00
6	5-6	-0.37	-0.09		0.00	0.00
6	6-5	0.37	0.09	0.38	0.00	0.00
7	5-6	-0.37	-0.09		0.00	0.00
7	6-5	0.37	0.09	0.38	0.00	0.00
8	5-6	-0.37	-0.09		0.00	0.00
8	6-5	0.37	0.09	0.38	0.00	0.00

S_total = 231717.31 kVA, Total_p_loss = 2.61 kW
C_total[9] = 4514.73 kVAR

CASE: 10
The slack bus is number 6
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 6
Number of lines = 8
Number of loads = 5
Tolerance (eps) = 1.0e-02
Last iteration = 777

Load flow results
....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	0.999	-0.26	0.00	0.00	0.00	0.75	0.12	0.99	0.00	0.00
2	11	0.999	-0.31	0.00	0.00	0.00	0.10	0.01	1.00	0.00	0.00
3	11	0.999	-0.28	0.00	0.00	0.00	0.05	0.01	0.98	-0.01	-0.01
4	11	0.999	-0.27	0.00	0.00	0.00	0.10	0.02	0.98	0.00	0.00
5	11	0.999	-0.21	0.00	0.00	0.00	1.00	0.20	0.98	0.00	0.00
6	13	1.000	0.00	2.00	0.37	0.98	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	1-2	0.10	0.01		0.00	0.00
1	2-1	-0.10	-0.01	0.10	0.00	0.00
2	1-3	0.05	0.01		0.00	0.00
2	3-1	-0.05	-0.01	0.05	0.00	0.00
3	1-6	-0.89	-0.14		0.00	0.00
3	6-1	0.89	0.14	0.90	0.00	0.00
4	3-4	-0.01	0.00		0.00	0.00
4	4-3	0.01	0.00	0.01	0.00	0.00
5	4-5	-0.11	-0.03		0.00	0.00
5	5-4	0.11	0.03	0.11	0.00	0.00
6	5-6	-0.37	-0.08		0.00	0.00
6	6-5	0.37	0.08	0.38	0.00	0.00
7	5-6	-0.37	-0.08		0.00	0.00
7	6-5	0.37	0.08	0.38	0.00	0.00
8	5-6	-0.37	-0.08		0.00	0.00
8	6-5	0.37	0.08	0.38	0.00	0.00

S_total = 230804.40 kVA, Total_p_loss = 2.39 kW
C_total[10] = 5232.15 kVAR

```
CASE: 11
 The slack bus is number    6
 Base KV          = 132.0 kV
 Base KVA         =   1.0e+05  kVA
 Number of buses =   6
 Number of lines =   8
 Number of loads =   5
 Tolerance (eps) =   1.0e-02
 Last iteration  = 897
     Load flow results
    ...................
              Voltage     Generator        Load       Mismatch
             ---------- ------------- ------------ ------------
No. b_type   mag    ang    p     q    pf    p    q    pf    d_p   d_q
 1   11     0.999 -0.25 0.00 0.00 0.00 0.75 0.11 0.99  0.01  0.00
 2   11     0.999 -0.31 0.00 0.00 0.00 0.10 0.01 1.00  0.00  0.00
 3   11     0.999 -0.28 0.00 0.00 0.00 0.05 0.01 0.99 -0.01 -0.01
 4   11     0.999 -0.28 0.00 0.00 0.00 0.10 0.01 0.99  0.01  0.00
 5   11     0.999 -0.21 0.00 0.00 0.00 1.00 0.14 0.99  0.00  0.00
 6   13     1.000  0.00 2.00 0.29 0.99 0.00 0.00 0.00  0.00  0.00
              Line Flow       Line Loss
           ---------------   ------------
No. F-T    P     Q      S      P     Q
 1  1-2  0.10  0.01          0.00  0.00
 1  2-1 -0.10 -0.01 0.10     0.00  0.00
 2  1-3  0.04  0.00          0.00  0.00
 2  3-1 -0.04  0.00 0.04     0.00  0.00
 3  1-6 -0.89 -0.12          0.00  0.00
 3  6-1  0.89  0.12 0.90     0.00  0.00
 4  3-4 -0.02 -0.01          0.00  0.00
 4  4-3  0.02  0.01 0.02     0.00  0.00
 5  4-5 -0.11 -0.02          0.00  0.00
 5  5-4  0.11  0.02 0.11     0.00  0.00
 6  5-6 -0.37 -0.05          0.00  0.00
 6  6-5  0.37  0.06 0.37     0.00  0.00
 7  5-6 -0.37 -0.05          0.00  0.00
 7  6-5  0.37  0.06 0.37     0.00  0.00
 8  5-6 -0.37 -0.05          0.00  0.00
 8  6-5  0.37  0.06 0.37     0.00  0.00
----------------------------------------------------
S_total = 229658.01 kVA, Total_p_loss =     2.26 kW
C_total[11] =  8262.92 kVAR
===================================================================
```

CASE: 12
The slack bus is number 6
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 6
Number of lines = 8
Number of loads = 5
Tolerance (eps) = 1.0e-02
Last iteration =1001
Load flow results
....

No.	b_type	Voltage mag	Voltage ang	Generator p	Generator q	Generator pf	Load p	Load q	Load pf	Mismatch d_p	Mismatch d_q
1	11	1.000	-0.25	0.00	0.00	0.00	0.75	0.00	1.00	0.01	0.01
2	11	1.000	-0.31	0.00	0.00	0.00	0.10	0.00	1.00	0.00	0.00
3	11	1.000	-0.29	0.00	0.00	0.00	0.05	0.00	1.00	-0.03	-0.03
4	11	1.000	-0.28	0.00	0.00	0.00	0.10	0.00	1.00	0.01	0.01
5	11	1.000	-0.21	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00
6	13	1.000	0.00	2.00	0.01	1.00	0.00	0.00	0.00	0.00	0.00

No.	F-T	Line Flow P	Line Flow Q	Line Flow S	Line Loss P	Line Loss Q
1	1-2	0.10	0.00		0.00	0.00
1	2-1	-0.10	0.00	0.10	0.00	0.00
2	1-3	0.05	-0.01		0.00	0.00
2	3-1	-0.05	0.01	0.05	0.00	0.00
3	1-6	-0.89	0.01		0.00	0.00
3	6-1	0.89	0.00	0.89	0.00	0.00
4	3-4	-0.03	-0.01		0.00	0.00
4	4-3	0.03	0.01	0.03	0.00	0.00
5	4-5	-0.11	-0.01		0.00	0.00
5	5-4	0.11	0.01	0.11	0.00	0.00
6	5-6	-0.37	0.00		0.00	0.00
6	6-5	0.37	0.00	0.37	0.00	0.00
7	5-6	-0.37	0.00		0.00	0.00
7	6-5	0.37	0.00	0.37	0.00	0.00
8	5-6	-0.37	0.00		0.00	0.00
8	6-5	0.37	0.00	0.37	0.00	0.00

S_total = 229192.50 kVA, Total_p_loss = 3.47 kW
C_total[12] = 28073.53 kVAR

===

No.	Dem.Red. ($)	Energy Red. ($)	Capacity Rel. ($)	T.Benefit ($)	Cap.Cost ($)	Savings (pu)
1	377.91	289.67	120941.46	121609.04	33052.11	1.000
2	-21.69	-16.63	4958.43	4920.10	2842.16	0.023
3	17.23	13.21	7799.21	7829.65	2931.91	0.055
4	16.13	12.37	7616.09	7644.59	3046.52	0.052
5	55.00	42.16	11997.27	12094.42	3195.10	0.100
6	-26.18	-20.07	2316.94	2270.69	3392.48	-0.013
7	52.43	40.19	13749.02	13841.63	3664.73	0.115
8	-29.17	-22.36	-2142.46	-2193.99	4063.26	-0.071
9	8.61	6.60	4382.00	4397.20	4708.93	-0.004
10	5.38	4.12	5502.66	5512.17	7436.63	-0.022
11	-48.47	-37.15	2234.43	2148.82	25266.18	-0.261

Load Flow Output of System # 7

CASE: 1
The slack bus is number 3
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 3
Number of lines = 3
Number of loads = 2
Tolerance (eps) = 1.0e-03
Last iteration = 16

