# POWER FLOW ANALYSIS

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# POWER FLOW ANALYSIS

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# ABSTRACT

This thesis emphasis on the load flow analysis of a 114 bus system. Mat lab codes are used for the analysis. Gauss-Seidel method was the main method employed in the Matlab codes for the analysis. Gauss-Seidel method algorithm is centered on a **Y-**bus admittance matrix to define the voltage level of the system bus. Line losses and line flow power are then calculated by using the line flow algorithm. Apart from the 114 bus system, case studies with different number of bus system were conducted (for 14 bus and 30 bus).

# ACKNOWLEDGEMENTS

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Overwhelmingly for any errors or shortfalls that may remain in this work the responsibility is entirely ours.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Power

Power (electric) is usually produced by electric generators, but can also be supplied by chemical sources such as electric batteries. The electric power in watts produced by an electric current I consisting of a charge of Q coulombs every t seconds passing through an electric potential (voltage) difference of V is

$$P = \text{work done per unit time} = \frac{QV}{t} = IV$$

The SI unit of power is the watt, one joule per second.

Electricity is most often generated at a power station by electromechanical generators, primarily driven by heat engines fueled by chemical combustion or nuclear fission but also by other means such as the kinetic energy of flowing water and wind. There are many other technologies that can be and are used to generate electricity such as solar photovoltaic and geothermal power.

Besides the generation of power, for electric utilities it has to be delivered to the consumers.

The processes involved here are

1. Electricity transmission
2. Electricity distribution
3. Power storage

Electric-power transmission is the bulk transfer of electrical energy, from generating power plants to electrical substations located near demand centers whereas Electricity distribution is the final stage in the delivery of electricity to end users.

A device which stores energy for further use is named an accumulator, this is mostly used in places where load shed is frequent to ensure continuity in power supply

Electric power transmission can be done by

1. Overhead cables
2. Underground cables

And depending on the capacity of conducting cables the are classified as

| | |
|---|---|
| -Extra high voltage transmission lines | ( >230kV ) |
| -High voltage transmission lines | (100kV< v < 230kV) |
| -Sub transmission voltage transmission lines | (33kV and 66kV) |
| -Low voltage transmission lines | (<33kV) |

In overhead transmission, High-voltage overhead conductors are not covered by insulation. The conductor material is nearly always an Aluminum alloy, made into several strands and possibly reinforced with steel strands. Copper was sometimes used for overhead transmission but Aluminum is lighter, yields only marginally reduced performance, and costs much less. Underground cables take up less right-of-way than overhead lines, have lower visibility, and are less affected by bad weather. However, costs of insulated cable and excavation are much higher than overhead construction. Faults in buried transmission lines take longer to locate and repair. Underground lines are strictly limited by their thermal capacity, which permits overload or re-rating than overhead lines. Long underground cables have significant capacitance, which may reduce their ability to provide useful power to loads.

Transmission lines, when interconnected with each other, become transmission networks. These transmission networks communicate via buses. The Interconnection of these buses results into nodes. The conducting wires contain some resistance and impedances.

In power system analysis, a matrix of these admittances can be dressed up to ease up power flow calculations known as the **BUS ADMITTANCE MATRIX**

# 1.2 Bus Admittance Matrix

The bus admittance matrix for an n-bus power system is a square matrix of size (n x n).The leading diagonal elements represents self-point admittances with respect to each bus. In other words ;

1. diagonal element $y_{ii}$ of the $Y_{bus}$ is the total admittance with respect to the $i^{th}$ bus
2. $y^{ik}$ is the admittance present between $i^{th}$ and $k^{th}$ buses

In order to obtain node-voltage equations the corresponding impedances are converted in per unit to a common MVA base and for simplicity resistances are neglected .Since the nodal solution is based on Kirchoff's current law impedances are converted to admittances by

$$y_{ij} = \frac{1}{z_{ij}} = \frac{1}{r_{ij} + jx_{ij}}$$

An example of finding the bus admittance matrix of a simple 4 bus system is as follows.

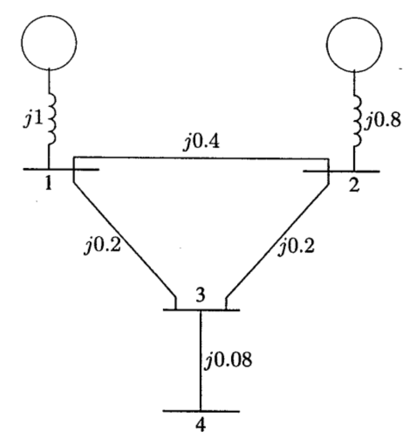


Figure 1.1 Impedance of a simple system

In the figure above the values against the line interconnecting the buses show the impedances.

Re-drawing Fig 1.1 in terms of admittances and transformation to current sources yield

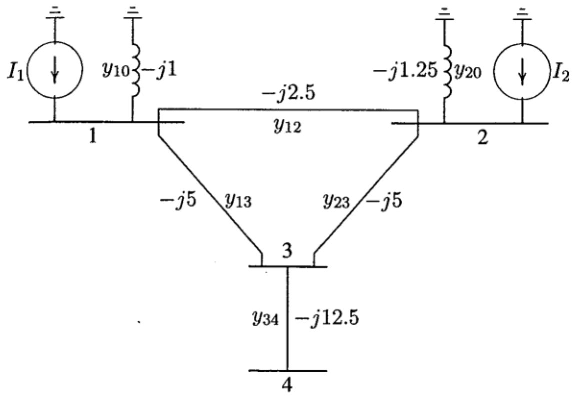


Figure 1.2 Admittance diagram of system in fig 1.1

Applying KCL to independent nodes taking Node 0 as reference we get

$$I_1 = y_{10}V_1 + y_{12}(V_1 - V_2) + y_{13}(V_1 - V_3)$$

$$I_2 = y_{20}V_2 + y_{12}(V_2 - V_1) + y_{23}(V_2 - V_3)$$

$$0 = y_{23}(V_3 - V_2) + y_{13}(V_3 - V_1) + y_{34}(V_3 - V_4)$$

$$0 = y_{34}(V_4 - V_3)$$

Re-arranging the above equations yield

$$I_1 = (y_{10} + y_{12} + y_{13})V_1 - y_{12}V_2 - y_{13}V_3$$

$$I_2 = -y_{12}V_1 + (y_{20} + y_{12} + y_{23})V_2 - y_{23}V_3$$

$$0 = -y_{13}V_1 - y_{23}V_2 + (y_{13} + y_{23} + y_{34})V_3 - y_{34}V_4$$

$$0 = -y_{34}V_3 + y_{34}V_4$$

Introducing the following admittances

$$Y_{11} = y_{10}+y_{12}+y_{13}$$

$$Y_{22} = y_{20}+y_{12}+y_{23}$$

$$Y_{33} = y_{13}+y_{32}+y_{34}$$

$$Y_{44} = y_{34}$$

$$Y_{12} = Y_{21} = -y_{12}$$

$$Y_{13} = Y_{31} = -y_{13}$$

$$Y_{23} = Y_{32} = -y_{23}$$

$$Y_{34} = Y_{43} = -y_{34}$$

Then the nodal equation reduces to

$$I_1 = Y_{11}V_1 + Y_{12}V_2 + Y_{13}V_3 + Y_{14}V_4$$

$$I_2 = Y_{21}V_1 + Y_{22}V_2 + Y_{23}V_3 + Y_{24}V_4$$

$$I_3 = Y_{31}V_1 + Y_{32}V_2 + Y_{33}V_3 + Y_{34}V_4$$

$$I_4 = Y_{41}V_1 + Y_{42}V_2 + Y_{43}V_3 + Y_{44}V_4$$

In the above network there is no connection between bus 1 and 4 so

$$Y_{14}=Y_{41}=0$$

Similarly ,

$$Y_{24}=Y_{42}=0$$

Extending the above relation to an n-bus system, the node voltage equation in matrix form is given by

$$\begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_i \\ \vdots \\ I_n \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & \cdots & Y_{1i} & \cdots & Y_{1n} \\ Y_{21} & Y_{22} & \cdots & Y_{2i} & \cdots & Y_{2n} \\ \vdots & \vdots & & \vdots & & \vdots \\ Y_{i1} & Y_{i2} & \cdots & Y_{ii} & \cdots & Y_{in} \\ \vdots & \vdots & & \vdots & & \vdots \\ Y_{n1} & Y_{n2} & \cdots & Y_{ni} & \cdots & Y_{nn} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ \vdots \\ V_i \\ \vdots \\ V_n \end{bmatrix}$$

Or

$$I_{BUS} = Y_{BUS} * V_{BUS}$$

$Y_{bus}$ is known as the bus admittance matrix.

The diagonal elements is the matrix is known as self-admittance that is

$$Y_{ii} = \sum_{j=0}^{n} y_{ij} \qquad j \neq i$$

And the off diagonal elements are known as the mutual admittance (negative of admittance between nodes ) ,that is

$$Y_{ij} = Y_{ji} = -y_{ij}$$

Furthermore , an algorithm can be developed using **Matlab** to calculate the bus admittance matrix. A function **Y=ybus(zdata)** [1] is written to calculate the bus admittance matrix. **zdata** is the line data input and contain 4columns,the first 2cloumns contain line bus numbers and the rest 2 give the line resistance and reactance per unit. In the program the impedances are converted to admittances.

<u>Example:</u>

Find the bus admittance by inversion using function **Y=ybus(zdata)** of figure 1 above.

---

**[1] SEE APPENDIX B**

Solution

```
        Z data=4;
    %     from      to     R     X
    z=[      0      1      0     1;
             0      2      0     .8;
             1      2      0     .4;
             1      3      0     .2;
             2      3      0     .2;
             3      4      0     .08];
          Y                  =           ybus       (z)
%bus admittance matrix
          Z bus   =   inv   (Y)                       %bus
impedance matrix
```

Y=

| | | | |
|---|---|---|---|
| 0-8.5000i | 0+2.5000i | 0+5.0000i | 0 |
| 0+2.5000i | 0-8.7500i | 0+5.0000i | 0 |
| 0+5.0000i | 0+5.0000i | 0-22.5000i | 0+12.5000i |
| 0 | 0 | 0 +12.5000i | 0 -12.5000i |

Z bus=

| | | | |
|---|---|---|---|
| 0 + 0.5000i | 0 + 0.4000i | 0 + 0.4500i | 0 + 0.4500i |
| 0 + 0.4000i | 0 + 0.4800i | 0 + 0.4400i | 0 + 0.4400i |
| 0 + 0.4500i | 0 + 0.4400i | 0 + 0.5450i | 0 + 0.5450i |
| 0 + 0.4500i | 0 + 0.4400i | 0 + 0.5450i | 0 + 0.6250i |

# CHAPTER 2
# SOLUTION TO NON-LINEAR ALGEBRIC EQUATIONS

There are 3 most commonly used methods of solving non-linear algebraic equations which are

1. Gauss-Seidel Method
2. Newton-Raphson Method
3. Quasi-Newton Method

Gauss-Seidel and Newton-Raphson Method can be extended to n-dimensional equation which makes them suitable for handling large amount of data.

## 2.1 Gauss-Seidel Method

This method is also known as continuous displacement method. Consider a linear equation whose solution is given by

$$\mathbf{f(x)=0} \qquad 2.1$$

Re-writing equation 2.1

$$\mathbf{x=g(x)} \qquad 2.2$$

If $x^{(k)}$ is the initial solution of equation 2.2 the next solution is given by $x^{(k+1)}$

So ,

$$\mathbf{X^{(k+1)} = g(x^{(k)})} \qquad 2.3$$

Convergence is primordial criteria , a final solution is obtained when the difference between two successive iteration is less than a specified accuracy.

Mathematically,

$|X^{(k+1)}-X^{(k)}| < \varepsilon$ where , $\varepsilon$ is the accuracy.

**Example 2,1;**

Use Gauss-Seidel method to find the root of the following equation

$$f(x)=x^3-6x^2+9x-4=0$$

or

$$x= -(1/9)x^3+(6/9)x^2+(4/9)$$

**Solution**

The above equation can be converted into MATLAB algorithm as shown

```
dx=1;                      %change in variable set
x=2;                       %initial estimate
iter=0;                    % iteraton counter
disp('Iter    g     dx      x')
while abs(dx)>=0.001 && iter<100  % convergence test
    iter=iter+1;                  % iteration number
    g =-1/9*x^3+6/9*2+4/9;
    dx=g-x;
    x =x+dx;
    fprintf('%g', iter),disp([g, dx, x])
end
```

| Iteration | g | dx | X |
|---|---|---|---|
| 1 | 2.222 | 0.2222 | 2.222 |
| 2 | 2.5173 | 0.2951 | 2.5173 |
| 3 | 2.8966 | 0.3793 | 2.8966 |
| 4 | 3.3376 | 0.4410 | 3.3376 |

| | | | |
|---|---|---|---|
| 5 | 3.7396 | 0.4022 | 3.7396 |
| 6 | 3.9568 | 0.2170 | 3.9568 |
| 7 | 3.9988 | 0.0420 | 3.9988 |
| 8 | 4.0000 | 0.0012 | 4.0000 |
| 9 | 4.0000 | 0.0000 | 4.0000 |

## 2.2 Newton-Raphson Method

This method is based on successive approximations based on an initial estimate of the unknown and use of Taylor's series expansion.

Consider the one dimensional equation given by

$$f(x) = c \qquad 2.5$$

if $x^{(0)}$ is an initial estimate of the solution, and $\Delta x^{(0)}$ is a little deviation then the deviation from the solution from the correct result is

$$f(x^{(0)} + \Delta x^{(0)}) = c \qquad 2.6$$

As mentioned, we'll use Taylor's series to expand the left hand side of the above equation yields about $x^{(0)}$

$$f(x^{(0)}) + (df/dx)^{(0)}\Delta x^{(0)} + (1/2!)(d^2f/dx^2)^{(0)}(\Delta x^{(0)})^2 \ldots\ldots = c \qquad 2.7$$

Assuming error $\Delta x^{(0)}$ is very small, higher order terms can be neglected gives

$$\Delta c^{(0)} \approx (df/dx)^{(0)}\Delta x^{(0)} \qquad 2.8$$

where

$$\Delta c^{(0)} = c - f(x^{(0)}) \qquad 2.9$$

Successive use of the Newton-Raphson algorithm yields

$$\Delta c^{(k)}=c - f(x^{(k)}) \qquad 2.10$$

$$\Delta x^{(k)} = \Delta c^{(k)}/ (df/dx)^{(k)} \qquad 2.11$$

So

$$x^{(k+1)}=x^{(k)}+\Delta x^{(k)} \qquad 2.12$$

**Example 2.2**

Newton-Raphson Method also can be solved by developing an algorithm on MATLAB. Example 2.1 above can be solved using Newton-Raphson's Method as follows

```
dx=1;
%change in variable is set to high value

x=input('Enter the initial estimate -> ')
%initial estimate

iter=0;
%iteration counter

disp('Iter      Dc       J        dx         x')

while abs(dx)>=0.001 & iter < 100               % test
for convergence

    iter=iter+1;
%  no of iteration

    Dc=0-(x^3-6*x^2+9*x-4);                        %
residual
```

```
    J=3*x^2-12*x+9;
% Derivative
    dx=Dc/J;
    x=x+dx;
% successive solution
    fprintf('%g',iter)
    disp([Dc   ,  J ,  dx  , x])
end
```

**Result**

| Iter | Dc | J | dx | x |
|---|---|---|---|---|
| 1 | -50.0000 | 45.0000 | -1.1111 | 4.8889 |
| 2 | -13.4431 | 22.0370 | -0.6100 | 4.2789 |
| 3 | -2.9981 | 12.5797 | -0.2383 | 4.0405 |
| 4 | 0.3748 | 9.4914 | -0.0395 | 4.0011 |
| 5 | 0.0095 | 9.0126 | -0.0011 | 4.0000 |
| 6 | 0.0000 | 9.0000 | 0.0000 | 4.0000 |

Conclusively, we see that in comparative study the Gauss-Seidel method converges after a higher number of iterations than the Newton-Raphson Method in solving non-linear algebric equations.