Load flow results
....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.020	-1.68	0.00	0.00	0.00	0.96	-2.07	0.42	0.00	0.00
2	11	1.001	-2.86	0.00	0.00	0.00	3.15	2.85	0.74	0.00	0.00
3	13	1.050	0.00	4.20	1.05	0.97	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	2-3	-1.05	-0.95		0.00	0.10
1	3-2	1.05	1.05	1.49	0.00	0.10
2	1-3	-3.06	0.09		0.09	0.09
2	3-1	3.15	0.00	3.15	0.09	0.09
3	1-2	2.10	1.98		0.00	0.08
3	2-1	-2.10	-1.90	2.89	0.00	0.08

S_total = 752159.43 kVA, Total_p_loss = 9002.70 kW
C_total[1] = 0.00 kVAR

```
CASE: 2
 The slack bus is number    3
 Base KV          = 132.0 kV
 Base KVA         =   1.0e+05  kVA
 Number of buses =   3
 Number of lines =   3
 Number of loads =   2
 Tolerance (eps) =   1.0e-03
 Last iteration  =  18
     Load flow results
    ...................
             Voltage    Generator        Load       Mismatch
            ---------- ------------- ------------- ------------
No. b_type   mag   ang   p     q    pf    p     q    pf   d_p   d_q
 1   11     1.031 -2.10 0.00  0.00 0.00 0.96 -2.07 0.42 0.00 0.00
 2   11     1.021 -3.17 0.00  0.00 0.00 3.15  1.53 0.90 0.00 0.00
 3   13     1.050  0.00 4.20 -0.33 1.00 0.00  0.00 0.00 0.00 0.00
             Line Flow      Line Loss
           ---------------  ------------
No. F-T    P     Q     S       P    Q
 1  2-3  -1.19 -0.55          0.00 0.08
 1  3-2   1.19  0.63 1.35     0.00 0.08
 2  1-3  -2.92  1.05          0.09 0.09
 2  3-1   3.01 -0.96 3.16     0.09 0.09
 3  1-2   1.96  1.02          0.00 0.05
 3  2-1  -1.96 -0.97 2.21     0.00 0.05
----------------------------------------------------
S_total = 672112.34 kVA, Total_p_loss =  9076.76 kW
C_total[2] = 132438.54 kVAR
==================================================================
```

```
CASE: 3
 The slack bus is number    3
 Base KV          = 132.0 kV
 Base KVA         =   1.0e+05  kVA
 Number of buses =   3
 Number of lines =   3
 Number of loads =   2
 Tolerance (eps) =   1.0e-03
 Last iteration  =  18
     Load flow results
    ...................
             Voltage    Generator        Load       Mismatch
           ---------- ------------- ------------- -------------
No. b_type   mag   ang   p      q   pf    p    q      pf   d_p   d_q
 1   11    1.032 -2.13 0.00  0.00 0.00 0.96 -2.07 0.42 0.00 0.00
 2   11    1.023 -3.19 0.00  0.00 0.00 3.15  1.44 0.91 0.00 0.00
 3   13    1.050  0.00 4.20 -0.42 1.00 0.00  0.00 0.00 0.00 0.00
             Line Flow        Line Loss
           ---------------   ------------
No. F-T    P     Q      S        P     Q
 1  2-3  -1.20 -0.52           0.00 0.08
 1  3-2   1.20  0.61 1.34      0.00 0.08
 2  1-3  -2.91  1.11           0.09 0.09
 2  3-1   3.01 -1.02 3.18      0.09 0.09
 3  1-2   1.95  0.96           0.00 0.04
 3  2-1  -1.95 -0.91 2.18      0.00 0.04
----------------------------------------------------
S_total = 669094.23 kVA, Total_p_loss =  9145.03 kW
C_total[3] =  9043.22 kVAR
===================================================================
```

CASE: 4
The slack bus is number 3
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 3
Number of lines = 3
Number of loads = 2
Tolerance (eps) = 1.0e-03
Last iteration = 18

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.033	-2.16	0.00	0.00	0.00	0.96	-2.07	0.42	0.00	0.00
2	11	1.024	-3.21	0.00	0.00	0.00	3.15	1.34	0.92	0.00	0.00
3	13	1.050	0.00	4.20	-0.51	0.99	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	2-3	-1.21	-0.50		0.00	0.08
1	3-2	1.21	0.58	1.34	0.00	0.08
2	1-3	-2.90	1.18		0.09	0.09
2	3-1	3.00	-1.09	3.19	0.09	0.09
3	1-2	1.94	0.89		0.00	0.04
3	2-1	-1.94	-0.85	2.14	0.00	0.04

S_total = 666330.24 kVA, Total_p_loss = 9223.54 kW
C_total[4] = 9328.80 kVAR

CASE: 5

The slack bus is number 3
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 3
Number of lines = 3
Number of loads = 2
Tolerance (eps) = 1.0e-03
Last iteration = 18

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.033	-2.19	0.00	0.00	0.00	0.96	-2.07	0.42	0.00	0.00
2	11	1.026	-3.24	0.00	0.00	0.00	3.15	1.24	0.93	0.00	0.00
3	13	1.050	0.00	4.20	-0.61	0.99	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	2-3	-1.22	-0.47		0.00	0.08
1	3-2	1.22	0.55	1.33	0.00	0.08
2	1-3	-2.89	1.25		0.09	0.09
2	3-1	2.99	-1.16	3.20	0.09	0.09
3	1-2	1.93	0.82		0.00	0.04
3	2-1	-1.93	-0.78	2.10	0.00	0.04

S_total = 663838.47 kVA, Total_p_loss = 9313.74 kW
C_total[5] = 9693.47 kVAR

===

CASE: 6

The slack bus is number 3
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 3
Number of lines = 3
Number of loads = 2
Tolerance (eps) = 1.0e-03
Last iteration = 18

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.034	-2.22	0.00	0.00	0.00	0.96	-2.07	0.42	0.00	0.00
2	11	1.027	-3.26	0.00	0.00	0.00	3.15	1.14	0.94	0.00	0.00
3	13	1.050	0.00	4.20	-0.71	0.99	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	2-3	-1.23	-0.44		0.00	0.08
1	3-2	1.23	0.52	1.33	0.00	0.08
2	1-3	-2.88	1.32		0.09	0.09
2	3-1	2.98	-1.23	3.22	0.09	0.09
3	1-2	1.92	0.75		0.00	0.04
3	2-1	-1.92	-0.71	2.06	0.00	0.04

S_total = 661646.40 kVA, Total_p_loss = 9417.69 kW
C_total[6] = 10166.23 kVAR

===

CASE: 7
The slack bus is number 3
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 3
Number of lines = 3
Number of loads = 2
Tolerance (eps) = 1.0e-03
Last iteration = 19
Load flow results
....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.035	-2.25	0.00	0.00	0.00	0.96	-2.07	0.42	0.00	0.00
2	11	1.029	-3.28	0.00	0.00	0.00	3.15	1.04	0.95	0.00	0.00
3	13	1.050	0.00	4.20	-0.82	0.98	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	2-3	-1.24	-0.40		0.00	0.08
1	3-2	1.24	0.48	1.33	0.00	0.08
2	1-3	-2.87	1.40		0.10	0.10
2	3-1	2.97	-1.30	3.24	0.10	0.10
3	1-2	1.91	0.67		0.00	0.04
3	2-1	-1.91	-0.63	2.03	0.00	0.04

S_total = 659723.03 kVA, Total_p_loss = 9533.66 kW
C_total[7] = 10794.24 kVAR

CASE: 8

The slack bus is number 3

Base KV = 132.0 kV

Base KVA = 1.0e+05 kVA

Number of buses = 3

Number of lines = 3

Number of loads = 2

Tolerance (eps) = 1.0e-03

Last iteration = 19

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.036	-2.29	0.00	0.00	0.00	0.96	-2.07	0.42	0.00	0.00
2	11	1.030	-3.31	0.00	0.00	0.00	3.15	0.92	0.96	0.00	0.00
3	13	1.050	0.00	4.21	-0.94	0.98	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	2-3	-1.25	-0.37		0.00	0.08
1	3-2	1.25	0.45	1.33	0.00	0.08
2	1-3	-2.86	1.48		0.10	0.10
2	3-1	2.96	-1.39	3.27	0.10	0.10
3	1-2	1.90	0.59		0.00	0.04
3	2-1	-1.90	-0.55	1.99	0.00	0.04