# CHAPTER 3

# POWER FLOW SOLUTION

Power flow studies, similarly known as load flow studies form an important part of power system analysis. It is essential for planning, economic scheduling and controlling of an existing system as well as for future expansion of a given system. The objective is to obtain voltages in their magnitude and phase angles at each bus plus active and reactive power flow at each line in the system.

In a given load flow problem, the system is assumed to be operated under a balanced conditions with a single phase model. There are four quantities associated with each bus and each bus name is derived from the known or unknown status of the four quantities in question. These quantities are the voltage magnitude $|V|$, phase angle $\delta$, real power $P$ and reactive power $Q$ .

The system buses are then classified into three types

- **Slack Bus:** This is distinguished by the fact that real and reactive powers at this bus are not specified. There is only one bus of this type in a power system. This bus makes up the difference between the scheduled loads and generated power caused by loses in the network. The magnitude and phase angle of voltage are specified. The presence of this bus important because the complex power is unspecified so that it supplies the difference in the total system load plus loses and the sum of the complex power specified at the remaining buses
- **Load buses:** At these buses active and reactive powers are specified. The magnitude and phase angle of bus voltages are unknown. These buses are also known as *P-Q* buses. Because of no generating capacity at these buses is also termed as **pure load buses**
- **Generator buses:** Here real power and voltage magnitudes are specified, the phase angles and reactive powers are to be determined. They are also known as voltage controlled buses.

## 3.1 <u>Power flow Equation</u>

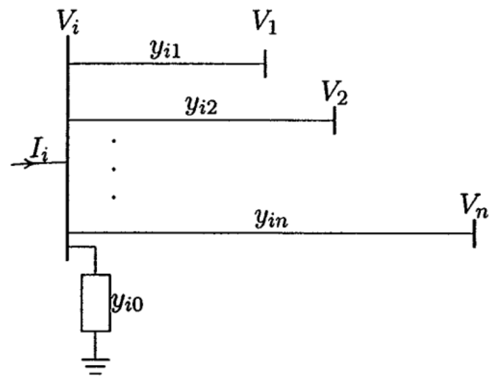


Figure 3.1 A typical bus of a system

Consider a typical bus of a system network shown in the above figure. The transmission lines are represented by its nominal π models and impedances have been converted to admittances in per unit at a common MVA base.

Applying KCL results in

$$\begin{aligned} I_i &= y_{i0}V_i + y_{i1}(V_i - V_1) + y_{i2}(V_i - V_2) + \cdots + y_{in}(V_i - V_n) \\ &= (y_{i0} + y_{i1} + y_{i2} + \cdots + y_{in})V_i - y_{i1}V_1 - y_{i2}V_2 - \cdots - y_{in}V_n \end{aligned}$$

3.1

Simplifying gives

$$I_i = V_i \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij}V_j \qquad j \neq i$$

3.2

Real and reactive power at bud $i$ is

$$P_i + jQ_i = V_i I_i^*$$

3.3

Or

$$I_i = \frac{P_i - jQ_i}{V_i^*}$$ 3.4

Substituting for I in equation 3.2 yields

$$\frac{P_i - jQ_i}{V_i^*} = V_i \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j \qquad j \neq i$$ 3.5

From the above relation, mathematical formulation of power flow problems can be solved by iteration techniques.

### 3.2 <u>Gauss-Seidel Power Flow Solution</u>

In solving for bus voltages bud Gauss-Seidel method the iteration equation becomes

$$V_i^{(k+1)} = \frac{\frac{P_i^{sch} - jQ_i^{sch}}{V_i^{*(k)}} + \sum y_{ij} V_j^{(k)}}{\sum y_{ij}} \qquad j \neq i$$ 3.6

$$P_i^{(k+1)} = \Re\{V_i^{*(k)}[V_i^{(k)} \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j^{(k)}]\} \qquad j \neq i$$ 3.7

$$Q_i^{(k+1)} = -\Im\{V_i^{*(k)}[V_i^{(k)} \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j^{(k)}]\} \qquad j \neq i$$ 3.8

The rate of convergence is increased by applying an accelerating factor to the approximated solution of each iteration

$$V_i^{(k+1)} = V_i^{(k)} + \alpha(V_{i\,cal}^{(k)} - V_i^{(k)})$$ 3.9

Where $\alpha$ is known as the acceleration factor.

The updated voltages instantly replaces the previous values in the solution of the subsequent equations, this is done by continuously changing in the real and imaginary components of bus voltages between two successive iterations within a specified accuracy. For the power mismatch to be reasonably small and acceptable a very tiny tolerance must be specified on both the voltage components, a voltage accuracy ( ε ) in the range 0.00001 to 0.00005 per unit is satisfactory.

$$e_i^{(k+1)} = \sqrt{|V_i|^2 - (f_i^{(k+1)})^2} \quad 3.10$$

$$|e_i^{(k+1)} - e_i^{(k)}| \leq \epsilon \quad 3.11$$

### 3.3 <u>Line Flows and Losses</u>

Line flow is the pattern which shows direction of transmission of power in a line whereas a line loss involves the total of the different energy losses occurring in a transmission line.

Consider the two bus system shown in the figure below

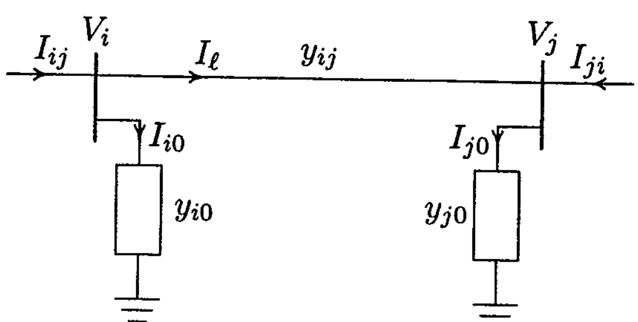


Figure 3.2 transmission line model for calculating flow and losses

i→j is given by

$$I_{ij} = I_\ell + I_{i0} = y_{ij}(V_i - V_j) + y_{i0}V_i \quad 3.1$$

Similarly $I_{ji}$ is measuredat bus j and defined positive direction in j→i is given by

$$I_{ji} = -I_\ell + I_{j0} = y_{ij}(V_j - V_i) + y_{j0}V_j \quad 3.2$$

So the complex powers from bus i→j, $S_{ij}$ and bus j→I, $S_{ji}$ are

$$S_{ij} = V_i I_{ij}^* \quad 3.3$$

$$S_{ji} = V_j I_{ji}^* \quad 3.4$$

So the power loss is the algebric sum of the power flows determined form equation 3.3 and equation 3.4

$$S_{L\,ij} = S_{ij} + S_{ji} \quad 3.5$$

# CHAPTER 4

# SIMULATION AND RESULTS

Mat lab was chosen as the simulation tool for this research because of the ease of manipulation of matrix structures and inputs. It has in-built routines such as inverse function, abs function, and so on, facilities of convergence when given a restricted range or accuracy.

## 4.1 Data Preparation

In order to perform power analysis in Mat lab window , certain variables are to be fixed which are

1. Base MVA , basemva = 100
2. Accuracy , accuracy = 0.001
3. Acceleration factor , accel = 1.6
4. Maximum iteration, maxiter = 1

### 4.1.1 Bus Data File

Here the information required are included in a matrix file known as the **bus data**. In this matrix file,

-Column 1 contains the bus number

-Column 2 contains the bus code

-Columns 3 and 4 contains voltage magnitude in per unit and phase angle in degrees respectively

-Columns 5 and 6 are load MW and Mvar respectively

-Columns 7 through 10 are MW, Mvar , minimum Mvar and maximum Mvar of generation in that order.

Furthermore column 2 is used for identifying load, voltage-controlled and slack buses as detail explained below

**Code 1** used for slack bus

**Code 2** used for voltage controlled buses

**Code 0** is used for load buses

### 4.1.2 Line Data File

Lines are identified by node pair method. The information gathered in this matrix forms the **linedata.** Columns 1 and 2 are the line bus numbers. Columns 3 through 5 contain the line resistance, reactance and one-half of the total line charging susceptance in per unit on a specified base.

## 4.2 Power Flow Programs

There are several programs developed for power flow analysis. The program for Gauss-Seidel method is **lfgauss,** this program is used in conjunction with **lfybus** and is followed by **busout** and **lineflow .**

- **lfgauss [1] :** this program obtains the power flow solution by Gauss-Seidel method
- **lfybus[2] :** this program converts impedances to admittances and obtain the bus admittance matrix
- **busout [3]:** it gives the bus output in tabulated form. Total generation and total loads are included as outlined in a sample case
- **lineflow [4]:** this program prepares line output data. It displays real and reactive powers entering the line terminals and the line losses as well as net power in the system .

**[1]** SEE APPENDIX A **. [2]** SEE APPENDIX B **, [3]** SEE APPENDIX C, **[4]** SEE APPENDIX D

## 4.3 Power Flow Analysis of 14 Bus System

## 4.3.1 Matlab algorithm

```
clear
basemva   = 200;
accuracy   = 0.011;
accel         = 1.8;
maxiter     = 100;

       % line data
  %        Bus    bus      R          X      1/2 b 1  for line code or
  %        nl     nr      pu          pu      pu       tap setting
value
 linedata=[
             1    2    0.01938   0.05917     0.0528    1
             1    5    0.05403   0.22304     0.0492    1
             2    3    0.04699   0.19797     0.0438    1
             2    4    0.05811   0.17632     0.0340    1
             2    5    0.05695   0.17388     0.0346    1
             3    4    0.06701   0.17103     0.0128    1
             4    5    0.01335   0.04211     0.0       1
             4    7    0.0       0.20912     0.0       0.978
             4    9    0.0       0.55618     0.0       0.969
             5    6    0.0       0.25202     0.0       0.932
             6    11   0.09498   0.19890     0.0       1
             6    12   0.12291   0.25581     0.0       1
             6    13   0.06615   0.13027     0.0       1
             7    8    0.0       0.17615     0.0       1
             7    9    0.0       0.11001     0.0       1
             9    10   0.03181   0.08450     0.0       1
             9    14   0.12711   0.27038     0.0       1
             10   11   0.08205   0.19207     0.0       1
             12   13   0.22092   0.19988     0.0       1
             13   14   0.17093   0.34802     0.0       1];


% bus  bus  voltage  angle    --load--     --generator--      injected
 %No  code Mag.    Degree    MW      Mvar   MW       Mvar   Qmin   Qmax   Mvar
Busdata=
[1     1   1.060   0.0      0.0     0.0    232.2   -16.9   0.0    0.0     0.0
 2     2   1.045  -4.98     21.7    12.7   40.0     42.4  -40.0   50.0    0.0
 3     2   1.010  -12.72    94.2    19.0   0.0      23.4   0.0    40.0    0.0
 4     0   1.019  -10.33    47.8   -3.9    0.0      0.0    0.0    0.0     0.0
 5     0   1.020  -8.78     7.6     1.6    0.0      0.0    0.0    0.0     0.0
 6     2   1.070  -14.22    11.2    7.5    0.0      12.2  -6.0    24.0    0.0
 7     0   1.062  -13.37    0.0     0.0    0.0      0.0    0.0    0.0     0.0
 8     2   1.090  -13.36    0.0     0.0    0.0      17.4  -6.0    24.0    0.0
 9     0   1.056  -14.94    29.5    16.6   0.0      0.0    0.0    0.0     0.0
 10    0   1.051  -15.10    9.0     5.8    0.0      0.0    0.0    0.0     0.0
 11    0   1.057  -14.79    3.5     1.8    0.0      0.0    0.0    0.0     0.0
```

```
 12    0   1.055  -15.07   6.1     1.6    0.0      0.0    0.0   0.0    0.0
 13    0   1.050  -15.16   13.5    5.8    0.0      0.0    0.0   0.0    0.0
 14    0   1.036  -16.04   14.9    5.0    0.0      0.0    0.0   0.0    0.0];
lfybus;
lfgauss;
busout  ;
lineflow;
```

## 4.3.2 RESULTS

**Maximum Power Mismatch = 0.00801602**
**No. of Iterations = 27**

| Bus No. | Voltage Mag. | Angle Degree | ------Load------ MW | Mvar | ---Generation--- MW | Mvar | Injected Mvar |
|---|---|---|---|---|---|---|---|
| 1 | 1.060 | 0.000 | 0.000 | 0.000 | 226.600 | -4.278 | 0.000 |
| 2 | 1.045 | -2.280 | 21.700 | 12.700 | 40.000 | -1.953 | 0.000 |
| 3 | 1.015 | -5.890 | 94.200 | 19.000 | 0.000 | -10.767 | 0.000 |
| 4 | 1.029 | -4.872 | 47.800 | -3.900 | 0.000 | 0.000 | 0.000 |
| 5 | 1.031 | -4.144 | 7.600 | 1.600 | 0.000 | 0.000 | 0.000 |
| 6 | 1.070 | -6.907 | 11.200 | 7.500 | 0.000 | -2.116 | 0.000 |
| 7 | 1.058 | -6.324 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 8 | 1.075 | -6.331 | 0.000 | 0.000 | 0.000 | 20.225 | 0.000 |
| 9 | 1.051 | -7.095 | 29.500 | 16.600 | 0.000 | 0.000 | 0.000 |
| 10 | 1.051 | -7.205 | 9.000 | 5.800 | 0.000 | 0.000 | 0.000 |
| 11 | 1.059 | -7.104 | 3.500 | 1.800 | 0.000 | 0.000 | 0.000 |
| 12 | 1.061 | -7.294 | 6.100 | 1.600 | 0.000 | 0.000 | 0.000 |
| 13 | 1.059 | -7.354 | 13.500 | 5.800 | 0.000 | 0.000 | 0.000 |
| 14 | 1.045 | -7.684 | 14.900 | 5.000 | 0.000 | 0.000 | 0.000 |
| **Total** | | | **259.000** | **73.500** | **266.600** | **1.112** | **0.000** |