S_total = 658279.75 kVA, Total_p_loss = 9675.70 kW

C_total[8] = 11660.49 kVAR

```
CASE: 9
 The slack bus is number    3
 Base KV          = 132.0 kV
 Base KVA         =    1.0e+05  kVA
 Number of buses =   3
 Number of lines =   3
 Number of loads =   2
 Tolerance (eps) =   1.0e-03
 Last iteration  =  19
     Load flow results
    ...................
              Voltage     Generator        Load        Mismatch
             ---------- ------------- ------------- ------------
No. b_type    mag   ang    p     q    pf   p     q    pf   d_p  d_q
 1   11     1.037 -2.33 0.00  0.00 0.00 0.96 -2.07 0.42 0.00 0.00
 2   11     1.032 -3.34 0.00  0.00 0.00 3.15  0.79 0.97 0.00 0.00
 3   13     1.050  0.00 4.21 -1.07 0.97 0.00  0.00 0.00 0.00 0.00
              Line Flow       Line Loss
           --------------  ------------
No. F-T    P     Q     S      P    Q
 1  2-3 -1.26 -0.33         0.00 0.08
 1  3-2  1.26  0.41 1.33    0.00 0.08
 2  1-3 -2.85  1.57         0.10 0.10
 2  3-1  2.95 -1.48 3.29    0.10 0.10
 3  1-2  1.89  0.50         0.00 0.04
 3  2-1 -1.89 -0.46 1.95    0.00 0.04
----------------------------------------------------
S_total = 657366.76 kVA, Total_p_loss =  9847.49 kW
C_total[9] = 12928.56 kVAR
==================================================================
```

```
CASE: 10
 The slack bus is number    3
 Base KV          = 132.0 kV
 Base KVA         =   1.0e+05  kVA
 Number of buses =   3
 Number of lines =   3
 Number of loads =   2
 Tolerance (eps) =   1.0e-03
 Last iteration  =  19
     Load flow results
    ...................
               Voltage    Generator        Load        Mismatch
              ---------- -------------- ------------- -------------
No. b_type    mag   ang   p     q   pf   p      q    pf   d_p   d_q
 1   11      1.038 -2.37 0.00  0.00 0.00 0.96 -2.07 0.42 0.00 0.00
 2   11      1.034 -3.37 0.00  0.00 0.00 3.15  0.64 0.98 0.00 0.00
 3   13      1.050  0.00 4.21 -1.22 0.96 0.00  0.00 0.00 0.00 0.00
               Line Flow       Line Loss
            ---------------  ------------
No. F-T    P     Q     S       P    Q
 1  2-3 -1.28 -0.28          0.00 0.08
 1  3-2  1.28  0.36 1.33     0.00 0.08
 2  1-3 -2.83  1.68          0.10 0.10
 2  3-1  2.93 -1.58 3.33     0.10 0.10
 3  1-2  1.87  0.39          0.00 0.03
 3  2-1 -1.87 -0.36 1.91     0.00 0.03
---------------------------------------------------
S_total = 657223.76 kVA, Total_p_loss = 10065.17 kW
C_total[10] = 14982.96 kVAR
=================================================================
```

```
CASE: 11
 The slack bus is number    3
 Base KV         = 132.0 kV
 Base KVA        =    1.0e+05  kVA
 Number of buses =    3
 Number of lines =    3
 Number of loads =    2
 Tolerance (eps) =    1.0e-03
 Last iteration  =  19
     Load flow results
    ....................
             Voltage    Generator         Load        Mismatch
            ---------- -------------- ------------- -------------
No. b_type   mag   ang   p     q    pf   p     q    pf  d_p  d_q
 1   11     1.039 -2.43 0.00  0.00 0.00 0.96 -2.07 0.42 0.00 0.00
 2   11     1.037 -3.41 0.00  0.00 0.00 3.15  0.45 0.99 0.00 0.00
 3   13     1.050  0.00 4.21 -1.40 0.95 0.00  0.00 0.00 0.00 0.00
             Line Flow      Line Loss
          ---------------   ------------
No. F-T    P     Q     S      P    Q
 1  2-3 -1.30 -0.23          0.00 0.08
 1  3-2  1.30  0.31  1.33   0.00 0.08
 2  1-3 -2.81  1.82          0.10 0.10
 2  3-1  2.92 -1.71  3.38   0.10 0.10
 3  1-2  1.85  0.25          0.00 0.03
 3  2-1 -1.85 -0.22  1.87   0.00 0.03
---------------------------------------------------
S_total = 658480.44 kVA, Total_p_loss = 10370.88 kW
C_total[11] = 19078.41 kVAR
=================================================================
```

CASE: 12
The slack bus is number 3
Base KV = 132.0 kV
Base KVA = 1.0e+05 kVA
Number of buses = 3
Number of lines = 3
Number of loads = 2
Tolerance (eps) = 1.0e-03
Last iteration = 20

Load flow results

....

		Voltage		Generator			Load			Mismatch	
No.	b_type	mag	ang	p	q	pf	p	q	pf	d_p	d_q
1	11	1.043	-2.56	0.00	0.00	0.00	0.96	-2.07	0.42	0.00	0.00
2	11	1.044	-3.52	0.00	0.00	0.00	3.15	0.00	1.00	0.00	0.00
3	13	1.050	0.00	4.22	-1.84	0.92	0.00	0.00	0.00	0.00	0.00

		Line Flow			Line Loss	
No.	F-T	P	Q	S	P	Q
1	2-3	-1.34	-0.09		0.00	0.08
1	3-2	1.34	0.18	1.36	0.00	0.08
2	1-3	-2.77	2.13		0.11	0.11
2	3-1	2.88	-2.02	3.52	0.11	0.11
3	1-2	1.81	-0.06		0.00	0.03
3	2-1	-1.81	0.09	1.81	0.00	0.03

S_total = 668061.98 kVA, Total_p_loss = 11218.58 kW
C_total[12] = 44885.07 kVAR

No.	Dem.Red. ($)	Energy Red. ($)	Capacity Rel. ($)	T.Benefit ($)	Cap.Cost ($)	Savings (pu)
1	-2962.45	-2270.72	384226.01	378992.84	119194.68	1.000
2	-2731.12	-2093.40	14486.95	9662.43	8138.90	0.006
3	-3140.37	-2407.09	13267.15	7719.69	8395.92	-0.003
4	-3607.79	-2765.37	11960.49	5587.32	8724.12	-0.012
5	-4157.95	-3187.07	10521.92	3176.90	9149.61	-0.023
6	-4638.94	-3555.75	9232.18	1037.49	9714.82	-0.033
7	-5681.63	-4354.97	6927.76	-3108.85	10494.44	-0.052
8	-6871.47	-5266.98	4382.34	-7756.11	11635.70	-0.075
9	-8707.37	-6674.20	686.39	-14695.17	13484.67	-0.108
10	-12228.30	-9373.00	-6032.04	-27633.34	17170.57	-0.172
11	-33908.05	-25990.52	-45991.40	-105889.97	40396.56	-0.563

APPENDIX B.

"LOAD_FLOW.C" Computer Program

```
/*****************************************************************
 *
 *
 *  SOURCE FILE:    load_flow.c
 *
 *
 *  DESCRIPTION:    Calculates the load flow of  an electric power
 *                  system.  Also, calculates  benefits  and costs
 *                  when adding shunt capacitors on load buses, in
 *                  order  to determine  the economic power factor
 *                  of  the  desired  power system  using  Hopkins
 *                  terminology.
 *
 *
 *  RETURN:         NORMAL
 *
 *
 *  AUTHER:         Khalid H. Abdel-Karim
 *
 *
 *  DATE CREATED:   16June88                      Version 1.00
 *
 *
 *  REVISIONS:      None
 *
 *
 ****************************************************************/
#define     TWO          2
#define     THREE        3
#define     FOUR         4
#define     FIVE         5
#define     TEN         10
#define     TWENTY      20
#define     FIFTY       50
#define     PI           3.141592654
#define     L           11
#define     G           12
#define     S           13
#define     RF           1.0
#define     FCR          0.2
#define     LsF          0.14
#define     kw_COST    200.0
#define     kwh_COST     0.025
#define     kva_COST    24.0
#define     kvar_COST    4.5
```

```
#define     YEAR        8760.0
#define     NORMAL        60
#include    <stdio.h>
#include    <math.h>
#include    "complex.h"
#include    "form_y.c"
#include    "form_b1.c"
#include    "form_b2.c"
#include    "lud.c"
#include    "subst.c"
#include    "inv.c"
#include    "sens.c"
#include    "stott.c"
main()
[
   COMPLEX   y_bus[TWENTY][TWENTY],
             se_imp[TWENTY],
             sh_adm[TWENTY],
             e_bus[TEN],
             flow, x, temp1, temp2;
   double    p_gen[TEN],
             q_gen[TEN],
             p_load[TEN],
             q_load[TEN],
             p_slack,
             q_slack,
             q_min[TEN],
             q_max[TEN],
             p_line[TWENTY][FIVE],
             q_line[TWENTY][FIVE],
             b1[TWENTY+1][TWENTY+1],
             ang[TEN],
             b2[TWENTY+1][TWENTY+1],
             se_nsc[TEN],
             e_mag[TEN],
             del_p[TEN],
             del_q[TEN],
             b_volt,
             b_pwr,
             p_loss, q_loss,
             sensc[TEN],
             eps ,
             xxx[21],
             bbb[21],
             lu[21][21],
             y1[21][21],
```

```
            gen_q[10],
            gen_p[10],
            y2[21][21],
            loss_p[21], loss_q[21],
            pf_l[10], pf_g[10],
            ptotal_loss ,
            s1[21], s2[21],
            s[21],
            s_total ,
            qtotal_loss ,
            pf = 0.89,
            c[15],
            temp ,
            tot_kva[15],
            loss_kw[15],
            del_kva[15],
            del_kw[15],
            load[15],
            dem_red[15],
            c_total[15],
            energy_red[15],
            capacity_rel[15],
            kvar_delta[15],
            cost_capacitor[15],
            tot_benefit[15],
            savings[15],
            pu_savings[15],
            abs;
char        title[FIFTY];
int         type[FIVE],
            b_type[TEN],
            i, j, k,
            l_from[TWENTY], l_to[TWENTY],
            n_bus,
            n_line,
            n_load,
            it_max,
            iter,
            l_f, l_t,
            pivot[21],
            nn ,
            aaa ,
            index = 1,
            i1 = 1 , i2 = 2 , i3 = 3 , i4 = 4 , i5 = 5 ,
            i6 = 6 , i7 = 7 , i8 = 8 , i9 = 9;
```

```
for ( i = 1 ; i <= 15 ; i++ )
      {
      load[i]             = 0.0;
      tot_kva[i]          = 0.0;
      loss_kw[i]          = 0.0;
      del_kva[i]          = 0.0;
      del_kw[i]           = 0.0;
      c[i]                = 0.0;
      c_total[i]          = 0.0;
      dem_red[i]          = 0.0;
      energy_red[i]       = 0.0;
      kvar_delta[i]       = 0.0;
      capacity_rel[i]     = 0.0;
      savings[i]          = 0.0;
      tot_benefit[i]      = 0.0;
      cost_capacitor[i]   = 0.0;
      pu_savings[i]       = 0.0;
      }

while ( pf <= 1.0 )
       {
pf  =  pf  +  0.01 ;
printf("\n");
printf("CASE: %d \n",index);
/*    INITIALIZATION                                                 */
   for  ( i = 1 ; i <= 10 ; i++ )
        {
         e_bus[i]   = cmplx( 0.0, 0.0 ); p_gen[i]   = 0.0;
         q_gen[i]   = 0.0; p_load[i]  = 0.0; q_load[i]  = 0.0;
         del_p[i]   = 0.0; del_q[i]   = 0.0; q_min[i]   = 0.0;
         q_max[i]   = 0.0; pf_l[i]    = 0.0; pf_g[i]    = 0.0;
         }
   for ( i = 1 ; i <= 15 ; i++ )
        {
        loss_p[i]  = 0.0 ; loss_q[i] = 0.0 ; s1[i] = 0.0 ;
        s2[i]      = 0.0 ; s[i]      = 0.0;
        }
        ptotal_loss    = 0.0; qtotal_loss    = 0.0;
        s_total        = 0.0; temp           = 0.0;
        p_loss         = 0.0; q_loss         = 0.0;
        title[FIFTY]   = " load flow start  " ;
        type[0]  = L;       type[1]  = G;      type[2]  = S;
        b_volt   = 132.0;   b_pwr    = 100000.0;
        n_bus    = 3;       n_line   = 3;     n_load   = 2;
        eps      = 1.0e-3;  iter     = 0;      it_max   = 1000;
```

```
/*                          BUS    DATA                              */
 b_type[i1] = L; e_bus[i1] = cmplx(1.0, 0.0); p_gen[i1] = 0.0;
 q_gen[i1] = 0.0; p_load[i1] = 0.96; q_load[i1] = -2.07 ;
 q_min[i1] = 0.0; q_max[i1] = 0.0;
 b_type[i2] = L; e_bus[i2] = cmplx(1.0, 0.0); p_gen[i2] = 0.0;
 q_gen[i2] = 0.0; p_load[i2] = 3.15 ; q_load[i2] = 2.85;
 q_min[i2] = 0.0; q_max[i2] = 0.0;
 b_type[i3] = S; e_bus[i3] = cmplx(1.05, 0.0); p_gen[i3] = 0.0;
 q_gen[i3] = 0.0; p_load[i3] = 0.0; q_load[i3] = 0.0;
 q_min[i3] = 0.0; q_max[i3] = 0.0;

/*                     LINE   DATA                                   */
 l_from[1]  = i2;  l_to[1]  = i3;
 se_imp[1]  = cmplx(0.0 , 0.05);
 sh_adm[1]  = cmplx(0.0 , 0.0];
 l_from[2]  = i1;  l_to[2]  = i3;
 se_imp[2]  = cmplx(0.01 , 0.01 );
 sh_adm[2]  = cmplx(0.0 , 0.0 );
 l_from[3]  = i1;  l_to[3]  = i2;
 se_imp[3]  = cmplx(0.0 , 0.01);
 sh_adm[3]  = cmplx(0.0 , 0.0 ];
if ( index > 1 ]
   {
   for ( i = 1 ; i <= n_bus ; i++ ]
       {
      q_load[i] = load[i];
      }
   ]

 for ( k = 1 ; k <= n_bus ; k++ )
     {
     if [ b_type[k] == type[2] )
        printf(" The slack bus is number  %3d \n",k);
     }
 printf(" Base KV          = %4.1lf kV \n",b_volt);
 printf(" Base KVA         =   %4.1e  kVA\n",b_pwr];
 printf(" Number of buses = %3d\n",n_bus);
 printf[" Number of lines = %3d\n",n_line);
 printf{" Number of loads = %3d\n",n_load);
 printf(" Tolerance (eps] = %.1e\n",eps];

/*                    SHUNT ADMITTANCE Y_BUS                         */
 y_matrix( &y_bus,  se_imp, sh_adm, l_from, l_to, n_line );

/*                          B1   MATRIX                              */
 form_b1( &b1, se_imp, l_from, l_to, n_line, n_bus ];
```

```
/*                      B2   MATRIX                              */
form_b2( &b2, &y_bus, n_bus, n_load , type, b_type);

/*              TO CALCULATE  SENSITIVITY                        */
 nn = n_bus - 1 ;

inv( &b1, nn , pivot, lu, &y1, xxx, bbb);

inv( &b2, n_load    , pivot, lu, &y2, xxx, bbb);

sens( &y_bus, &y2, &sensc, n_load, n_bus);

for ( i = 1 ; i <= n_bus ; i++ )
    {
    ang[i]   = ( 180.0 / PI ) * cphase( e_bus[i] );
    e_mag[i] = cmag( e_bus[i] );
    }

stott( &y_bus, e_bus, &y1, &y2, p_gen, q_gen, &del_p, &del_q,
       &sensc, &e_mag, &ang, iter, n_bus, n_load, p_load,