**Line Flow and Losses**

| % --Line-- from | to | Power at bus & line flow MW | Mvar | MVA | --Line loss-- MW | Mvar | Transformer tap |
|---|---|---|---|---|---|---|---|
| 1 | | 226.600 | -4.278 | 226.641 | | | |
| | 2 | 151.293 | -4.706 | 151.366 | 1.978 | -17.357 | |
| | 5 | 73.791 | 1.206 | 73.801 | 1.345 | -15.962 | |
| 2 | | 18.300 | -14.653 | 23.443 | | | |
| | 1 | -149.315 | -12.650 | 149.850 | 1.978 | -17.357 | |
| | 3 | 71.533 | 7.612 | 71.937 | 1.164 | -13.679 | |
| | 4 | 55.783 | -5.526 | 56.056 | 0.829 | -12.110 | |
| | 5 | 41.586 | -3.682 | 41.749 | 0.455 | -13.524 | |
| 3 | | -94.200 | -29.767 | 98.791 | | | |
| | 2 | -70.368 | -21.291 | 73.519 | 1.164 | -13.679 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 4 | -24.502 | -9.787 | 26.384 | 0.212 | -4.805 | |
| 4 | | -47.800 | 3.900 | 47.959 | | | |
| | 2 | -54.954 | -6.584 | 55.347 | 0.829 | -12.110 | |
| | 3 | 24.714 | 4.982 | 25.211 | 0.212 | -4.805 | |
| | 5 | -60.907 | 9.694 | 61.674 | 0.240 | 0.756 | |
| | 7 | 26.979 | -5.713 | 27.578 | -0.000 | 0.718 | 0.978 |
| | 9 | 15.571 | 4.270 | 16.146 | 0.000 | 0.643 | 0.969 |
| 5 | | -7.600 | -1.600 | 7.767 | | | |
| | 1 | -72.446 | -17.167 | 74.452 | 1.345 | -15.962 | |
| | 2 | -41.131 | -9.841 | 42.292 | 0.455 | -13.524 | |
| | 4 | 61.147 | -8.938 | 61.797 | 0.240 | 0.756 | |
| | 6 | 45.272 | 32.881 | 55.953 | 0.000 | 3.224 | 0.932 |
| 6 | | -11.200 | -9.616 | 14.762 | | | |
| | 5 | -45.272 | -29.657 | 54.121 | 0.000 | 3.224 | |
| | 11 | 7.990 | 8.512 | 11.675 | 0.057 | 0.118 | |
| | 12 | 7.841 | 3.824 | 8.724 | 0.041 | 0.085 | |
| | 13 | 18.305 | 9.292 | 20.528 | 0.122 | 0.240 | |
| 7 | | 0.000 | 0.000 | 0.000 | | | |
| | 4 | -26.979 | 6.432 | 27.736 | -0.000 | 0.718 | |
| | 8 | 0.158 | -20.610 | 20.611 | 0.000 | 0.334 | |
| | 9 | 27.201 | 12.951 | 30.127 | 0.000 | 0.446 | |
| 8 | | 0.000 | 20.225 | 20.225 | | | |
| | 7 | -0.158 | 20.944 | 20.945 | 0.000 | 0.334 | |
| 9 | | -29.500 | -16.600 | 33.850 | | | |
| | 4 | -15.571 | -3.627 | 15.988 | 0.000 | 0.643 | |
| | 7 | -27.201 | -12.505 | 29.938 | 0.000 | 0.446 | |
| | 10 | 4.608 | -1.098 | 4.737 | 0.003 | 0.009 | |
| | 14 | 8.858 | 1.062 | 8.922 | 0.046 | 0.097 | |
| 10 | | -9.000 | -5.800 | 10.707 | | | |
| | 9 | -4.605 | 1.107 | 4.736 | 0.003 | 0.009 | |
| | 11 | -4.615 | -6.059 | 7.616 | 0.022 | 0.050 | |
| 11 | | -3.500 | -1.800 | 3.936 | | | |
| | 6 | -7.934 | -8.394 | 11.550 | 0.057 | 0.118 | |
| | 10 | 4.636 | 6.109 | 7.669 | 0.022 | 0.050 | |
| 12 | | -6.100 | -1.600 | 6.306 | | | |
| | 6 | -7.801 | -3.739 | 8.651 | 0.041 | 0.085 | |
| | 13 | 1.708 | 0.481 | 1.775 | 0.003 | 0.003 | |
| 13 | | -13.500 | -5.800 | 14.693 | | | |
| | 6 | -18.183 | -9.052 | 20.312 | 0.122 | 0.240 | |
| | 12 | -1.705 | -0.478 | 1.771 | 0.003 | 0.003 | |
| | 14 | 6.300 | 5.384 | 8.287 | 0.052 | 0.107 | |
| 14 | | -14.900 | -5.000 | 15.717 | | | |
| | 9 | -8.813 | -0.965 | 8.865 | 0.046 | 0.097 | |
| | 13 | -6.248 | -5.277 | 8.178 | 0.052 | 0.107 | |
| **Total loss** | | | | | **6.569** | **-70.605** | |

## 4.4 Power Flow Analysis of 30 Bus System

### 4.4.1 Mat lab algorithm

```
Basemva    = 100;
accuracy   = 0.001;
accel      = 1.8;
maxiter    = 100;


  %IEEE 30-bus test system(American Electric Power)
        % bus  bus  voltage  angle  --load--  --generator--  injected
        % No   code  Mag.  Degree   MW   Mvar   MW     Mvar  Qmin Qmax Mvar
busdata =[ 1    1    1.06   0      0.0    0.0   0.0   0.0    0    0    0
           2    2    1.043  0      21.70  12.7  40.0  0     -40   50    0
           3    0    1.0    0      2.4    1.2   0     0      0    0    0
           4    0    1.06   0      7.6    1.6   0     0      0    0    0
           5    2    1.01   0      94.2   19.0  0     0     -40   40    0
           6    0    1.0    0      0.0    0.0   0     0      0    0    0
           7    0    1.0    0      22.8   10.9  0     0      0    0    0
           8    2    1.01   0      30.0   30.0  0     0     -10   40    0
           9    0    1.0    0      0.0    0.0   0     0      0    0    0
           10   0    1.0    0      5.8    2.0   0     0      0    0    19
           11   2    1.082  0      0.0    0.0   0     0     -6    24    0
           12   0    1.0    0      11.2   7.5   0     0      0    0    0
           13   2    1.071  0      0.0    0.0   0     0     -6    24    0
           14   0    1.0    0      6.2    1.6   0     0      0    0    0
           15   0    1.0    0      8.2    2.5   0     0      0    0    0
           16   0    1.0    0      3.5    1.8   0     0      0    0    0
           17   0    1.0    0      9.0    5.8   0     0      0    0    0
           18   0    1.0    0      3.2    0.9   0     0      0    0    0
           19   0    1.0    0      9.5    3.4   0     0      0    0    0
           20   0    1.0    0      2.2    0.7   0     0      0    0    0
           21   0    1.0    0      17.5   11.2  0     0      0    0    0
           22   0    1.0    0      0.0    0.0   0     0      0    0    0
           23   0    1.0    0      3.2    1.6   0     0      0    0    0
           24   0    1.0    0      8.7    6.7   0     0      0    0    4.3
           25   0    1.0    0      0.0    0.0   0     0      0    0    0
           26   0    1.0    0      3.5    2.3   0     0      0    0    0
           27   0    1.0    0      0.0    0.0   0     0      0    0    0
           28   0    1.0    0      0.0    0.0   0     0      0    0    0
           29   0    1.0    0      2.4    0.9   0     0      0    0    0
           30   0    1.0    0      10.6   1.9   0     0      0    0    0];
```

```
% line data
  %        Bus    bus      R           X      1/2 b 1  for line code or
  %        nl     nr     pu           pu     pu       tap setting value
linedata =[1      2     0.0192      0.0575     0.02640     1
           1      3     0.0452      0.1852     0.02040     1
           2      4     0.0570      0.1737     0.01840     1
           3      4     0.0132      0.0379     0.00420     1
           2      5     0.0472      0.1983     0.02090     1
           2      6     0.0581      0.1763     0.01870     1
           4      6     0.0119      0.0414     0.00450     1
           5      7     0.0460      0.1160     0.01020     1
           6      7     0.0267      0.0820     0.00850     1
           6      8     0.0120      0.0420     0.00450     1
           6      9     0.0         0.2080     0.0         0.978
           6      10    0.0         0.5560     0.0         0.969
           9      11    0.0         0.2080     0.0         1
           9      10    0.0         0.1100     0.0         1
           4      12    0.0         0.2560     0.0         0.932
           12     13    0.0         0.1400     0.0         1
           12     14    0.1231      0.2559     0.0         1
           12     15    0.0662      0.1304     0.0         1
           12     16    0.0945      0.1987     0.0         1
           14     15    0.2210      0.1997     0.0         1
           16     17    0.0824      0.1923     0.0         1
           15     18    0.1073      0.2185     0.0         1
           18     19    0.0639      0.1292     0.0         1
           19     20    0.0340      0.0680     0.0         1
           10     20    0.0936      0.2090     0.0         1
           10     17    0.0324      0.0845     0.0         1
           10     21    0.0348      0.0749     0.0         1
           10     22    0.0727      0.1499     0.0         1
           21     22    0.0116      0.0236     0.0         1
           15     23    0.1000      0.2020     0.0         1
           22     24    0.1150      0.1790     0.0         1
           23     24    0.1320      0.2700     0.0         1
           24     25    0.1885      0.3292     0.0         1
           25     26    0.2544      0.3800     0.0         1
           25     27    0.1093      0.2807     0.0         1
           28     27    0.0000      0.3960     0.0         0.968
           27     29    0.2198      0.4153     0.0         1
           27     30    0.3202      0.6027     0.0         1
           29     30    0.2399      0.4533     0.0         1
           8      28    0.0636      0.2000     0.0214      1
           6      28    0.0169      0.0599     0.065       1];

       lfybus ;
       lfgauss ;
       busout  ;
       lineflow ;
```

## 4.4.2 RESULTS

Maximum Power Mismatch = 0.000829895
No. of Iterations = 32

| Bus No. | Voltage Mag. | Angle Degree | ------Load------ MW | Mvar | ---Generation--- MW | Mvar | Injected Mvar |
|---|---|---|---|---|---|---|---|
| 1 | 1.060 | 0.000 | 0.000 | 0.000 | 260.964 | -17.044 | 0.000 |
| 2 | 1.043 | -5.495 | 21.700 | 12.700 | 40.000 | 48.781 | 0.000 |
| 3 | 1.021 | -8.002 | 2.400 | 1.200 | 0.000 | 0.000 | 0.000 |
| 4 | 1.013 | -9.660 | 7.600 | 1.600 | 0.000 | 0.000 | 0.000 |
| 5 | 1.010 | -14.378 | 94.200 | 19.000 | 0.000 | 35.994 | 0.000 |
| 6 | 1.012 | -11.393 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 7 | 1.003 | -13.145 | 22.800 | 10.900 | 0.000 | 0.000 | 0.000 |
| 8 | 1.010 | -12.109 | 30.000 | 30.000 | 0.000 | 30.788 | 0.000 |
| 9 | 1.051 | -14.440 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 10 | 1.044 | -16.038 | 5.800 | 2.000 | 0.000 | 0.000 | 19.000 |
| 11 | 1.082 | -14.443 | 0.000 | 0.000 | 0.000 | 16.121 | 0.000 |
| 12 | 1.057 | -15.312 | 11.200 | 7.500 | 0.000 | 0.000 | 0.000 |
| 13 | 1.071 | -15.314 | 0.000 | 0.000 | 0.000 | 10.419 | 0.000 |
| 14 | 1.042 | -16.206 | 6.200 | 1.600 | 0.000 | 0.000 | 0.000 |
| 15 | 1.038 | -16.294 | 8.200 | 2.500 | 0.000 | 0.000 | 0.000 |
| 16 | 1.045 | -15.890 | 3.500 | 1.800 | 0.000 | 0.000 | 0.000 |
| 17 | 1.039 | -16.200 | 9.000 | 5.800 | 0.000 | 0.000 | 0.000 |
| 18 | 1.028 | -16.900 | 3.200 | 0.900 | 0.000 | 0.000 | 0.000 |
| 19 | 1.025 | -17.065 | 9.500 | 3.400 | 0.000 | 0.000 | 0.000 |
| 20 | 1.029 | -16.866 | 2.200 | 0.700 | 0.000 | 0.000 | 0.000 |
| 21 | 1.032 | -16.486 | 17.500 | 11.200 | 0.000 | 0.000 | 0.000 |
| 22 | 1.033 | -16.475 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 23 | 1.027 | -16.686 | 3.200 | 1.600 | 0.000 | 0.000 | 0.000 |
| 24 | 1.021 | -16.868 | 8.700 | 6.700 | 0.000 | 0.000 | 4.300 |
| 25 | 1.018 | -16.509 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 26 | 1.001 | -16.922 | 3.500 | 2.300 | 0.000 | 0.000 | 0.000 |
| 27 | 1.026 | -15.852 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 28 | 1.011 | -12.046 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 29 | 1.006 | -17.073 | 2.400 | 0.900 | 0.000 | 0.000 | 0.000 |
| 30 | 0.994 | -17.956 | 10.600 | 1.900 | 0.000 | 0.000 | 0.000 |
| **Total** | | | **283.400** | **126.200** | **300.964** | **125.058** | **23.300** |