       q_load, q_min, q_max, eps, it_max, type, b_type
       , &gen_p, &gen_q );

/*              LINE FLOW CALCULATION                            */

for ( i = 1 ; i <= n_bus ; i++ )
    {
    p_gen[i] = gen_p[i];
    q_gen[i] = gen_q[i];
    }

for ( j = 1 ; j <= n_line ; j++ )
    {
    l_f            = l_from[j];
    l_t            = l_to[j];
    x              = cdiv( csub( e_bus[l_f], e_bus[l_t]) ,
                                 se_imp[j] ) ;
    temp1          = cadd( x, cmult( e_bus[l_f],
                                     sh_adm[j]) );
    flow           = cmult( e_bus[l_f], cconj( temp1 ) );
    p_line[j][1]   = flow.re;
    q_line[j][1]   = flow.im;
    temp2          = cadd(  cneg( x ) , cmult( e_bus[l_t],
                                        sh_adm[j] ));
    flow           = cmult( e_bus[l_t], cconj( temp2 ) );
    p_line[j][2]   = flow.re;
```

```
     q_line[j][2]  = flow.im;
     ]

/*  TO CALCULATE LINE FLOW APPARENT POWER                          */

 for ( j = 1 ; j <= n_line ; j++ )
     [
     s1[j]   =  sqrt( ( p_line[j][1] * p_line[j][1]) +
                      ( q_line[j][1] * q_line[j][1]) );
     s2[j]   =  sqrt( ( p_line[j][2] * p_line[j][2]) +
                      ( q_line[j][2] * q_line[j][2]) );
     if ( s1[j] > s2[j] )
          s[j]  =  s1[j];
     else
          s[j]  =  s2[j];
     }

/*                  SLACK BUS POWER CALCULATION                     */
 p_slack = 0.0;
 q_slack = 0.0;

 for ( k = 1 ; k <= n_bus ; k++ )
     [
     if ( b_type[k] == type[2] )
        [
        aaa = k ;
        for ( j = 1 ; j <= n_line ; j++ )
                  [
                  if ( l_from[j] == k )
                     [
                     p_slack  =  p_slack + p_line[j][1];
                     q_slack  =  q_slack + q_line[j][1];
                     )
                  )
    )
        ]
 for ( j = 1 ; j <= n_line ; j++ )
     [
     if ( l_to[j] == aaa )
        [
     p_slack = p_slack + p_line[j][2];
     q_slack = q_slack + q_line[j][2];
        ]
     ]
 p_gen[aaa]    = p_slack + p_load[aaa];
 q_gen[aaa]    = q_slack + q_load[aaa];
```

```
    for ( i = 1 ; i <= n_bus ; i++ )
        [
        if ( p_load[i] != 0.0 )
        pf_l[i] = cos( atan( q_load[i] / p_load[i] ) );
        else
        pf_l[i] = 0.0;
        ]

    for ( i = ( n_load + 1 ) ; i <= n_bus ; i++ )
        pf_g[i] = cos( atan( q_gen[i] / p_gen[i] ) );
    printf("     Load flow results        \n");
    printf("    ...................       \n");
printf("                Voltage     Generator         Load  ");
printf("     Mismatch\n");
printf("                ---------- ------------- ------------");
printf(" -------------\n");
printf("No. b_type   mag   ang   p     q   pf   p    q    pf ");
printf(" d_p   d_q\n");
    for ( i = 1 ; i <= n_bus ; i++ )
        [
        printf("%2d   %2d     %4.3lf %4.2lf %4.2lf %4.2lf %.2lf",
          i,b_type[i],e_mag[i],ang[i],p_gen[i],q_gen[i],pf_g[i]);
        printf(" %4.2lf %4.2lf %.2lf %.2lf %.2lf\n",
                  p_load[i],q_load[i],pf_l[i],del_p[i],del_q[i]);
        )

  /*                    LINE LOSSES                              */
    printf("                Line Flow       Line Loss        \n");
    printf("              ---------------  ------------      \n");
    printf("No. F-T    P     Q      S        P     Q         \n");

    for ( j = 1 ; j <= n_line ; j++ )
        [
        p_loss  = p_line[j][1] + p_line[j][2];
        q_loss  = q_line[j][1] + q_line[j][2];
        loss_p[j] =  p_loss;
        loss_q[j] =  q_loss;
    ]


    for ( j = 1 ; j <= n_line ; j++ )
        [
        p_loss  = p_line[j][1] + p_line[j][2];
        q_loss  = q_line[j][1] + q_line[j][2];
  printf("%2d %2d-%d   %4.2lf %4.2lf        %4.2lf %4.2lf\n",
        j,l_from[j],l_to[j],p_line[j][1],q_line[j][1],
```

```
            p_loss,q_loss);
      printf("%2d %2d-%d   %4.21f %4.21f %4.21f %4.21f %4.21f\n",
            j,l_to[j],l_from[j],p_line[j][2],q_line[j][2],s[j],
            p_loss,q_loss);
        }

    for ( j = 1 ; j <= n_line ; j++ )
        {
        s_total      =  s_total + s[j];
        ptotal_loss  =  ptotal_loss + loss_p[j];
        qtotal_loss  =  qtotal_loss + loss_q[j];
        }
    printf("---------------------------------------------------------\n");
    printf("S_total = %8.21f kVA, Total_p_loss = %8.21f kW\n",
          s_total * b_pwr,ptotal_loss * b_pwr);
    tot_kva[index]  =  s_total;
    loss_kw[index]  =  ptotal_loss;
    temp = 0.0;
    for ( i = 1 ; i <= n_bus ; i++ )
        {
        temp = temp + c[i];
        }
    c_total[index] = temp;
    printf("C_total[%d] = %8.21f kVAR\n",index,
                                       b_pwr * c_total[index]);
    temp = 0.0;
    for ( i = 1 ; i <=  n_load   ; i++ )
        {
        if ( ( pf_l[i] <  pf ) && ( pf <= 1.0 )  &&
                                       ( q_load[i] >= 0.0 ) )
          {
          temp       =  p_load[i] * ( tan( acos( pf ) )  );
          c[i]       =  q_load[i] - temp;
          load[i]  =  temp;
          }
         else
          {
          load[i] = q_load[i];  c[i]  = 0.0;
          }
       }
      for ( i = ( n_load + 1 ) ; i <= n_bus ; i++ )
          load[i] = q_load[i];
      index = index + 1;
   printf("=======================================================");
   printf("==========\n");
     }
```

```
  for ( i = 1 ; i <  ( index - 1 ) ; i++ )
    {
    del_kva[i]     =  tot_kva[i] - tot_kva[i+1] ;
    del_kw[i]      =  loss_kw[i] - loss_kw[i+1] ;
    kvar_delta[i] =  c_total[i+1];
    }
for ( i = 1 ; i < ( index - 1 ) ; i++ )
    {
    dem_red[i]        = b_pwr * del_kw[i] * RF * kw_COST * FCR ;
    energy_red[i]     = b_pwr * del_kw[i] * YEAR * LsF * kwh_COST;
    capacity_rel[i]   = b_pwr * del_kva[i] * kva_COST * FCR;
    cost_capacitor[i]= b_pwr * kvar_delta[i] * kvar_COST * FCR;
    tot_benefit[i]    = dem_red[i] + energy_red[i] +
                          capacity_rel[i];
    savings[i]        = ( tot_benefit[i] - cost_capacitor[i] );
    abs               =
               ( savings[1] < 0.0 ) ? -savings[1] : savings[1];
    pu_savings[i]     = savings[i] / abs;
       }
   printf("\n");
printf("No. Dem.Red. Energy Red. Capacity Rel. T.Benefit");
printf(" Cap.Cost Savings\n");
printf("      ($)       ($)          ($)          ($)    ");
printf("    ($)     (pu)  \n");
printf("-------------------------------------------------------");
printf("-----------\n");
for ( i = 1 ; i < ( index - 1 ) ; i++ )
    {
printf("%3d %8.2lf %8.2lf      %8.2lf     %8.2lf %8.2lf",
            i,dem_red[i],energy_red[i],capacity_rel[i],
            tot_benefit[i] ,cost_capacitor[i]);
printf("   %4.3lf\n",pu_savings[i]);
    }
return(NORMAL);
  }
/*                           END    MAIN()                      */
```

```
/*******************************************************************
 *
 *
 *   SOURCE FILE:   complex.h
 *
 *
 *   DESCRIPTION:   Contains functions that perform complex oper-
 *                  ations.
 *
 *
 *   FUNCTIONS:
 *
 *      COMPLEX     cadd( COMPLEX, COMPLEX )
 *      COMPLEX     csub( COMPLEX, COMPLEX )
 *      COMPLEX     cconj( COMPLEX )
 *      double      cmag( COMPLEX )
 *      COMPLEX     cmplx( double, double )
 *      COMPLEX     cmult( COMPLEX, COMPLEX )
 *      double      cphase( COMPLEX )
 *      COMPLEX     cdiv( COMPLEX, COMPLEX )
 *      double      cmagsq( COMPLEX )
 *      COMPLEX     cneg( COMPLX )
 *
 *
 *   AUTHER:        Khalid H. Abdel-Karim
 *
 *
 *   DATE CREATED:  15May88                Version 1.00
 *
 *
 *   REVISIONS:     None
 *
 *
 *******************************************************************/
typedef    struct   complex
           {
           double   re, im;
           }COMPLEX;

COMPLEX   cadd( x, y )
          COMPLEX  x,y;
          {
          COMPLEX  sum;
          sum.re = x.re + y.re;
          sum.im = x.im + y.im;
```

```
        return(sum);
        }

COMPLEX  csub( x, y )
         COMPLEX   x,y;
         {
         COMPLEX   diff;
         diff.re  =  x.re - y.re;
         diff.im  =  x.im - y.im;
         return( diff );
         }

COMPLEX  cconj( x )
         COMPLEX    x;
         {
         x.re  =  x.re;
         x.im  = -x.im;
         return( x );
         }

double   cmag( x )
         COMPLEX  x;
         {
         double  product, pro1, pro2, result, temp;
         pro1    =  x.re * x.re;
         temp    = ( x.im < 0.0 ) ? -x.im : x.im ;
         pro2    = temp * temp;
         temp    = pro1 + pro2;
         product = sqrt( temp );
         return( product );
         }

COMPLEX  cmplx( w, z )
         double  w, z;
         {
         COMPLEX  x;
         x.re  =  w;
         x.im  =  z;
         return( x );
         }

COMPLEX  cmult( x, y)
         COMPLEX  x, y ;
         {
         COMPLEX    product;
         product.re = ( x.re * y.re ) - ( x.im * y.im );
```

```
        product.im = ( x.im * y.re ) + ( x.re * y.im );
        return( product );
        }

double  cphase( x )
        COMPLEX  x;
        {
        double  phase;
        double  pi = 3.141592654;
        if ( ( x.re == 0.0 ) && ( x.im == 0.0 ) )
             phase = 0.0 ;
       else if ( ( x.re != 0.0 ) && ( x.im == 0.0 ) )
              {
              if ( x.re > 0.0 ) phase = 0.0 ;
              if ( x.re < 0.0 ) phase = pi ;
              }
       else if ( ( x.re == 0.0 ) && ( x.im != 0.0 ) )
               {
               if ( x.im > 0.0 )  phase =  pi / 2.0 ;
               if ( x.im < 0.0 )  phase = -pi / 2.0 ;
               }
       else
            phase = atan( x.im / x.re );

          return( phase );
         }

COMPLEX   cdiv( x, y )
         COMPLEX  x, y ;
         {
         COMPLEX  division, num;
         double   denom;
        if ( ( y.re != 0.0 ) || ( y.im != 0.0 ) )
         {
         denom        = cmag( y ) * cmag( y );
         num          = cmult( x, cconj( y ) );
         division.re  = num.re / denom;
         division.im  = num.im / denom;
         return( division );
         }
       else
         {
         printf(" Error  ...........!  Can not divide by ZERO \n");
         division.re =  9999.9999;
         division.im =  9999.9999;
         return(division);
```

```
            }
        }

double  cmagsq( x )
        COMPLEX  x;
        {
        double   square;
        square   = cmag( x ) * cmag( x );
        return( square );
        }

COMPLEX cneg( x )
        COMPLEX  x;
        {
        x.re = -x.re;
        x.im = -x.im;
        return( x );
        }
```

```
/*******************************************************************
 *
 *
 *  SOURCE FILE:   form_y.c
 *
 *
 *  DESCRIPTION:   Function  to calculate  the admittance  matrix
 *                 for  a given  electric power  system and data.
 *
 *
 *  RETURN:        NORMAL
 *
 *
 *  AUTHER:        Khalid H. Abdel-Karim
 *
 *
 *  DATE CREATED:  31may88               Version 1.00
 *
 *
 *  REVISIONS:     None
 *
 *
 *******************************************************************/
int   y_matrix( y_bus, se_imp, sh_adm, l_from, l_to, n_line )

      COMPLEX  y_bus[TWENTY][TWENTY],
               se_imp[TWENTY],
               sh_adm[TWENTY];
      int      l_from[TWENTY],
               l_to[TWENTY],
               n_line;
      {
      COMPLEX  se_adm, temp ,
               temp2 = cmplx( 1.0, 0.0 );
      int      i, k,
               l_f, l_t;

      for  ( i = 1 ; i <= n_line ; i++ )
           {
           for ( k = 1 ; k <= n_line ; k++ )
               {
               y_bus[i][k].re =  0.0;
               y_bus[i][k].im =  0.0;
               }
           }
      for  ( k = 1 ; k <= n_line ; k++ )
```

```
        {
        l_f                  = l_from[k];
        l_t                  = l_to[k];
        se_adm               = cdiv( temp2 , se_imp[k] );
        temp                 = cadd( se_adm , sh_adm[k] );
        y_bus[l_f][l_f]      = cadd( y_bus[l_f][l_f] , temp );
        y_bus[l_f][l_t]      = csub( y_bus[l_f][l_t] , se_adm );
        y_bus[l_t][l_f]      = csub( y_bus[l_t][l_f] , se_adm );
        y_bus[l_t][l_t]      = cadd( y_bus[l_t][l_t] , temp );
        }
    return(NORMAL);
  }
/*          END  OF  FORM_Y()                                    */
```

```
/*******************************************************************
 *
 *
 *   SOURCE FILE:   form_b1.c
 *
 *
 *   DESCRIPTION:   Function  to form  the matrix  B'  needed for
 *                  Stott's decoupled method.
 *
 *
 *   RETURN:        NORMAL
 *
 *
 *   AUTHER:        Khalid H. Abdel-Karim
 *
 *
 *   DATE CREATED:  18June88             Version 1.00
 *
 *
 *   REVISIONS:     None
 *
 *
 *******************************************************************/
 int   form_b1( b1, se_imp, l_from, l_to, n_line, n_bus, type,
               b_type )

      COMPLEX   se_imp[TWENTY];
      double    b1[TWENTY+1][TWENTY+1] ;
      int       l_from[TWENTY],
                l_to[TWENTY],
                n_line,
                n_bus,
                type[FIVE],
                b_type[TWENTY];
      {
      COMPLEX   se_adm ,
                temp = cmplx( 1.0, 0.0 );
      int       i, j, k,
                l_f, l_t;
      double    b_pq;
      for ( j = 1 ; j <= n_line ; j++ )
          {
          for ( k = 1 ; k <= n_line ; k++ )
              {
              b1[j][k]  = 0.0;
              }
```

```
            }
        for ( k = 1 ; k <= n_line ; k++ )
            {
            l_f             = l_from[k];
            l_t             = l_to[k];
            se_adm          = cdiv( temp , se_imp[k] );
            b_pq            = -se_adm.im;
            b1[l_f][l_f]    = b1[l_f][l_f] + b_pq;
            b1[l_f][l_t]    = b1[l_f][l_t] - b_pq;
            b1[l_t][l_f]    = b1[l_t][l_f] - b_pq;
            b1[l_t][l_t]    = b1[l_t][l_t] + b_pq;
            }
        return( NORMAL );
    }
/*            END  FUNCTION  FORM_B1()                                    */
```

```
/*******************************************************************
 *
 *
 *   SOURCE FILE:   form_b2.c
 *
 *
 *   DESCRIPTION:   Function to  form the matrix  B"  needed  for
 *                  Stott's decoubled method.
 *
 *
 *   RETURN:        NORMAL
 *
 *
 *   AUTHER:        Khalid H. Abdel-Karim
 *
 *
 *   DATE CREATED:  18June88                   Version 1.00
 *
 *
 *   REVISIONS:     None
 *
 *
 *******************************************************************/
  int    form_b2( b2, y_bus, n_bus, n_load, type, b_type  )

         COMPLEX    y_bus[TWENTY][TWENTY];
         int        n_bus, n_load, type[FIVE], b_type[TWENTY];
         double     b2[TWENTY + 1][TWENTY + 1];
         {
         int        i, j;
         for ( i = 1 ; i <= n_bus ; i++ )
             {
             for ( j = 1 ; j <= n_bus ; j++ )
                 {
                 b2[i][j] = 0.0;
                 ]
             ]
         for ( i = 1 ; i <= n_bus ; i++ )
             {
             for ( j = 1 ; j <= n_bus ; j++ )
                 {
                 b2{i][j]  =  -y_bus[i][j].im;