**Line Flow and Losses**

| --Line-- from | to | Power at bus & line flow MW | Mvar | MVA | --Line loss-- MW | Mvar | Transformer tap |
|---|---|---|---|---|---|---|---|
| 1 | | 260.964 | -17.044 | 261.520 | | | |
| | 2 | 177.735 | -22.138 | 179.109 | 5.461 | 10.516 | |
| | 3 | 83.201 | 5.131 | 83.359 | 2.807 | 7.080 | |
| 2 | | 18.300 | 36.081 | 40.457 | | | |
| | 1 | -172.274 | 32.654 | 175.342 | 5.461 | 10.516 | |
| | 4 | 45.713 | 2.711 | 45.794 | 1.107 | -0.517 | |
| | 5 | 82.972 | 1.706 | 82.990 | 2.994 | 8.172 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 6 | 61.882 | -0.949 | 61.889 | 2.046 | 2.258 | |
| 3 | | -2.400 | -1.200 | 2.683 | | | |
| | 1 | -80.394 | 1.949 | 80.418 | 2.807 | 7.080 | |
| | 4 | 78.045 | -3.151 | 78.109 | 0.771 | 1.346 | |
| 4 | | -7.600 | -1.600 | 7.767 | | | |
| | 2 | -44.607 | -3.228 | 44.724 | 1.107 | -0.517 | |
| | 3 | -77.274 | 4.497 | 77.405 | 0.771 | 1.346 | |
| | 6 | 69.991 | -17.509 | 72.148 | 0.602 | 1.172 | |
| | 12 | 44.204 | 14.646 | 46.567 | 0.000 | 4.701 | 0.932 |
| 5 | | -94.200 | 16.994 | 95.721 | | | |
| | 2 | -79.978 | 6.466 | 80.239 | 2.994 | 8.172 | |
| | 7 | -14.214 | 10.505 | 17.674 | 0.151 | -1.686 | |
| 6 | | 0.000 | 0.000 | 0.000 | | | |
| | 2 | -59.836 | 3.207 | 59.922 | 2.046 | 2.258 | |
| | 4 | -69.389 | 18.680 | 71.860 | 0.602 | 1.172 | |
| | 7 | 37.531 | -1.889 | 37.578 | 0.367 | -0.598 | |
| | 8 | 29.453 | -3.743 | 29.690 | 0.103 | -0.560 | |
| | 9 | 27.789 | -7.316 | 28.736 | 0.000 | 1.604 | 0.978 |
| | 10 | 15.884 | 0.657 | 15.897 | 0.000 | 1.288 | 0.969 |
| | 28 | 18.641 | -9.466 | 20.907 | 0.059 | -13.089 | |
| 7 | | -22.800 | -10.900 | 25.272 | | | |
| | 5 | 14.365 | -12.191 | 18.841 | 0.151 | -1.686 | |
| | 6 | -37.163 | 1.291 | 37.186 | 0.367 | -0.598 | |
| 8 | | -30.000 | 0.788 | 30.010 | | | |
| | 6 | -29.350 | 3.183 | 29.522 | 0.103 | -0.560 | |
| | 28 | -0.610 | -2.325 | 2.404 | 0.000 | -4.368 | |
| 9 | | 0.000 | 0.000 | 0.000 | | | |
| | 6 | -27.789 | 8.920 | 29.185 | 0.000 | 1.604 | |
| | 11 | 0.029 | -15.661 | 15.661 | 0.000 | 0.462 | |
| | 10 | 27.821 | 6.738 | 28.625 | 0.000 | 0.816 | |
| 10 | | -5.800 | 17.000 | 17.962 | | | |
| | 6 | -15.884 | 0.631 | 15.896 | 0.000 | 1.288 | |
| | 9 | -27.821 | -5.922 | 28.444 | 0.000 | 0.816 | |
| | 20 | 9.031 | 3.564 | 9.708 | 0.081 | 0.181 | |
| | 17 | 5.340 | 4.407 | 6.924 | 0.014 | 0.037 | |
| | 21 | 15.839 | 9.853 | 18.653 | 0.111 | 0.239 | |
| | 22 | 7.662 | 4.478 | 8.875 | 0.052 | 0.108 | |
| 11 | | 0.000 | 16.121 | 16.121 | | | |
| | 9 | -0.029 | 16.123 | 16.123 | 0.000 | 0.462 | |
| 12 | | -11.200 | -7.500 | 13.479 | | | |
| | 4 | -44.204 | -9.946 | 45.309 | 0.000 | 4.701 | |
| | 13 | 0.032 | -10.286 | 10.286 | 0.000 | 0.132 | |
| | 14 | 7.894 | 2.439 | 8.262 | 0.075 | 0.156 | |
| | 15 | 17.945 | 6.944 | 19.242 | 0.219 | 0.432 | |
| | 16 | 7.209 | 3.355 | 7.951 | 0.053 | 0.112 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 13 | | 0.000 | 10.419 | 10.419 | | |
| | 12 | -0.032 | 10.419 | 10.419 | 0.000 | 0.132 |
| 14 | | -6.200 | -1.600 | 6.403 | | |
| | 12 | -7.819 | -2.282 | 8.145 | 0.075 | 0.156 |
| | 15 | 1.589 | 0.686 | 1.731 | 0.006 | 0.006 |
| 15 | | -8.200 | -2.500 | 8.573 | | |
| | 12 | -17.726 | -6.512 | 18.884 | 0.219 | 0.432 |
| | 14 | -1.583 | -0.680 | 1.723 | 0.006 | 0.006 |
| | 18 | 6.003 | 1.708 | 6.242 | 0.039 | 0.079 |
| | 23 | 5.069 | 2.934 | 5.857 | 0.032 | 0.064 |
| 16 | | -3.500 | -1.800 | 3.936 | | |
| | 12 | -7.155 | -3.243 | 7.856 | 0.053 | 0.112 |
| | 17 | 3.675 | 1.445 | 3.949 | 0.012 | 0.027 |
| 17 | | -9.000 | -5.800 | 10.707 | | |
| | 16 | -3.663 | -1.417 | 3.928 | 0.012 | 0.027 |
| | 10 | -5.326 | -4.370 | 6.889 | 0.014 | 0.037 |
| 18 | | -3.200 | -0.900 | 3.324 | | |
| | 15 | -5.965 | -1.629 | 6.183 | 0.039 | 0.079 |
| | 19 | 2.764 | 0.822 | 2.883 | 0.005 | 0.010 |
| 19 | | -9.500 | -3.400 | 10.090 | | |
| | 18 | -2.759 | -0.812 | 2.876 | 0.005 | 0.010 |
| | 20 | -6.733 | -2.659 | 7.239 | 0.017 | 0.034 |
| 20 | | -2.200 | -0.700 | 2.309 | | |
| | 19 | 6.749 | 2.693 | 7.267 | 0.017 | 0.034 |
| | 10 | -8.950 | -3.383 | 9.568 | 0.081 | 0.181 |
| 21 | | -17.500 | -11.200 | 20.777 | | |
| | 10 | -15.728 | -9.614 | 18.433 | 0.111 | 0.239 |
| | 22 | -1.712 | -1.701 | 2.413 | 0.001 | 0.001 |
| 22 | | 0.000 | 0.000 | 0.000 | | |
| | 10 | -7.610 | -4.370 | 8.775 | 0.052 | 0.108 |
| | 21 | 1.712 | 1.703 | 2.415 | 0.001 | 0.001 |
| | 24 | 5.811 | 2.758 | 6.432 | 0.045 | 0.069 |
| 23 | | -3.200 | -1.600 | 3.578 | | |
| | 15 | -5.037 | -2.870 | 5.797 | 0.032 | 0.064 |
| | 24 | 1.857 | 1.285 | 2.259 | 0.006 | 0.013 |
| 24 | | -8.700 | -2.400 | 9.025 | | |
| | 22 | -5.766 | -2.688 | 6.362 | 0.045 | 0.069 |
| | 23 | -1.851 | -1.272 | 2.246 | 0.006 | 0.013 |
| | 25 | -1.077 | 1.570 | 1.904 | 0.007 | 0.011 |
| 25 | | 0.000 | 0.000 | 0.000 | | |
| | 24 | 1.083 | -1.558 | 1.898 | 0.007 | 0.011 |

```
         26    3.517    2.366    4.239    0.044    0.066
         27   -4.589   -0.830    4.663    0.023    0.059

   26         -3.500   -2.300    4.188
         25   -3.473   -2.300    4.166    0.044    0.066

   27          0.000    0.000    0.000
         25    4.612    0.888    4.696    0.023    0.059
         28  -17.954   -4.181   18.434    0.000    1.279
         29    6.173    1.669    6.395    0.085    0.161
         30    7.090    1.650    7.279    0.161    0.304

   28          0.000    0.000    0.000
         27   17.954    5.460   18.766    0.000    1.279    0.968
          8    0.610   -2.043    2.132    0.000   -4.368
          6  -18.582   -3.623   18.932    0.059  -13.089

   29         -2.400   -0.900    2.563
         27   -6.088   -1.508    6.272    0.085    0.161
         30    3.715    0.589    3.762    0.034    0.063

   30        -10.600   -1.900   10.769
         27   -6.928   -1.346    7.058    0.161    0.304
         29   -3.682   -0.526    3.719    0.034    0.063

   Total loss                            17.590   22.242
```

## 4.5 Power Flow Analysis of 30 Bus System

### 4.5.1Matlab algorithm

```
clear
basemva=100;
accuracy=0.001;
accel=1.8;
maxiter=100;

% line data
  %       Bus    bus      R           X        1/2 b 1       for line code or
  %        nl     nr      pu          pu         pu         tap setting value
linedata=[
           1       2     0.0303      0.0999     0.0254                    0
           1       3     0.0129      0.0424     0.01082                   0
           4       5     0.00176     0.00798    0.0021                    0
           3       5     0.0241      0.108      0.0284                    0
           5       6     0.0119      0.054      0.01426 0
           6       7     0.00459     0.0208     0.0055                    0
           8       9     0.00244     0.0305     1.162                     0
           8       5     0           0.0267     0                     0.985
           9      10     0.00258     0.0322     1.23                      0
           4      11     0.0209      0.0688     0.01748                   0
           5      11     0.0203      0.0682     0.01738                   0
```

| | | | | | |
|---|---|---|---|---|---|
| 11 | 12 | 0.00595 | 0.0196 | 0.00502 | 0 |
| 2 | 12 | 0.0187 | 0.0616 | 0.01572 | 0 |
| 3 | 12 | 0.0484 | 0.16 | 0.0406 | 0 |
| 7 | 12 | 0.00862 | 0.034 | 0.00874 | 0 |
| 11 | 13 | 0.02225 | 0.0731 | 0.01876 | 0 |
| 12 | 14 | 0.0215 | 0.0707 | 0.01816 | 0 |
| 13 | 15 | 0.0744 | 0.2444 | 0.06268 | 0 |
| 14 | 15 | 0.0595 | 0.195 | 0.0502 | 0 |
| 12 | 16 | 0.0212 | 0.0834 | 0.0214 | 0 |
| 15 | 17 | 0.0132 | 0.0437 | 0.0444 | 0 |
| 16 | 17 | 0.0454 | 0.1801 | 0.0466 | 0 |
| 17 | 18 | 0.0123 | 0.0505 | 0.01298 | 0 |
| 18 | 19 | 0.01119 | 0.0493 | 0.01142 | 0 |
| 19 | 20 | 0.0252 | 0.117 | 0.0298 | 0 |
| 15 | 19 | 0.012 | 0.0394 | 0.0101 | 0 |
| 20 | 21 | 0.0183 | 0.0849 | 0.0216 | 0 |
| 21 | 22 | 0.0209 | 0.097 | 0.0246 | 0 |
| 22 | 23 | 0.0342 | 0.159 | 0.0404 | 0 |
| 23 | 24 | 0.0135 | 0.0492 | 0.0498 | 0 |
| 23 | 25 | 0.0156 | 0.08 | 0.0864 | 0 |
| 26 | 25 | 0 | 0.0382 | 0 | 0.96 |
| 25 | 27 | 0.0318 | 0.163 | 0.1764 | 0 |
| 27 | 28 | 0.01913 | 0.0855 | 0.0216 | 0 |
| 28 | 29 | 0.0237 | 0.0943 | 0.0238 | 0 |
| 30 | 17 | 0 | 0.0388 | 0 | 0.96 |
| 8 | 30 | 0.00431 | 0.0504 | 0.514 | 0 |
| 26 | 30 | 0.00799 | 0.086 | 0.908 | 0 |
| 17 | 31 | 0.0474 | 0.1563 | 0.0399 | 0 |
| 29 | 31 | 0.0108 | 0.0331 | 0.0083 | 0 |
| 23 | 32 | 0.0317 | 0.1153 | 0.1173 | 0 |
| 31 | 32 | 0.0298 | 0.0985 | 0.0251 | 0 |
| 27 | 32 | 0.0229 | 0.0755 | 0.01926 | 0 |
| 15 | 33 | 0.038 | 0.1244 | 0.03194 | 0 |
| 19 | 34 | 0.0752 | 0.247 | 0.0632 | 0 |
| 35 | 36 | 0.00224 | 0.0102 | 0.00268 | 0 |
| 35 | 37 | 0.011 | 0.0497 | 0.01318 | 0 |
| 33 | 37 | 0.0415 | 0.142 | 0.0366 | 0 |
| 34 | 36 | 0.00871 | 0.0268 | 0.00568 | 0 |
| 34 | 37 | 0.00256 | 0.0094 | 0.00984 | 0 |
| 38 | 37 | 0 | 0.0375 | 0 | 0.935 |
| 37 | 39 | 0.0321 | 0.106 | 0.027 | 0 |
| 37 | 40 | 0.0593 | 0.168 | 0.042 | 0 |
| 30 | 38 | 0.00464 | 0.054 | 0.422 | 0 |
| 39 | 40 | 0.0184 | 0.0605 | 0.01552 | 0 |
| 40 | 41 | 0.0145 | 0.0487 | 0.01222 | 0 |
| 40 | 42 | 0.0555 | 0.183 | 0.0466 | 0 |
| 41 | 42 | 0.041 | 0.135 | 0.0344 | 0 |
| 43 | 44 | 0.0608 | 0.2454 | 0.06068 | 0 |
| 34 | 43 | 0.0413 | 0.1681 | 0.04226 | 0 |
| 44 | 45 | 0.0224 | 0.0901 | 0.0224 | 0 |
| 45 | 46 | 0.04 | 0.1356 | 0.0332 | 0 |
| 46 | 47 | 0.038 | 0.127 | 0.0316 | 0 |
| 46 | 48 | 0.0601 | 0.89 | 0.0472 | 0 |
| 47 | 49 | 0.0191 | 0.0625 | 0.01604 | 0 |
| 42 | 49 | 0.0715 | 0.323 | 0.086 | 0 |
| 42 | 49 | 0.0715 | 0.323 | 0.086 | 0 |
| 45 | 49 | 0.0684 | 0.186 | 0.0444 | 0 |

| | | | | | |
|---|---|---|---|---|---|
| 48 | 49 | 0.0179 | 0.0505 | 0.01258 | 0 |
| 49 | 50 | 0.0267 | 0.0752 | 0.01874 | 0 |
| 49 | 51 | 0.0486 | 0.137 | 0.0342 | 0 |
| 51 | 52 | 0.0203 | 0.0588 | 0.01396 | 0 |
| 52 | 53 | 0.0405 | 0.1635 | 0.04058 | 0 |
| 53 | 54 | 0.0263 | 0.122 | 0.031 | 0 |
| 49 | 54 | 0.073 | 0.289 | 0.0738 | 0 |
| 49 | 54 | 0.0869 | 0.291 | 0.073 | 0 |
| 54 | 55 | 0.0169 | 0.0707 | 0.0202 | 0 |
| 54 | 56 | 0.00275 | 0.00955 | 0.00732 | 0 |
| 55 | 56 | 0.00488 | 0.0151 | 0.00374 | 0 |
| 56 | 57 | 0.0343 | 0.0966 | 0.0242 | 0 |
| 50 | 57 | 0.0474 | 0.134 | 0.0332 | 0 |
| 56 | 58 | 0.0343 | 0.0966 | 0.0242 | 0 |
| 51 | 58 | 0.0255 | 0.0719 | 0.01788 | 0 |
| 54 | 59 | 0.0503 | 0.2293 | 0.0598 | 0 |
| 56 | 59 | 0.0825 | 0.251 | 0.0569 | 0 |
| 56 | 59 | 0.0803 | 0.239 | 0.0536 | 0 |
| 55 | 59 | 0.04739 | 0.2158 | 0.05646 | 0 |
| 59 | 60 | 0.0317 | 0.145 | 0.0376 | 0 |
| 59 | 61 | 0.0328 | 0.15 | 0.0388 | 0 |
| 60 | 61 | 0.00264 | 0.0135 | 0.01456 | 0 |
| 60 | 62 | 0.0123 | 0.0561 | 0.01468 | 0 |
| 61 | 62 | 0.00824 | 0.0376 | 0.0098 | 0 |
| 63 | 59 | 0 | 0.0386 | 0 | 0.96 |
| 63 | 64 | 0.00172 | 0.02 | 0.216 | 0 |
| 64 | 61 | 0 | 0.0268 | 0 | 0.985 |
| 38 | 65 | 0.00901 | 0.0986 | 1.046 | 0 |
| 64 | 65 | 0.00269 | 0.0302 | 0.38 | 0 |
| 49 | 66 | 0.018 | 0.0919 | 0.0248 | 0 |
| 49 | 66 | 0.018 | 0.0919 | 0.0248 | 0 |
| 62 | 66 | 0.0482 | 0.218 | 0.0578 | 0 |
| 62 | 67 | 0.0258 | 0.117 | 0.031 | 0 |
| 65 | 66 | 0 | 0.037 | 0 | 0.935 |
| 66 | 67 | 0.0224 | 0.1015 | 0.02682 | 0 |
| 65 | 68 | 0.00138 | 0.016 | 0.638 | 0 |
| 47 | 69 | 0.0844 | 0.2778 | 0.07092 | 0 |
| 49 | 69 | 0.0985 | 0.324 | 0.0828 | 0 |
| 68 | 69 | 0 | 0.037 | 0 | 0.935 |
| 69 | 70 | 0.03 | 0.127 | 0.122 | 0 |
| 24 | 70 | 0.00221 | 0.4115 | 0.10198 | 0 |
| 70 | 71 | 0.00882 | 0.0355 | 0.00878 | 0 |
| 24 | 72 | 0.0488 | 0.196 | 0.0488 | 0 |
| 71 | 72 | 0.0446 | 0.18 | 0.04444 | 0 |
| 71 | 73 | 0.00866 | 0.0454 | 0.01178 | 0 |
| 70 | 74 | 0.0401 | 0.1323 | 0.03368 | 0 |
| 70 | 75 | 0.0428 | 0.141 | 0.036 | 0 |
| 69 | 75 | 0.0405 | 0.122 | 0.124 | 0 |
| 74 | 75 | 0.0123 | 0.0406 | 0.01034 | 0 |
| 76 | 77 | 0.0444 | 0.148 | 0.0368 | 0 |
| 69 | 77 | 0.0309 | 0.101 | 0.1038 | 0 |
| 75 | 77 | 0.0601 | 0.1999 | 0.04978 | 0 |
| 77 | 78 | 0.00376 | 0.0124 | 0.01264 | 0 |
| 78 | 79 | 0.00546 | 0.0244 | 0.00648 | 0 |
| 77 | 80 | 0.017 | 0.0485 | 0.0472 | 0 |