                 }
             ]
     return(NORMAL);
   }
/*             END   FUNCTION  FORM_B2()                          */
```

```
/*******************************************************************
 *
 *
 *   SOURCE FILE:   lud.c
 *
 *
 *   DESCRIPTION:   Function to perform lower upper decomposition
 *                  for an nxn real matrix.
 *
 *
 *   RETURN:        NORMAL
 *
 *
 *   AUTHER:        Khalid H. Abdel-Karim
 *
 *
 *   DATE CREATED:  31May88                      Version 1.00
 *
 *
 *   REVISIONS:     None
 *
 *
 ******************************************************************/
int     lud( a, n, pivot, lu )

        double   a[21][21],
                 lu[21][21];
        int      n,
                 pivot[21];
    {
        int      i, j, k,
                 imax;
        double   aamax,
                 abs1, abs2,
                 vv[21], tiny = 1.0e-30,
                 det = 1.0,
                 sum, dum;
    for ( i = 1 ; i <= n ; i++ )
        {
        aamax  = 0.0;
        for ( j = 1 ; j <= n ; j++ )
            {
            abs1  = ( a[i][j] < 0.0 ) ?  -a[i][j] : a[i][j];
            if ( abs1 > aamax ) aamax = abs1;
            }
            if ( aamax == 0.0 )
```

```
                printf(" Singular Matrix...........! ERROR?\n");
         vv[i]  = 1.0 / aamax;
         }
   for ( i = 1 ; i <= n ; i++ )
       {
       for ( j = 1 ; j <= n ; j++ )
           {
           lu[i][j]   =  a[i][j];
           }
       }
  for ( j = 1 ; j <= n ; j++ )
      {
      for ( i = 1 ; i <= ( j - 1 ) ; i++ )
          {
          sum = lu[i][j];
          for ( k = 1 ; k <= ( i - 1 ) ; k++ )
              {
              sum = sum - ( lu[i][k] * lu[k][j]);
              }
          lu[i][j] = sum;
          }
     aamax = 0.0;
     for ( i = j ; i <= n ; i++ )
         {
         sum = lu[i][j];
         for ( k = 1 ; k <= ( j - 1 ) ; k++ )
             {
             sum = sum - ( lu[i][k] * lu[k][j] );
             }
        lu[i][j] = sum;
        abs2     = ( sum < 0.0 ) ? -sum : sum ;
        dum      = vv[i] * abs2 ;
        if ( dum >= aamax )
           {
           imax   = i;
           aamax  = dum;
           }
        }
    if ( j != imax )
       {
       for ( k = 1 ; k <= n ; k++ )
           {
           dum           = lu[imax][k];
           lu[imax][k]   = lu[j][k];
           lu[j][k]      = dum;
           }
```

```
        det          =  -det ;
        vv[imax]  = vv[j];
        }
     pivot[j] = imax;
     if ( lu[j][j] == 0.0 )
        {
        lu[j][j] = tiny;
        }
     if ( j != n )
        {
        dum = 1.0 / lu[j][j];
        for ( i = ( j + 1 ) ; i <= n ; i++ )
            lu[i][j] = dum * lu[i][j];
        }
   }
 for ( j = 1 ; j <= n ; j++ )
     {
     det = det * lu[j][j];
     }
 return(NORMAL);
 }
/*         END OF LUD()                                              */
```

```
/*****************************************************************
 *
 *
 *   SOURCE FILE:   subst.c
 *
 *
 *   DESCRIPTION:   Function to perform  backward substitution of
 *                  an  nxn  real matrix  from  lu  decomposition
 *                  function.
 *
 *
 *   RETURN:        NORMAL
 *
 *
 *   AUTHER:        Khalid H. Abdel-Karim
 *
 *
 *   DATE CREATED:  2June88               Version 1.00
 *
 *
 *   REVISIONS:     None
 *
 *
 *****************************************************************/
int    subst( lu, n, pivot, x, b]

       double   lu[21][21],
                x[21],
                b[21];
       int      n,
                pivot[21];
    {
       int      i, j,
                ii = 0,
                ll;
       double   sum;
       for ( i = 1 ; i <= n ; i++ )
           {
           x[i] = b[i];
          }
       for ( i = 1 ; i <= n ; i++ )
           {
           ll    = pivot[i];
           sum   = x[ll];
           x[ll] = x[i];
           if ( ii != 0 )
```

```
            {
            for ( j = ii ; j <= ( i - 1 ) ; j++ )
                {
                sum = sum - ( lu[i][j] * x[j] );
                }
            }
        else
           if ( sum != 0.0 )
              {
              ii = i ;
              }
           x[i]  = sum;
        }
      for ( i = n ; i >= 1 ; i -= 1 )
          {
          sum = x[i];
          if ( i < n )
             {
             for ( j = ( i + 1 ) ; j <= n ; j++ )
                 {
                 sum = sum - ( lu[i][j] * x[j] );
                 }
             }
         x[i] = sum / lu[i][i];
}
      return(NORMAL);
  }
/*          End of subst()                                         */
```

```
/********************************************************************
 *
 *
 *   SOURCE FILE:    inv.c
 *
 *
 *   DESCRIPTION:    Function  to find the inverse of an  nxn real
 *                   matrix using lud() and subst().
 *
 *
 *   RETURN:         NORMAL
 *
 *
 *   AUTHER:         Khalid H. Abdel-Karim
 *
 *
 *   DATE CREATED:   5June88               Version 1.00
 *
 *
 *   REVISIONS:      None
 *
 *
 ********************************************************************/
int     inv( a, n, pivot, lu, y, x, b )

        int      n,
                 pivot[21];
        double   a[21][21],
                 lu(21][21],
                 y[21][21],
                 x[21],
                 b[21];
    {
        int      i, j, k;
        for ( i = 1 ; i <= n ; i++ )
            {
            for ( j = 1 ; j <= n ; j++ )
                {
                y[i][j] = 0.0 ;
                ]
            y[i][i] = 1.0 ;
          ]
       lud( a, n, pivot, lu );
       for ( i = 1 ; i <= n ; i++ )
           {
            for ( j = 1 ; j <= n ; j++ ]
```

```
            {
            b[j] = y[j][i];
            }

        subst( lu, n, pivot, x, b);

       for ( k = 1 ; k <= n ; k++ )
           {
           y[k][i] = x[k];
           }
       }
    return(NORMAL);
   }
/*                          End of    inv()                          */
```

```
/*****************************************************************
 *
 *
 *   SOURCE FILE:   sens.c
 *
 *
 *   DESCRIPTION:   Function to calculate sensitivity coefficients
 *                  for  reactive  power  limits  correction   of
 *                  generator buses.
 *
 *
 *   RETURN:        NORMAL
 *
 *
 *   AUTHER:        Khalid H. Abdel-Karim
 *
 *
 *   DATE CREATED:  16June88                    Version 1.00
 *
 *
 *   REVISIONS:     None
 *
 *
 *****************************************************************/
  int    sens( y_bus, b2, sensc, n_load, n_bus )

         COMPLEX   y_bus[TWENTY][TWENTY];
         double    b2[TWENTY + 1][TWENTY + 1],
                   sensc[TEN];
         int       n_load,
                   n_bus;
         {
         double    c[TEN],
                   x[TEN],
                   d, temp;
         int       l, m, i, j , k;

         for ( i = 1 ; i <= TEN ; i++ )
             {
             x[i]      = 0.0;
             sensc[i] = 0.0;
             }
         for ( i = n_load + 1 ; i <= n_bus - 1 ; i++ )
             {
             for ( k = 1 ; k <= n_load ; k++ )
                 {
```

```
        c[k] = -y_bus[k][i].im;
        ]
    d = -y_bus[i][i].im;
    for ( l = 1 ; l <= n_load ; l++ )
        {
        for ( m = 1 ; m <= n_load ; m++ )
            {
            x[l] = x[l] + ( b2[l][m] * c[m] );
            ]
        ]
        temp = 0.0;
        for ( m = 1 ; m <= n_load ; m++ )
            {
            temp = temp - ( c[m] * x[m] );
            ]
        temp     = temp + d;
        sensc[i] = 1.0 / temp;
        ]
    return(NORMAL);

    ]
/*              END  OF  FUNCTION  SENSC()                         */
```

```
/*******************************************************************
 *
 *
 *  SOURCE FILE:   stott.c
 *
 *
 *  DESCRIPTION:   Function to calculate  load flow using Stott's
 *                 fast decoupled load flow method.Stott's method
 *                 is used because of its fast convergence.
 *
 *
 *  RETURN:        NORMAL
 *
 *
 *  AUTHER:        Khalid H. Abdel-Karim
 *
 *
 *  DATE CREATED:  16June88                     Version 1.00
 *
 *
 *  REVISIONS:     None
 *
 *
 *******************************************************************/
  int    stott( y_bus, e_bus, b1, b2, p_gen, q_gen, del_p,
                del_q, sensc, e_mag, ang,   iter, n_bus, n_load,
                p_load, q_load, q_min, q_max, eps, it_max, type,
                b_type, gen_p, gen_q )

         COMPLEX    y_bus[TWENTY][TWENTY],
                    e_bus[TEN];
         double     b1[TWENTY + 1][TWENTY + 1],
                    b2[TWENTY + 1][TWENTY + 1],
                    p_gen[TEN], q_gen[TEN],
                    p_load[TEN], q_load[TEN],
                    q_min[TEN], q_max[TEN],
                    del_p[TEN], del_q[TEN],
                    sensc[TEN],
                    e_mag[TEN], ang[TEN],
                    eps,
                    gen_p[10], gen_q[10];
         int        iter,
                    n_bus,
                    n_load,
                    it_max,
                    type[FIVE],
```

```
                b_type[TEN];
      {
      COMPLEX   aux;
      double    del_a[TEN],
                del_m[TEN],
                v_aux,
                angl,
                q_bus,
                de_mag ,
                d_pq,
                abs1, abs2, abs3, abs4,
                eps2 = 1.0e-4,
                esp_mag[10],
                mag[10]  ;
       int      i, j, k, l,
                i_flag = 1;

    for ( i = 1 ; i <= n_bus ; i++ )
       {
       gen_p[i]     =  p_gen[i];
       gen_q[i]     =  q_gen[i];

       esp_mag[i]   =  0.0;
       mag[i]       =  0.0;
       }

    for ( i = n_load + 1 ; i < n_bus ; i++ )
       {
       esp_mag[i]   =  e_mag[i];
       }

while  ( ( iter  <=  it_max )  &&  ( i_flag == 1 ) )
     {
        for ( i = 1 ; i <= TEN ; i++ )
            {
            del_a[i]  = 0.0 ;
            del_m[i]  = 0.0 ;
            }
       i_flag = 0;
       iter   = iter + 1;
  /*  POWER  MISMATCH CALCULATIONS                              */

   for ( k = 1 ; k <= ( n_bus - 1 ) ; k++ )
       {
       aux = cmplx( 0.0, 0.0 );
       for ( j = 1 ; j <= n_bus ; j++ )
```

```
            {
            aux         = cadd( aux, cmult( cconj( y_bus[k][j] )
                                    , cconj(e_bus[j]) ));
            }
        aux         = cmult( aux, e_bus[k] );
        del_p[k]    = ( gen_p[k] - p_load[k] ) - aux.re;
        abs3        = ( del_p[k] < 0.0 ) ? -del_p[k] : del_p[k] ;
        if ( abs3 > eps )  i_flag = 1 ;
        v_aux      = cmag( e_bus[k] );
        del_p[k]   = del_p[k] / v_aux ;
        }
/*      ANGLE CALCULATIONS                                          */
    for ( i = 1 ; i < n_bus ; i++ )
        {
        for ( l = 1 ; l < n_bus ; l++ )
            {
            del_a[i]    = del_a[i] + ( bl[i][l] * del_p[l] );
            }
        del_a[i]   = del_a[i]  * ( 180.0 / PI );
        ang[i]     = ang[i]    + del_a[i];
        angl       = ang[i]    * ( PI / 180.0 );
        e_bus[i]   = cmplx( e_mag[i] * cos(angl ) ,
                            e_mag[i] * sin( angl) );
        }
    for ( k = 1 ; k <= n_load ; k++ )
        {
        aux = cmplx( 0.0, 0.0 ) ;
        for ( j = 1 ; j <= n_bus ; j++ )
            {
            aux         =  cadd( aux , cmult( cconj( y_bus[k][j])
                                , cconj( e_bus[j]) ));
            }
        aux        = cmult( aux , e_bus[k] );
        del_q[k] = ( -1.0 * q_load[k] ) - aux.im ;
        abs1       = ( del_q[k] < 0.0 )  ? -del_q[k] : del_q[k];
        if ( abs1  > eps )  i_flag = 1 ;
        v_aux       =  cmag( e_bus[k] );
        del_q[k]    =  del_q[k] / v_aux ;
        }

 /*             TO FIND MAGNITUDE                                   */

    for ( i = 1 ; i <= n_load ; i++ )
        {
        for ( l = 1 ; l <= n_load ; l++ )
            {
```

```
        del_m[i] = del_m[i] + ( b2[i][l] * del_g[l] );
        }
      e_mag[i]  = e_mag[i]  +  del_m[i] ;
      angl      = ang[i]    * [ PI / 180.0 );
      e_bus[i]  = cmplx( e_mag[i] * cos( angl ) ,
                         e_mag[i] * sin( angl ) );
      }
if ( iter > 3 )
  [
  for ( i = n_load + 1 ; i < n_bus ; i++ )
      [
      aux = cmplx( 0.0, 0.0 );
      for ( j = 1 ; j <= n_bus ; j++ )
          {
          aux       =  cadd( aux , cmult[cconj[ y_bus[i][j])
                                   , cconj[ e_bus[j] )) );
          ]
      aux             = cmult[ aux, e_bus[i] );
      q_bus           = aux.im;
      gen_g[i]        = g_bus + g_load[i] ;
     if ( ( gen_g[i] > g_max[i] ) || [ gen_g[i] < q_min[i] ) )
      [
      if [ gen_g[i] > g_max[i] )
         {
         d_pq       =  g_max[i] - gen_g[i] ;
         gen_g[i]   =  g_max[i];
         }
      if [ gen_g[i] < g_min[i]  )
         [
         d_pg       =  g_min[i] - gen_g[i] ;
         gen_g[i]   =  g_min[i];
         }
      de_mag        =  sensc[i] * ( d_pq / e_mag[i] );
      mag[i]        =  e_mag[i];
      e_mag[i]      =  esp_mag[i] + de_mag;
      angl          =  ang[i] * ( PI / 180.0 );
      e_bus[i]      =  cmplx[ e_mag[i] * cos( angl ) ,
                                 e_mag[i] * sin( angl ) );
     if ( i_flag == 0 )
        [
       abs4     =  ( e_mag[i] - mag[i] );
       abs4     =  [ abs4 < 0.0 ) ? -abs4 : abs4;
        if ( abs4 > eps2 ) [ i_flag = 1 ; ]
       }

     }
```

```
    if ( ( gen_q[i] < q_max[i] ) && ( gen_q[i] > q_min[i] ) )
       {
          angl          =  ( PI / 180.0 ) * ang[i];
          e_bus[i]      =  cmplx( e_mag[i] * cos( angl ),
                                  e_mag[i] * sin( angl ) );

       }

     }

 }
   }
printf(" Last iteration  = %d \n",iter);
return(NORMAL);
 }
/*       END FUNCTION   STOTT()                                   */
```

ECONOMIC POWER FACTOR DETERMINATION
OF ELECTRIC POWER SYSTEMS

by

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Abstract

Excessive use of motor operated appliances causes the power factor of electric power systems to be lowered, consequently, lesser active power can be carried over a given line. Generation of extra reactive power in order to compensate for the inductive loads is not economical. Instead, shunt capacitor banks can be installed at load buses to improve the power system operation. However, the cost of installation of capacitors must be compared with the benefits to arrive at an optimal solution. In this report the cost of shunt capacitors is compared with three major benefits: 1) release of generation capacity, 2) release of transmission capacity, and 3) reduction in energy losses. A computer program is developed, using the method suggested by Hopkins, to determine the incremental cost and benefits of correcting the power factor by one percent. At the optimal power factor the incremental cost and benefits are equal. Several examples are shown to illustrate the method. It has been found that every electric power system has its own economic power factor.