| | | | | | |
|---|---|---|---|---|---|
| 77 | 80 | 0.0294 | 0.105 | 0.0228 | 0 |
| 79 | 80 | 0.0156 | 0.0704 | 0.0187 | 0 |
| 68 | 81 | 0.00175 | 0.0202 | 0.808 | 0 |
| 81 | 80 | 0 | 0.037 | 0 | 0.935 |
| 77 | 82 | 0.0298 | 0.0853 | 0.08174 | 0 |
| 82 | 83 | 0.0112 | 0.03665 | 0.03796 | 0 |
| 83 | 84 | 0.0625 | 0.132 | 0.0258 | 0 |
| 83 | 85 | 0.043 | 0.148 | 0.0348 | 0 |
| 84 | 85 | 0.0302 | 0.0641 | 0.01234 | 0 |
| 85 | 86 | 0.035 | 0.123 | 0.0276 | 0 |
| 86 | 87 | 0.02828 | 0.2074 | 0.0445 | 0 |
| 85 | 88 | 0.02 | 0.102 | 0.0276 | 0 |
| 85 | 89 | 0.0239 | 0.173 | 0.047 | 0 |
| 88 | 89 | 0.0139 | 0.0712 | 0.01934 | 0 |
| 89 | 90 | 0.0518 | 0.188 | 0.0528 | 0 |
| 89 | 90 | 0.0238 | 0.0997 | 0.106 | 0 |
| 90 | 91 | 0.0254 | 0.0836 | 0.0214 | 0 |
| 89 | 92 | 0.0099 | 0.0505 | 0.0548 | 0 |
| 89 | 92 | 0.0393 | 0.1581 | 0.0414 | 0 |
| 91 | 92 | 0.0387 | 0.1272 | 0.03268 | 0 |
| 92 | 93 | 0.0258 | 0.0848 | 0.0218 | 0 |
| 92 | 94 | 0.0481 | 0.158 | 0.0406 | 0 |
| 93 | 94 | 0.0223 | 0.0732 | 0.01876 | 0 |
| 94 | 95 | 0.0132 | 0.0434 | 0.0111 | 0 |
| 80 | 96 | 0.0356 | 0.182 | 0.0494 | 0 |
| 82 | 96 | 0.0162 | 0.053 | 0.0544 | 0 |
| 94 | 96 | 0.0269 | 0.0869 | 0.023 | 0 |
| 80 | 97 | 0.0183 | 0.0934 | 0.0254 | 0 |
| 80 | 98 | 0.0238 | 0.108 | 0.0286 | 0 |
| 80 | 99 | 0.0454 | 0.206 | 0.0546 | 0 |
| 92 | 100 | 0.0648 | 0.295 | 0.0472 | 0 |
| 94 | 100 | 0.0178 | 0.058 | 0.0604 | 0 |
| 95 | 96 | 0.0171 | 0.0547 | 0.01474 | 0 |
| 96 | 97 | 0.0173 | 0.0885 | 0.024 | 0 |
| 98 | 100 | 0.0397 | 0.179 | 0.0476 | 0 |
| 99 | 100 | 0.018 | 0.0813 | 0.0216 | 0 |
| 100 | 101 | 0.0277 | 0.1262 | 0.0328 | 0 |
| 92 | 102 | 0.0123 | 0.0559 | 0.01464 | 0 |
| 101 | 102 | 0.0246 | 0.112 | 0.0294 | 0 |
| 100 | 103 | 0.016 | 0.0525 | 0.0536 | 0 |
| 100 | 104 | 0.0451 | 0.204 | 0.0541 | 0 |
| 103 | 104 | 0.0466 | 0.1584 | 0.0407 | 0 |
| 103 | 105 | 0.0535 | 0.1625 | 0.0408 | 0 |
| 100 | 106 | 0.0605 | 0.229 | 0.062 | 0 |
| 104 | 105 | 0.00994 | 0.0378 | 0.00986 | 0 |
| 105 | 106 | 0.014 | 0.0547 | 0.01434 | 0 |
| 105 | 107 | 0.053 | 0.183 | 0.0472 | 0 |
| 105 | 108 | 0.0261 | 0.0703 | 0.01844 | 0 |
| 106 | 107 | 0.053 | 0.183 | 0.0472 | 0 |
| 108 | 109 | 0.0105 | 0.0288 | 0.0076 | 0 |
| 103 | 110 | 0.03906 | 0.1813 | 0.0461 | 0 |
| 109 | 110 | 0.0278 | 0.0762 | 0.0202 | 0 |
| 110 | 111 | 0.022 | 0.0755 | 0.02 | 0 |
| 110 | 112 | 0.0247 | 0.064 | 0.062 | 0 |
| 17 | 113 | 0.00913 | 0.0301 | 0.00768 | 0 |
| 32 | 113 | 0.0615 | 0.203 | 0.0518 | 0 |

```
        32     114    0.0135      0.0612     0.01628             0
        27     115    0.0164      0.0741     0.01972             0
        114    115    0.0023      0.0104     0.00276             0
        68     116    0.00034     0.00405    0.164               0
        12     117    0.0329      0.14       0.0358              0
        75     118    0.0145      0.0481     0.01198             0
        76     118    0.0164      0.0544     0.01356            0];


% bus  bus voltage angle  --load--  --generator--   injected
% No  code  Mag.  Degree   MW   Mvar  MW   Mvar   Qmin  Qmax   Mvar

busdata=[

     1   2   0.955   10.67   51   27    0     0     15    -5     0
     2   1   0.971   11.22   20   9     0     0     0      0     0
     3   1   0.968   11.56   39   10    0     0     0      0     0
     4   2   0.998   15.28   30   12   -9     0     300   -300   0
     5   1   1.002   15.73   0    0     0     0     0      0     0
     6   2   0.99    13      52   22    0     0     50    -13    0
     7   1   0.989   12.56   19   2     0     0     0      0     0
     8   2   1.015   20.77   0    0    -28    0     300   -300   0
     9   1   1.043   28.02   0    0     0     0     0      0     0
    10   2   1.05    35.61   0    0     450   0     200   -147   0
    11   1   0.985   12.72   70   23    0     0     0      0     0
    12   2   0.99    12.2    47   10    85    0     120   -35    0
    13   1   0.968   11.35   34   16    0     0     0      0     0
    14   1   0.984   11.5    14   1     0     0     0      0     0
    15   2   0.97    11.23   90   30    0     0     30    -10    0
    16   1   0.984   11.91   25   10    0     0     0      0     0
    17   1   0.995   13.74   11   3     0     0     0      0     0
    18   2   0.973   11.53   60   34    0     0     50    -16    0
    19   2   0.963   11.05   45   25    0     0     24    -8     0
    20   1   0.958   11.93   18   3     0     0     0      0     0
    21   1   0.959   13.52   14   8     0     0     0      0     0
    22   1   0.97    16.08   10   5     0     0     0      0     0
    23   1   1       21      7    3     0     0     0      0     0
    24   2   0.992   20.89   0    0    -13    0     300   -300   0
    25   2   1.05    27.93   0    0     220   0     140   -47    0
    26   2   1.015   29.71   0    0     314   0     1000  -1000  0
    27   2   0.968   15.35   62   13   -9     0     300   -300   0
    28   1   0.962   13.62   17   7     0     0     0      0     0
    29   1   0.963   12.63   24   4     0     0     0      0     0
    30   1   0.968   18.79   0    0     0     0     0      0     0
    31   2   0.967   12.75   43   27    0     0     300   -300   0
    32   2   0.964   14.8    59   23    0     0     42    -14    0
    33   1   0.972   10.63   23   9     0     0     0      0     0
    34   2   0.986   11.3    59   26    0     0     24    -8     0
    35   1   0.981   10.87   33   9     0     0     0      0     0
    36   2   0.98    10.87   31   17    0     0     24    -8     0
    37   1   0.992   11.77   0    0     0     0     0      0     0
    38   1   0.962   16.91   0    0     0     0     0      0     0
    39   1   0.97    8.41    27   11    0     0     0      0     0
    40   2   0.97    7.35    20   23   -46    0     300   -300   0
    41   1   0.967   6.92    37   10    0     0     0      0     0
```

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 42 | 2 | 0.985 | 8.53 | 37 | 23 | -59 | 0 | 300 | -300 | 0 |
| 43 | 1 | 0.978 | 11.28 | 18 | 7 | 0 | 0 | 0 | 0 | 0 |
| 44 | 1 | 0.985 | 13.82 | 16 | 8 | 0 | 0 | 0 | 0 | 0 |
| 45 | 1 | 0.987 | 15.67 | 53 | 22 | 0 | 0 | 0 | 0 | 0 |
| 46 | 2 | 1.005 | 18.49 | 28 | 10 | 19 | 0 | 100 | -100 | 0 |
| 47 | 1 | 1.017 | 20.73 | 34 | 0 | 0 | 0 | 0 | 0 | 0 |
| 48 | 1 | 1.021 | 19.93 | 20 | 11 | 0 | 0 | 0 | 0 | 0 |
| 49 | 2 | 1.025 | 20.94 | 87 | 30 | 201 | 0 | 210 | -85 | 0 |
| 50 | 1 | 1.001 | 18.9 | 17 | 4 | 0 | 0 | 0 | 0 | 0 |
| 51 | 1 | 0.967 | 16.28 | 17 | 8 | 0 | 0 | 0 | 0 | 0 |
| 52 | 1 | 0.957 | 15.32 | 18 | 5 | 0 | 0 | 0 | 0 | 0 |
| 53 | 1 | 0.946 | 14.35 | 23 | 11 | 0 | 0 | 0 | 0 | 0 |
| 54 | 2 | 0.955 | 15.26 | 113 | 32 | 48 | 0 | 300 | -300 | 0 |
| 55 | 2 | 0.952 | 14.97 | 63 | 22 | 0 | 0 | 23 | -8 | 0 |
| 56 | 2 | 0.954 | 15.16 | 84 | 18 | 0 | 0 | 15 | -8 | 0 |
| 57 | 1 | 0.971 | 16.36 | 12 | 3 | 0 | 0 | 0 | 0 | 0 |
| 58 | 1 | 0.959 | 15.51 | 12 | 3 | 0 | 0 | 0 | 0 | 0 |
| 59 | 2 | 0.985 | 19.37 | 277 | 113 | 155 | 0 | 180 | -60 | 0 |
| 60 | 1 | 0.993 | 23.15 | 78 | 3 | 0 | 0 | 0 | 0 | 0 |
| 61 | 2 | 0.995 | 24.04 | 0 | 0 | 160 | 0 | 300 | -100 | 0 |
| 62 | 2 | 0.998 | 23.43 | 77 | 14 | 0 | 0 | 20 | -20 | 0 |
| 63 | 1 | 0.969 | 22.75 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 64 | 1 | 0.984 | 24.52 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 65 | 2 | 1.005 | 27.65 | 0 | 0 | 391 | 0 | 200 | -67 | 0 |
| 66 | 2 | 1.05 | 27.48 | 39 | 18 | 392 | 0 | 200 | -67 | 0 |
| 67 | 1 | 1.02 | 24.84 | 28 | 7 | 0 | 0 | 0 | 0 | 0 |
| 68 | 1 | 1.003 | 27.55 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 69 | 3 | 1.035 | 30 | 0 | 0 | 516 | 0 | 300 | -300 | 0 |
| 70 | 2 | 0.984 | 22.58 | 66 | 20 | 0 | 0 | 32 | -10 | 0 |
| 71 | 1 | 0.987 | 22.15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 72 | 2 | 0.98 | 20.98 | 0 | 0 | -12 | 0 | 100 | -100 | 0 |
| 73 | 2 | 0.991 | 21.94 | 0 | 0 | -6 | 0 | 100 | -100 | 0 |
| 74 | 2 | 0.958 | 21.64 | 68 | 27 | 0 | 0 | 9 | -6 | 0 |
| 75 | 1 | 0.967 | 22.91 | 47 | 11 | 0 | 0 | 0 | 0 | 0 |
| 76 | 2 | 0.943 | 21.77 | 68 | 36 | 0 | 0 | 23 | -8 | 0 |
| 77 | 2 | 1.006 | 26.72 | 61 | 28 | 0 | 0 | 70 | -20 | 0 |
| 78 | 1 | 1.003 | 26.42 | 71 | 26 | 0 | 0 | 0 | 0 | 0 |
| 79 | 1 | 1.009 | 26.72 | 39 | 32 | 0 | 0 | 0 | 0 | 0 |
| 80 | 2 | 1.04 | 28.96 | 130 | 26 | 477 | 0 | 280 | -165 | 0 |
| 81 | 1 | 0.997 | 28.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 82 | 1 | 0.989 | 27.24 | 54 | 27 | 0 | 0 | 0 | 0 | 0 |
| 83 | 1 | 0.985 | 28.42 | 20 | 10 | 0 | 0 | 0 | 0 | 0 |
| 84 | 1 | 0.98 | 30.95 | 11 | 7 | 0 | 0 | 0 | 0 | 0 |
| 85 | 2 | 0.985 | 32.51 | 24 | 15 | 0 | 0 | 23 | -8 | 0 |
| 86 | 1 | 0.987 | 31.14 | 21 | 10 | 0 | 0 | 0 | 0 | 0 |
| 87 | 2 | 1.015 | 31.4 | 0 | 0 | 0 | 0 | 1000 | -100 | 0 |
| 88 | 1 | 0.987 | 35.64 | 48 | 10 | 0 | 0 | 0 | 0 | 0 |
| 89 | 2 | 1.005 | 39.69 | 0 | 0 | 607 | 0 | 300 | -210 | 0 |
| 90 | 2 | 0.985 | 33.29 | 78 | 42 | -85 | 0 | 300 | -300 | 0 |
| 91 | 2 | 0.98 | 33.31 | 0 | 0 | -10 | 0 | 100 | -100 | 0 |
| 92 | 2 | 0.993 | 33.8 | 65 | 10 | 0 | 0 | 9 | -3 | 0 |
| 93 | 1 | 0.987 | 30.79 | 12 | 7 | 0 | 0 | 0 | 0 | 0 |
| 94 | 1 | 0.991 | 28.64 | 30 | 16 | 0 | 0 | 0 | 0 | 0 |
| 95 | 1 | 0.981 | 27.67 | 42 | 31 | 0 | 0 | 0 | 0 | 0 |
| 96 | 1 | 0.993 | 27.51 | 38 | 15 | 0 | 0 | 0 | 0 | 0 |
| 97 | 1 | 1.011 | 27.88 | 15 | 9 | 0 | 0 | 0 | 0 | 0 |
| 98 | 1 | 1.024 | 27.4 | 34 | 8 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 99 | 2 | 1.01 | 27.04 | 0 | 0 | -42 | 0 | 100 | -100 | 0 |
| 100 | 2 | 1.017 | 28.03 | 37 | 18 | 252 | 0 | 155 | -50 | 0 |
| 101 | 1 | 0.993 | 29.61 | 22 | 15 | 0 | 0 | 0 | 0 | 0 |
| 102 | 1 | 0.991 | 32.3 | 5 | 3 | 0 | 0 | 0 | 0 | 0 |
| 103 | 2 | 1.001 | 24.44 | 23 | 16 | 40 | 0 | 40 | -15 | 0 |
| 104 | 2 | 0.971 | 21.69 | 38 | 25 | 0 | 0 | 23 | -8 | 0 |
| 105 | 2 | 0.965 | 20.57 | 31 | 26 | 0 | 0 | 23 | -8 | 0 |
| 106 | 1 | 0.962 | 20.32 | 43 | 16 | 0 | 0 | 0 | 0 | 0 |
| 107 | 2 | 0.952 | 17.53 | 28 | 12 | -22 | 0 | 200 | -200 | 0 |
| 108 | 1 | 0.967 | 19.38 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| 109 | 1 | 0.967 | 18.93 | 8 | 3 | 0 | 0 | 0 | 0 | 0 |
| 110 | 2 | 0.973 | 18.09 | 39 | 30 | 0 | 0 | 23 | -8 | 0 |
| 111 | 2 | 0.98 | 19.74 | 0 | 0 | 36 | 0 | 1000 | -100 | 0 |
| 112 | 2 | 0.975 | 14.99 | 25 | 13 | -43 | 0 | 1000 | -100 | 0 |
| 113 | 2 | 0.993 | 13.74 | 0 | 0 | -6 | 0 | 200 | -100 | 0 |
| 114 | 1 | 0.96 | 14.46 | 8 | 3 | 0 | 0 | 0 | 0 | 0 |
| 115 | 1 | 0.96 | 14.46 | 22 | 7 | 0 | 0 | 0 | 0 | 0 |
| 116 | 2 | 1.005 | 27.12 | 0 | 0 | -184 | 0 | 1000 | -1000 | 0 |
| 117 | 1 | 0.974 | 10.67 | 20 | 8 | 0 | 0 | 0 | 0 | 0 |
| 118 | 1 | 0.949 | 21.92 | 33 | 15 | 0 | 0 | 0 | 0 | 0 |

```
lfybus;
lfgauss;
busout;
lineflow;
```

## 4.5.2 RESULTS

**Maximum Power Mismatch = 0.000902031**

**No. of Iterations = 19**

| Bus No. | Voltage Mag. | Angle Degree | ---Generation--- MW | Mvar | ------Load------ MW | Mvar | Injected Mvar |
|---|---|---|---|---|---|---|---|
| 1 | 0.965 | 10.510 | 51.000 | 27.000 | 0.000 | 26.951 | 0.000 |
| 2 | 0.971 | 11.220 | 20.000 | 9.000 | -0.908 | -28.176 | 0.000 |
| 3 | 0.968 | 11.560 | 39.000 | 10.000 | -0.163 | -31.327 | 0.000 |
| 4 | 1.028 | 14.896 | 30.000 | 12.000 | -9.000 | 414.377 | 0.000 |
| 5 | 1.002 | 15.730 | 0.000 | 0.000 | 3.108 | -553.240 | 0.000 |
| 6 | 1.000 | 12.878 | 52.000 | 22.000 | 0.000 | 83.024 | 0.000 |
| 7 | 0.989 | 12.560 | 19.000 | 2.000 | 0.258 | -79.935 | 0.000 |
| 8 | 1.045 | 20.679 | 0.000 | 0.000 | -28.000 | 292.080 | 0.000 |
| 9 | 1.043 | 28.020 | 0.000 | 0.000 | 10.527 | -396.508 | 0.000 |
| 10 | 1.100 | 35.035 | 0.000 | 0.000 | 450.000 | 36.507 | 0.000 |
| 11 | 0.985 | 12.720 | 70.000 | 23.000 | -4.805 | -95.245 | 0.000 |
| 12 | 1.000 | 12.035 | 47.000 | 10.000 | 85.000 | 222.036 | 0.000 |
| 13 | 0.968 | 11.350 | 34.000 | 16.000 | -0.332 | -8.068 | 0.000 |
| 14 | 0.984 | 11.500 | 14.000 | 1.000 | -0.167 | -21.491 | 0.000 |
| 15 | 0.980 | 11.076 | 90.000 | 30.000 | 0.000 | 33.342 | 0.000 |
| 16 | 0.984 | 11.910 | 25.000 | 10.000 | 0.389 | -14.973 | 0.000 |
| 17 | 0.995 | 13.740 | 11.000 | 3.000 | 5.462 | -201.423 | 0.000 |
| 18 | 0.983 | 11.400 | 60.000 | 34.000 | 0.000 | 44.845 | 0.000 |
| 19 | 0.973 | 10.924 | 45.000 | 25.000 | 0.000 | -8.024 | 0.000 |
| 20 | 0.958 | 11.930 | 18.000 | 3.000 | 0.025 | -10.712 | 0.000 |
| 21 | 0.959 | 13.520 | 14.000 | 8.000 | 0.035 | -1.614 | 0.000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 22 | 0.970 | 16.080 | 10.000 | 5.000 | -0.492 | -32.098 | 0.000 |
| 23 | 1.047 | 20.270 | 7.000 | 3.000 | 0.000 | 0.000 | 0.000 |
| 24 | 1.042 | 20.252 | 0.000 | 0.000 | -13.000 | -12.561 | 0.000 |
| 25 | 1.100 | 26.691 | 0.000 | 0.000 | 220.000 | 32.572 | 0.000 |
| 26 | 1.065 | 28.501 | 0.000 | 0.000 | 314.000 | 43.330 | 0.000 |
| 27 | 1.018 | 14.728 | 62.000 | 13.000 | -9.000 | 114.832 | 0.000 |
| 28 | 0.962 | 13.620 | 17.000 | 7.000 | -1.711 | -57.117 | 0.000 |
| 29 | 0.963 | 12.630 | 24.000 | 4.000 | 0.607 | -148.151 | 0.000 |
| 30 | 0.968 | 18.790 | 0.000 | 0.000 | -2.320 | -334.035 | 0.000 |
| 31 | 1.017 | 11.804 | 43.000 | 27.000 | 0.000 | 217.044 | 0.000 |
| 32 | 1.014 | 14.112 | 59.000 | 23.000 | 0.000 | 59.340 | 0.000 |
| 33 | 0.972 | 10.630 | 23.000 | 9.000 | -0.288 | -10.358 | 0.000 |
| 34 | 0.996 | 11.153 | 59.000 | 26.000 | 0.000 | 113.712 | 0.000 |
| 35 | 0.981 | 10.870 | 33.000 | 9.000 | 0.309 | -93.297 | 0.000 |
| 36 | 0.990 | 10.748 | 31.000 | 17.000 | 0.000 | 91.454 | 0.000 |
| 37 | 0.992 | 11.770 | 0.000 | 0.000 | -11.117 | -163.756 | 0.000 |
| 38 | 0.962 | 16.910 | 0.000 | 0.000 | -19.686 | -60.199 | 0.000 |
| 39 | 0.970 | 8.410 | 27.000 | 11.000 | -31.862 | -73.797 | 0.000 |
| 40 | 1.020 | 7.747 | 20.000 | 23.000 | -46.000 | 248.598 | 0.000 |
| 41 | 0.967 | 6.920 | 37.000 | 10.000 | -163.716 | -72.490 | 0.000 |
| 42 | 1.035 | 18.457 | 37.000 | 23.000 | -59.000 | -615.810 | 0.000 |
| 43 | 0.978 | 11.280 | 18.000 | 7.000 | -0.171 | -11.222 | 0.000 |
| 44 | 0.985 | 13.820 | 16.000 | 8.000 | -0.050 | 5.516 | 0.000 |
| 45 | 0.987 | 15.670 | 53.000 | 22.000 | -65.425 | -23.804 | 0.000 |
| 46 | 1.055 | 17.643 | 28.000 | 10.000 | 19.000 | 106.260 | 0.000 |
| 47 | 1.017 | 20.730 | 34.000 | 0.000 | -212.168 | -67.201 | 0.000 |
| 48 | 1.021 | 19.930 | 20.000 | 11.000 | -247.424 | -8.004 | 0.000 |
| 49 | 1.075 | 27.504 | 87.000 | 30.000 | 201.000 | -3629.981 | 0.000 |
| 50 | 1.001 | 18.900 | 17.000 | 4.000 | -163.254 | 3.568 | 0.000 |
| 51 | 0.967 | 16.280 | 17.000 | 8.000 | -86.108 | 4.501 | 0.000 |
| 52 | 0.957 | 15.320 | 18.000 | 5.000 | -0.160 | -2.253 | 0.000 |
| 53 | 0.946 | 14.350 | 23.000 | 11.000 | -114.982 | -7.116 | 0.000 |
| 54 | 1.005 | 23.652 | 113.000 | 32.000 | 48.000 | -698.579 | 0.000 |
| 55 | 1.002 | 22.904 | 63.000 | 22.000 | 0.000 | -1.128 | 0.000 |
| 56 | 1.004 | 23.170 | 84.000 | 18.000 | 0.000 | -754.131 | 0.000 |
| 57 | 0.971 | 16.360 | 12.000 | 3.000 | -137.661 | 3.604 | 0.000 |
| 58 | 0.959 | 15.510 | 12.000 | 3.000 | -135.982 | 5.333 | 0.000 |
| 59 | 1.035 | 24.081 | 277.000 | 113.000 | 155.000 | -540.287 | 0.000 |
| 60 | 0.993 | 23.150 | 78.000 | 3.000 | -138.475 | -284.927 | 0.000 |
| 61 | 1.025 | 24.132 | 0.000 | 0.000 | 160.000 | 285.353 | 0.000 |
| 62 | 1.028 | 23.745 | 77.000 | 14.000 | 0.000 | 70.231 | 0.000 |
| 63 | 0.969 | 22.750 | 0.000 | 0.000 | -215.069 | -143.872 | 0.000 |
| 64 | 0.984 | 24.520 | 0.000 | 0.000 | -70.197 | -227.347 | 0.000 |
| 65 | 1.035 | 28.544 | 0.000 | 0.000 | 391.000 | 241.461 | 0.000 |
| 66 | 1.100 | 32.035 | 39.000 | 18.000 | 392.000 | -2408.863 | 0.000 |
| 67 | 1.020 | 24.840 | 28.000 | 7.000 | -104.201 | -48.338 | 0.000 |
| 68 | 1.003 | 27.550 | 0.000 | 0.000 | -160.181 | -1154.288 | 0.000 |
| 69 | 1.085 | 30.704 | 0.000 | 0.000 | 516.000 | 149.293 | 0.000 |
| 70 | 0.994 | 22.675 | 66.000 | 20.000 | 0.000 | -9.465 | 0.000 |
| 71 | 0.987 | 22.150 | 0.000 | 0.000 | -9.588 | -163.360 | 0.000 |
| 72 | 1.030 | 20.322 | 0.000 | 0.000 | -12.000 | 11.670 | 0.000 |
| 73 | 1.041 | 21.394 | 0.000 | 0.000 | -6.000 | 123.884 | 0.000 |
| 74 | 0.968 | 21.542 | 68.000 | 27.000 | 0.000 | 27.639 | 0.000 |
| 75 | 0.967 | 22.910 | 47.000 | 11.000 | -81.919 | -73.640 | 0.000 |
| 76 | 0.953 | 23.466 | 68.000 | 36.000 | 0.000 | 1.007 | 0.000 |
| 77 | 1.056 | 32.239 | 61.000 | 28.000 | 0.000 | -2844.111 | 0.000 |
| 78 | 1.003 | 26.420 | 71.000 | 26.000 | -854.776 | -106.566 | 0.000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 79 | 1.009 | 26.720 | 39.000 | 32.000 | -167.070 | -0.440 | 0.000 |
| 80 | 1.090 | 34.860 | 130.000 | 26.000 | 477.000 | -2773.935 | 0.000 |
| 81 | 0.997 | 28.100 | 0.000 | 0.000 | -325.141 | -160.001 | 0.000 |
| 82 | 0.989 | 27.240 | 54.000 | 27.000 | -120.767 | -0.577 | 0.000 |
| 83 | 0.985 | 28.420 | 20.000 | 10.000 | -28.782 | 10.472 | 0.000 |
| 84 | 0.980 | 30.950 | 11.000 | 7.000 | -60.639 | 15.036 | 0.000 |
| 85 | 0.995 | 35.074 | 24.000 | 15.000 | 0.000 | 25.823 | 0.000 |
| 86 | 0.987 | 31.140 | 21.000 | 10.000 | -30.468 | -23.948 | 0.000 |
| 87 | 1.065 | 30.522 | 0.000 | 0.000 | 0.000 | 35.035 | 0.000 |
| 88 | 0.987 | 35.640 | 48.000 | 10.000 | -507.073 | 136.162 | 0.000 |
| 89 | 1.055 | 59.438 | 0.000 | 0.000 | 607.000 | -4213.548 | 0.000 |
| 90 | 1.035 | 62.012 | 78.000 | 42.000 | -85.000 | -1634.961 | 0.000 |
| 91 | 1.030 | 57.331 | 0.000 | 0.000 | -10.000 | -9.773 | 0.000 |
| 92 | 1.043 | 50.851 | 65.000 | 10.000 | 0.000 | -2451.004 | 0.000 |
| 93 | 0.987 | 30.790 | 12.000 | 7.000 | -322.135 | 108.708 | 0.000 |
| 94 | 0.991 | 28.640 | 30.000 | 16.000 | -214.936 | 23.223 | 0.000 |
| 95 | 0.981 | 27.670 | 42.000 | 31.000 | -0.510 | -2.341 | 0.000 |
| 96 | 0.993 | 27.510 | 38.000 | 15.000 | -63.094 | -17.012 | 0.000 |
| 97 | 1.011 | 27.880 | 15.000 | 9.000 | -126.639 | -24.474 | 0.000 |
| 98 | 1.024 | 27.400 | 34.000 | 8.000 | -124.934 | -31.662 | 0.000 |
| 99 | 1.060 | 29.437 | 0.000 | 0.000 | -42.000 | 4.730 | 0.000 |
| 100 | 1.047 | 29.099 | 37.000 | 18.000 | 252.000 | 189.467 | 0.000 |
| 101 | 0.993 | 29.610 | 22.000 | 15.000 | -18.642 | -21.922 | 0.000 |
| 102 | 0.991 | 32.300 | 5.000 | 3.000 | -516.103 | 116.433 | 0.000 |
| 103 | 1.031 | 24.949 | 23.000 | 16.000 | 40.000 | 36.429 | 0.000 |
| 104 | 1.001 | 21.874 | 38.000 | 25.000 | 0.000 | 3.088 | 0.000 |
| 105 | 0.995 | 20.469 | 31.000 | 26.000 | 0.000 | 81.983 | 0.000 |
| 106 | 0.962 | 20.320 | 43.000 | 16.000 | -23.332 | -87.388 | 0.000 |
| 107 | 1.002 | 17.069 | 28.000 | 12.000 | -22.000 | 44.543 | 0.000 |
| 108 | 0.967 | 19.380 | 2.000 | 1.000 | -10.801 | -34.700 | 0.000 |
| 109 | 0.967 | 18.930 | 8.000 | 3.000 | -9.332 | -38.669 | 0.000 |
| 110 | 1.003 | 17.921 | 39.000 | 30.000 | 0.000 | -16.087 | 0.000 |
| 111 | 1.030 | 19.103 | 0.000 | 0.000 | 36.000 | 24.514 | 0.000 |
| 112 | 1.025 | 14.610 | 25.000 | 13.000 | -43.000 | 70.645 | 0.000 |
| 113 | 1.043 | 12.899 | 0.000 | 0.000 | -6.000 | 177.061 | 0.000 |
| 114 | 0.960 | 14.460 | 8.000 | 3.000 | -0.613 | -81.531 | 0.000 |
| 115 | 0.960 | 14.460 | 22.000 | 7.000 | 0.271 | -65.390 | 0.000 |
| 116 | 1.035 | 26.982 | 0.000 | 0.000 | -184.000 | 816.916 | 0.000 |
| 117 | 0.974 | 10.670 | 20.000 | 8.000 | 0.308 | -8.660 | 0.000 |
| 118 | 0.949 | 21.920 | 33.000 | 15.000 | -49.821 | -3.934 | 0.000 |
| **Total** | | | **3668.000** | **1438.000** | **-1945.891** | **-23001.211** | **0.00** |

Line Flow and Losses

| --Line-- from | to | Power at bus & line flow MW | Mvar | MVA | --Line loss-- MW | Mvar | Transformer tap |
|---|---|---|---|---|---|---|---|
| 1 | | -51.000 | -0.049 | 51.000 | | | |
| | 2 | -12.238 | -4.377 | 12.998 | 0.050 | -4.595 | |
| | 3 | -38.762 | 4.328 | 39.002 | 0.212 | -1.324 | |
| 2 | | -20.908 | -37.176 | 42.652 | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 12.288 | -0.218 | 12.290 | 0.050 | -4.595 | |
| | 12 | -33.197 | -36.958 | 49.678 | 0.468 | -1.512 | |
| 3 | | -39.163 | -41.327 | 56.936 | | | |
| | 1 | 38.974 | -5.652 | 39.381 | 0.212 | -1.324 | |
| | 5 | -68.180 | -15.543 | 69.929 | 1.238 | 0.037 | |
| | 12 | -9.957 | -20.132 | 22.459 | 0.189 | -7.240 | |
| 4 | | -39.000 | 402.377 | 404.262 | | | |
| | 5 | -108.336 | 359.975 | 375.924 | 2.356 | 10.251 | |
| | 11 | 69.336 | 42.402 | 81.273 | 1.338 | 0.861 | |
| 5 | | 3.108 | -553.240 | 553.248 | | | |
| | 4 | 110.692 | -349.724 | 366.824 | 2.356 | 10.251 | |
| | 3 | 69.418 | 15.580 | 71.145 | 1.238 | 0.037 | |
| | 6 | 89.302 | -15.102 | 90.570 | 0.967 | 1.532 | |
| | 8 | -343.486 | -206.247 | 400.651 | 0.000 | 42.688 | |
| | 11 | 77.182 | 2.255 | 77.215 | 1.208 | 0.626 | |
| 6 | | -52.000 | 61.024 | 80.175 | | | |
| | 5 | -88.335 | 16.634 | 89.887 | 0.967 | 1.532 | |
| | 7 | 36.335 | 44.390 | 57.364 | 0.153 | -0.393 | |
| 7 | | -18.742 | -81.935 | 84.051 | | | |
| | 6 | -36.181 | -44.783 | 57.573 | 0.153 | -0.393 | |
| | 12 | 17.440 | -37.151 | 41.041 | 0.143 | -1.165 | |
| 8 | | -28.000 | 292.080 | 293.419 | | | |
| | 9 | -450.819 | -54.685 | 454.124 | 4.658 | -195.081 | |
| | 5 | 343.486 | 248.936 | 424.207 | 0.000 | 42.688 | 0.985 |
| | 30 | 79.333 | 97.829 | 125.954 | 1.184 | -90.449 | |
| 9 | | 10.527 | -396.508 | 396.648 | | | |
| | 8 | 455.477 | -140.396 | 476.624 | 4.658 | -195.081 | |
| | 10 | -444.950 | -256.113 | 513.395 | 5.050 | -219.606 | |
| 10 | | 450.000 | 36.507 | 451.478 | | | |
| | 9 | 450.000 | 36.507 | 451.478 | 5.050 | -219.606 | |
| 11 | | -74.805 | -118.245 | 139.921 | | | |
| | 4 | -67.998 | -41.540 | 79.683 | 1.338 | 0.861 | |
| | 5 | -75.974 | -1.629 | 75.992 | 1.208 | 0.626 | |
| | 12 | 34.141 | -85.875 | 92.413 | 0.519 | 0.719 | |
| | 13 | 35.026 | 10.799 | 36.653 | 0.318 | -2.534 | |
| 12 | | 38.000 | 212.036 | 215.414 | | | |
| | 11 | -33.622 | 86.594 | 92.892 | 0.519 | 0.719 | |
| | 2 | 33.665 | 35.446 | 48.885 | 0.468 | -1.512 | |
| | 3 | 10.146 | 12.892 | 16.405 | 0.189 | -7.240 | |
| | 7 | -17.297 | 35.986 | 39.927 | 0.143 | -1.165 | |
| | 14 | 18.217 | 15.336 | 23.813 | 0.135 | -3.132 | |
| | 16 | 7.003 | 15.267 | 16.797 | 0.075 | -3.918 | |
| | 117 | 19.888 | 10.515 | 22.497 | 0.195 | -6.144 | |
| 13 | | -34.332 | -24.068 | 41.928 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 11 | -34.708 | -13.332 | 37.181 | 0.318 | -2.534 |
| | 15 | 0.376 | -10.736 | 10.743 | 0.019 | -11.831 |
| 14 | | -14.167 | -22.491 | 26.581 | | |
| | 12 | -18.082 | -18.468 | 25.846 | 0.135 | -3.132 |
| | 15 | 3.915 | -4.023 | 5.614 | 0.010 | -9.650 |
| 15 | | -90.000 | 3.342 | 90.062 | | |
| | 13 | -0.357 | -1.095 | 1.152 | 0.019 | -11.831 |
| | 14 | -3.906 | -5.626 | 6.849 | 0.010 | -9.650 |
| | 17 | -103.684 | -4.172 | 103.768 | 1.478 | -3.768 |
| | 19 | 10.729 | 13.182 | 16.996 | 0.039 | -1.797 |
| | 33 | 7.219 | 1.053 | 7.295 | 0.027 | -5.996 |
| 16 | | -24.611 | -24.973 | 35.062 | | |
| | 12 | -6.929 | -19.186 | 20.398 | 0.075 | -3.918 |
| | 17 | -17.682 | -5.788 | 18.605 | 0.147 | -8.541 |
| 17 | | -5.538 | -204.423 | 204.498 | | |
| | 15 | 105.162 | 0.404 | 105.163 | 1.478 | -3.768 |
| | 16 | 17.829 | -2.754 | 18.041 | 0.147 | -8.541 |
| | 18 | 80.456 | 4.377 | 80.575 | 0.808 | 0.779 |
| | 30 | -227.615 | -24.155 | 228.894 | 0.000 | 20.533 |
| | 31 | 16.239 | -22.511 | 27.757 | 0.291 | -7.117 |
| | 113 | 2.391 | -159.785 | 159.803 | 2.333 | 6.095 |
| 18 | | -60.000 | 10.845 | 60.972 | | |
| | 17 | -79.648 | -3.598 | 79.729 | 0.808 | 0.779 |
| | 19 | 19.648 | 14.443 | 24.385 | 0.073 | -1.864 |
| 19 | | -45.000 | -33.024 | 55.818 | | |
| | 18 | -19.575 | -16.307 | 25.478 | 0.073 | -1.864 |
| | 20 | -10.774 | 12.097 | 16.199 | 0.090 | -5.138 |
| | 15 | -10.689 | -14.979 | 18.402 | 0.039 | -1.797 |
| | 34 | -3.961 | -13.834 | 14.390 | 0.061 | -12.051 |
| 20 | | -17.975 | -13.712 | 22.608 | | |
| | 19 | 10.865 | -17.234 | 20.373 | 0.090 | -5.138 |
| | 21 | -28.839 | 3.522 | 29.054 | 0.172 | -3.171 |
| 21 | | -13.965 | -9.614 | 16.954 | | |
| | 20 | 29.011 | -6.694 | 29.773 | 0.172 | -3.171 |
| | 22 | -42.976 | -2.921 | 43.075 | 0.420 | -2.629 |
| 22 | | -10.492 | -37.098 | 38.554 | | |
| | 21 | 43.396 | 0.292 | 43.397 | 0.420 | -2.629 |
| | 23 | -53.888 | -37.391 | 65.589 | 1.466 | -1.415 |
| 23 | | -7.000 | -3.000 | 7.616 | | |
| | 22 | 55.354 | 35.976 | 66.017 | 1.466 | -1.415 |
| | 24 | 3.296 | 3.972 | 5.162 | 0.012 | -10.820 |
| | 25 | -166.445 | -37.524 | 170.623 | 4.056 | 0.875 |
| | 32 | 100.795 | -5.424 | 100.941 | 2.955 | -14.169 |
| 24 | | -13.000 | -12.561 | 18.077 | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 23 | -3.284 | -14.792 | 15.152 | 0.012 | -10.820 | |
| | 70 | -10.575 | 1.364 | 10.663 | 0.005 | -20.139 | |
| | 72 | 0.859 | 0.868 | 1.221 | 0.017 | -10.406 | |
| 25 | | 220.000 | 32.572 | 222.398 | | | |
| | 23 | 170.501 | 38.399 | 174.771 | 4.056 | 0.875 | |
| | 26 | -100.886 | -25.403 | 104.035 | -0.000 | 3.417 | |
| | 27 | 150.385 | 19.575 | 151.654 | 6.384 | -6.904 | |
| 26 | | 314.000 | 43.330 | 316.976 | | | |
| | 25 | 100.886 | 28.820 | 104.922 | -0.000 | 3.417 | 0.960 |
| | 30 | 213.114 | 14.511 | 213.607 | 4.172 | -143.165 | |
| 27 | | -71.000 | 101.832 | 124.140 | | | |
| | 25 | -144.001 | -26.479 | 146.416 | 6.384 | -6.904 | |
| | 28 | 35.343 | 56.744 | 66.850 | 0.873 | -0.337 | |
| | 32 | 14.966 | -1.063 | 15.004 | 0.050 | -3.812 | |
| | 115 | 22.692 | 72.630 | 76.092 | 0.964 | 0.494 | |
| 28 | | -18.711 | -64.117 | 66.792 | | | |
| | 27 | -34.470 | -57.081 | 66.681 | 0.873 | -0.337 | |
| | 29 | 15.759 | -7.037 | 17.259 | 0.070 | -4.133 | |
| 29 | | -23.393 | -152.151 | 153.939 | | | |
| | 28 | -15.689 | 2.904 | 15.956 | 0.070 | -4.133 | |
| | 31 | -7.704 | -155.055 | 155.246 | 2.779 | 6.889 | |
| 30 | | -2.320 | -334.035 | 334.043 | | | |
| | 17 | 227.615 | 44.688 | 231.961 | 0.000 | 20.533 | 0.960 |
| | 8 | -78.149 | -188.278 | 203.853 | 1.184 | -90.449 | |
| | 26 | -208.942 | -157.675 | 261.760 | 4.172 | -143.165 | |
| | 38 | 57.156 | -32.770 | 65.883 | 0.164 | -76.687 | |
| 31 | | -43.000 | 190.044 | 194.848 | | | |
| | 17 | -15.948 | 15.394 | 22.166 | 0.291 | -7.117 | |
| | 29 | 10.483 | 161.944 | 162.283 | 2.779 | 6.889 | |
| | 32 | -37.535 | 12.707 | 39.627 | 0.473 | -3.612 | |
| 32 | | -59.000 | 36.340 | 69.293 | | | |
| | 23 | -97.841 | -8.745 | 98.231 | 2.955 | -14.169 | |
| | 31 | 38.008 | -16.319 | 41.363 | 0.473 | -3.612 | |
| | 27 | -14.917 | -2.749 | 15.168 | 0.050 | -3.812 | |
| | 113 | 6.122 | -21.549 | 22.402 | 0.180 | -10.367 | |
| | 114 | 9.627 | 85.702 | 86.241 | 1.015 | 1.425 | |
| 33 | | -23.288 | -19.358 | 30.283 | | | |
| | 15 | -7.191 | -7.049 | 10.070 | 0.027 | -5.996 | |
| | 37 | -16.096 | -12.309 | 20.264 | 0.148 | -6.552 | |
| 34 | | -59.000 | 87.712 | 105.709 | | | |
| | 19 | 4.023 | 1.783 | 4.400 | 0.061 | -12.051 | |
| | 36 | 30.110 | 12.041 | 32.429 | 0.094 | -0.832 | |
| | 37 | -94.397 | 67.724 | 116.178 | 0.352 | -0.653 | |
| | 43 | 1.264 | 6.164 | 6.292 | 0.045 | -8.050 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 35 | | -32.691 | -102.297 | 107.394 | | | |
| | 36 | 1.159 | -87.050 | 87.057 | 0.175 | 0.278 | |
| | 37 | -33.850 | -15.247 | 37.125 | 0.153 | -1.873 | |
| 36 | | -31.000 | 74.454 | 80.650 | | | |
| | 35 | -0.983 | 87.328 | 87.333 | 0.175 | 0.278 | |
| | 34 | -30.017 | -12.874 | 32.661 | 0.094 | -0.832 | |
| 37 | | -11.117 | -163.756 | 164.132 | | | |
| | 35 | 34.003 | 13.374 | 36.539 | 0.153 | -1.873 | |
| | 33 | 16.245 | 5.757 | 17.235 | 0.148 | -6.552 | |
| | 34 | 94.749 | -68.376 | 116.845 | 0.352 | -0.653 | |
| | 38 | -243.838 | -86.607 | 258.762 | 0.000 | 25.516 | |
| | 39 | 54.879 | 2.873 | 54.954 | 0.992 | -1.920 | |
| | 40 | 32.846 | -30.776 | 45.012 | 1.078 | -5.449 | |
| 38 | | -19.686 | -60.199 | 63.336 | | | |
| | 37 | 243.838 | 112.123 | 268.382 | 0.000 | 25.516 | 0.935 |
| | 30 | -56.992 | -43.917 | 71.950 | 0.164 | -76.687 | |
| | 65 | -206.532 | -128.404 | 243.194 | 4.250 | -162.341 | |
| 39 | | -58.862 | -84.797 | 103.224 | | | |
| | 37 | -53.886 | -4.794 | 54.099 | 0.992 | -1.920 | |
| | 40 | -4.975 | -80.003 | 80.158 | 1.211 | 0.908 | |
| 40 | | -66.000 | 225.598 | 235.054 | | | |
| | 37 | -31.768 | 25.327 | 40.629 | 1.078 | -5.449 | |
| | 39 | 6.187 | 80.911 | 81.147 | 1.211 | 0.908 | |
| | 41 | 57.282 | 92.891 | 109.133 | 1.693 | 3.272 | |
| | 42 | -97.701 | 26.469 | 101.223 | 5.615 | 8.675 | |
| 41 | | -200.716 | -82.490 | 217.006 | | | |
| | 40 | -55.589 | -89.618 | 105.459 | 1.693 | 3.272 | |
| | 42 | -145.127 | 7.128 | 145.302 | 9.282 | 23.660 | |
| 42 | | -96.000 | -638.810 | 645.983 | | | |
| | 40 | 103.316 | -17.794 | 104.838 | 5.615 | 8.675 | |
| | 41 | 154.408 | 16.532 | 155.291 | 9.282 | 23.660 | |
| | 49 | -53.439 | -5.915 | 53.765 | 1.913 | -10.508 | |
| | 49 | -53.439 | -5.915 | 53.765 | 1.913 | -10.508 | |
| 43 | | -18.171 | -18.222 | 25.733 | | | |
| | 44 | -16.952 | -4.008 | 17.419 | 0.185 | -10.946 | |
| | 34 | -1.219 | -14.214 | 14.266 | 0.045 | -8.050 | |
| 44 | | -16.050 | -2.484 | 16.241 | | | |
| | 43 | 17.137 | -6.938 | 18.488 | 0.185 | -10.946 | |
| | 45 | -33.186 | 4.453 | 33.484 | 0.264 | -3.292 | |
| 45 | | -118.425 | -45.804 | 126.975 | | | |
| | 44 | 33.451 | -7.745 | 34.336 | 0.264 | -3.292 | |
| | 46 | -37.627 | -41.175 | 55.778 | 1.172 | -2.955 | |
| | 49 | -114.249 | 3.117 | 114.292 | 9.204 | 15.572 | |
| 46 | | -9.000 | 96.260 | 96.680 | | | |

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|---|---|---|---|---|---|---|
| | 45 | 38.799 | 38.220 | 54.463 | 1.172 | -2.955 |
| | 47 | -32.755 | 39.077 | 50.989 | 0.986 | -3.491 |
| | 48 | -15.044 | 18.963 | 24.206 | 0.439 | -8.794 |
| 47 | | -246.168 | -67.201 | 255.176 | | |
| | 46 | 33.741 | -42.568 | 54.318 | 0.986 | -3.491 |
| | 49 | -211.674 | -19.137 | 212.537 | 8.331 | 23.747 |
| | 69 | -68.235 | -5.496 | 68.456 | 3.802 | -3.169 |
| 48 | | -267.424 | -19.004 | 268.099 | | |
| | 46 | 15.483 | -27.757 | 31.783 | 0.439 | -8.794 |
| | 49 | -282.908 | 8.753 | 283.043 | 13.761 | 36.057 |
| 49 | | 114.000 | -3659.981 | 3661.756 | | |
| | 47 | 220.004 | 42.885 | 224.145 | 8.331 | 23.747 |
| | 42 | 55.352 | -4.593 | 55.542 | 1.913 | -10.508 |
| | 42 | 55.352 | -4.593 | 55.542 | 1.913 | -10.508 |
| | 45 | 123.453 | 12.455 | 124.080 | 9.204 | 15.572 |
| | 48 | 296.668 | 27.304 | 297.922 | 13.761 | 36.057 |
| | 50 | 228.545 | 38.578 | 231.779 | 12.452 | 31.026 |
| | 51 | 162.460 | 37.673 | 166.771 | 11.828 | 26.193 |
| | 54 | 29.991 | 10.779 | 31.869 | 0.804 | -12.801 |
| | 54 | 30.219 | 9.238 | 31.600 | 0.922 | -12.723 |
| | 66 | -102.645 | -7.984 | 102.955 | 1.645 | 2.533 |
| | 66 | -102.645 | -7.984 | 102.955 | 1.645 | 2.533 |
| | 69 | -19.159 | -6.501 | 20.232 | 0.321 | -18.260 |
| 50 | | -180.254 | -0.432 | 180.254 | | |
| | 49 | -216.094 | -7.551 | 216.226 | 12.452 | 31.026 |
| | 57 | 35.840 | 7.119 | 36.540 | 0.659 | -4.593 |
| 51 | | -103.108 | -3.499 | 103.167 | | |
| | 49 | -150.632 | -11.480 | 151.069 | 11.828 | 26.193 |
| | 52 | 28.702 | 5.452 | 29.215 | 0.189 | -2.037 |
| | 58 | 18.823 | 2.528 | 18.992 | 0.101 | -3.030 |
| 52 | | -18.160 | -7.253 | 19.555 | | |
| | 51 | -28.513 | -7.489 | 29.480 | 0.189 | -2.037 |
| | 53 | 10.353 | 0.237 | 10.356 | 0.054 | -7.129 |
| 53 | | -137.982 | -18.116 | 139.166 | | |
| | 52 | -10.299 | -7.366 | 12.662 | 0.054 | -7.129 |
| | 54 | -127.683 | -10.751 | 128.135 | 4.810 | 16.407 |
| 54 | | -65.000 | -730.579 | 733.465 | | |
| | 53 | 132.493 | 27.157 | 135.247 | 4.810 | 16.407 |
| | 49 | -29.187 | -23.579 | 37.522 | 0.804 | -12.801 |
| | 49 | -29.298 | -21.961 | 36.615 | 0.922 | -12.723 |
| | 55 | 18.587 | -2.097 | 18.705 | 0.058 | -3.827 |
| | 56 | 85.030 | -14.326 | 86.228 | 0.202 | -0.776 |
| | 59 | -5.992 | -17.861 | 18.840 | 0.087 | -12.047 |
| 55 | | -63.000 | -23.128 | 67.111 | | |
| | 54 | -18.529 | -1.729 | 18.610 | 0.058 | -3.827 |
| | 56 | -31.860 | -3.279 | 32.028 | 0.050 | -0.599 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 59 | -12.611 | -18.120 | 22.077 | 0.148 | -11.042 | |
| 56 | | -84.000 | -772.131 | 776.687 | | | |
| | 54 | -84.828 | 13.550 | 85.903 | 0.202 | -0.776 | |
| | 55 | 31.910 | 2.680 | 32.022 | 0.050 | -0.599 | |
| | 57 | 119.325 | -3.391 | 119.374 | 4.845 | 8.925 | |
| | 58 | 135.531 | 5.101 | 135.627 | 6.270 | 12.992 | |
| | 59 | -9.607 | -14.925 | 17.750 | 0.145 | -11.391 | |
| | 59 | -10.131 | -14.967 | 18.073 | 0.155 | -10.685 | |
| 57 | | -149.661 | 0.604 | 149.662 | | | |
| | 56 | -114.480 | 12.316 | 115.141 | 4.845 | 8.925 | |
| | 50 | -35.181 | -11.712 | 37.079 | 0.659 | -4.593 | |
| 58 | | -147.982 | 2.333 | 148.001 | | | |
| | 56 | -129.261 | 7.891 | 129.502 | 6.270 | 12.992 | |
| | 51 | -18.721 | -5.559 | 19.529 | 0.101 | -3.030 | |
| 59 | | -122.000 | -653.287 | 664.581 | | | |
| | 54 | 6.080 | 5.814 | 8.412 | 0.087 | -12.047 | |
| | 56 | 9.752 | 3.535 | 10.373 | 0.145 | -11.391 | |
| | 56 | 10.285 | 4.282 | 11.141 | 0.155 | -10.685 | |
| | 55 | 12.759 | 7.079 | 14.591 | 0.148 | -11.042 | |
| | 60 | 17.271 | 22.269 | 28.182 | 0.293 | -6.396 | |
| | 61 | 0.848 | 2.559 | 2.695 | 0.014 | -8.169 | |
| | 63 | 62.885 | 69.440 | 93.683 | 0.000 | 3.162 | |
| 60 | | -216.475 | -287.927 | 360.227 | | | |
| | 59 | -16.978 | -28.665 | 33.315 | 0.293 | -6.396 | |
| | 61 | -168.533 | -202.749 | 263.649 | 1.846 | 6.472 | |
| | 62 | -30.965 | -56.512 | 64.439 | 0.498 | -0.728 | |
| 61 | | 160.000 | 285.353 | 327.149 | | | |
| | 59 | -0.834 | -10.727 | 10.760 | 0.014 | -8.169 | |
| | 60 | 170.378 | 209.221 | 269.819 | 1.846 | 6.472 | |
| | 62 | 16.353 | -12.728 | 20.723 | 0.032 | -1.921 | |
| | 64 | -25.898 | 99.586 | 102.899 | 0.000 | 2.701 | |
| 62 | | -77.000 | 56.231 | 95.346 | | | |
| | 60 | 31.462 | 55.784 | 64.045 | 0.498 | -0.728 | |
| | 61 | -16.322 | 10.807 | 19.575 | 0.032 | -1.921 | |
| | 66 | -77.319 | -17.545 | 79.284 | 2.786 | -0.500 | |
| | 67 | -14.822 | 7.185 | 16.472 | 0.080 | -6.137 | |
| 63 | | -215.069 | -143.872 | 258.754 | | | |
| | 59 | -62.885 | -66.278 | 91.363 | 0.000 | 3.162 | 0.960 |
| | 64 | -152.184 | -77.594 | 170.824 | 0.484 | -35.563 | |
| 64 | | -70.197 | -227.347 | 237.937 | | | |
| | 63 | 152.668 | 42.031 | 158.348 | 0.484 | -35.563 | |
| | 61 | 25.898 | -96.885 | 100.287 | 0.000 | 2.701 | 0.985 |
| | 65 | -248.763 | -172.492 | 302.716 | 2.231 | -52.455 | |
| 65 | | 391.000 | 241.461 | 459.548 | | | |
| | 38 | 210.783 | -33.936 | 213.497 | 4.250 | -162.341 | |

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|---|---|---|---|---|---|---|---|
| | 64 | 250.994 | 120.037 | 278.221 | 2.231 | -52.455 | |
| | 66 | -200.356 | 26.903 | 202.154 | -0.000 | 12.340 | 0.935 |
| | 68 | 129.579 | 128.457 | 182.461 | 0.715 | -124.235 | |
| 66 | | 353.000 | -2426.863 | 2452.402 | | | |
| | 49 | 104.290 | 10.517 | 104.819 | 1.645 | 2.533 | |
| | 49 | 104.290 | 10.517 | 104.819 | 1.645 | 2.533 | |
| | 62 | 80.105 | 17.045 | 81.898 | 2.786 | -0.500 | |
| | 65 | 200.356 | -14.563 | 200.884 | -0.000 | 12.340 | |
| | 67 | 152.094 | 58.593 | 162.990 | 4.990 | 16.577 | |
| 67 | | -132.201 | -55.338 | 143.316 | | | |
| | 62 | 14.902 | -13.322 | 19.989 | 0.080 | -6.137 | |
| | 66 | -147.103 | -42.016 | 152.986 | 4.990 | 16.577 | |
| 68 | | -160.181 | -1154.288 | 1165.349 | | | |
| | 65 | -128.864 | -252.692 | 283.653 | 0.715 | -124.235 | |
| | 69 | -173.050 | -30.818 | 175.773 | -0.000 | 9.934 | 0.935 |
| | 81 | -44.585 | -47.403 | 65.076 | 0.055 | -160.972 | |
| | 116 | 186.318 | -823.375 | 844.192 | 2.318 | -6.459 | |
| 69 | | 516.000 | 149.293 | 537.163 | | | |
| | 47 | 72.037 | 2.326 | 72.075 | 3.802 | -3.169 | |
| | 49 | 19.480 | -11.760 | 22.754 | 0.321 | -18.260 | |
| | 68 | 173.050 | 40.752 | 177.784 | -0.000 | 9.934 | |
| | 70 | 131.594 | 40.620 | 137.720 | 5.183 | -4.473 | |
| | 75 | 138.797 | 52.213 | 148.293 | 8.163 | -1.602 | |
| | 77 | -18.958 | 25.141 | 31.488 | 0.461 | -22.289 | |
| 70 | | -66.000 | -29.465 | 72.278 | | | |
| | 69 | -126.410 | -45.094 | 134.213 | 5.183 | -4.473 | |
| | 24 | 10.581 | -21.502 | 23.965 | 0.005 | -20.139 | |
| | 71 | 28.462 | 11.777 | 30.802 | 0.087 | -1.374 | |
| | 74 | 18.637 | 10.700 | 21.490 | 0.221 | -5.755 | |
| | 75 | 2.731 | 14.654 | 14.906 | 0.147 | -6.439 | |
| 71 | | -9.588 | -163.360 | 163.641 | | | |
| | 70 | -28.375 | -13.151 | 31.275 | 0.087 | -1.374 | |
| | 72 | 11.532 | -30.478 | 32.587 | 0.374 | -7.535 | |
| | 73 | 7.255 | -119.731 | 119.950 | 1.255 | 4.154 | |
| 72 | | -12.000 | 11.670 | 16.739 | | | |
| | 24 | -0.842 | -11.273 | 11.305 | 0.017 | -10.406 | |
| | 71 | -11.158 | 22.943 | 25.512 | 0.374 | -7.535 | |
| 73 | | -6.000 | 123.884 | 124.030 | | | |
| | 71 | -6.000 | 123.884 | 124.030 | 1.255 | 4.154 | |
| 74 | | -68.000 | 0.639 | 68.003 | | | |
| | 70 | -18.416 | -16.455 | 24.696 | 0.221 | -5.755 | |
| | 75 | -49.584 | 17.095 | 52.448 | 0.366 | -0.729 | |
| 75 | | -128.919 | -84.640 | 154.221 | | | |
| | 70 | -2.584 | -21.093 | 21.251 | 0.147 | -6.439 | |
| | 69 | -130.634 | -53.815 | 141.284 | 8.163 | -1.602 | |

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|---|---|---|---|---|---|---|---|
| | 74 | 49.950 | -17.824 | 53.035 | 0.366 | -0.729 | |
| | 77 | -85.947 | -15.112 | 87.266 | 4.818 | 5.819 | |
| | 118 | 40.297 | 23.204 | 46.500 | 0.344 | -1.060 | |
| 76 | | -68.000 | -34.993 | 76.476 | | | |
| | 77 | -111.211 | -28.347 | 114.767 | 6.352 | 13.727 | |
| | 118 | 43.211 | -6.646 | 43.719 | 0.342 | -1.317 | |
| 77 | | -61.000 | -2872.111 | 2872.759 | | | |
| | 76 | 117.563 | 42.075 | 124.865 | 6.352 | 13.727 | |
| | 69 | 19.419 | -47.430 | 51.251 | 0.461 | -22.289 | |
| | 75 | 90.765 | 20.931 | 93.148 | 4.818 | 5.819 | |
| | 78 | 930.582 | 211.776 | 954.376 | 30.732 | 98.668 | |
| | 80 | -119.015 | -35.091 | 124.081 | 2.295 | -4.324 | |
| | 80 | -55.079 | -20.167 | 58.655 | 0.882 | -2.102 | |
| | 82 | 122.350 | 35.742 | 127.464 | 4.538 | -4.120 | |
| 78 | | -925.776 | -132.566 | 935.219 | | | |
| | 77 | -899.851 | -113.108 | 906.932 | 30.732 | 98.668 | |
| | 79 | -25.925 | -19.458 | 32.415 | 0.056 | -1.063 | |
| 79 | | -206.070 | -32.440 | 208.608 | | | |
| | 78 | 25.981 | 18.395 | 31.834 | 0.056 | -1.063 | |
| | 80 | -232.051 | -50.835 | 237.554 | 8.618 | 34.766 | |
| 80 | | 347.000 | -2799.935 | 2821.355 | | | |
| | 77 | 121.310 | 30.768 | 125.151 | 2.295 | -4.324 | |
| | 77 | 55.961 | 18.065 | 58.805 | 0.882 | -2.102 | |
| | 79 | 240.669 | 85.601 | 255.439 | 8.618 | 34.766 | |
| | 81 | 369.781 | 91.629 | 380.964 | 0.000 | 45.198 | |
| | 96 | 85.146 | 40.456 | 94.268 | 2.815 | 3.653 | |
| | 97 | 157.132 | 67.135 | 170.873 | 4.561 | 17.665 | |
| | 98 | 143.810 | 40.270 | 149.342 | 4.525 | 14.136 | |
| | 99 | 54.416 | -0.095 | 54.416 | 1.147 | -7.417 | |
| 81 | | -325.141 | -160.001 | 362.377 | | | |
| | 68 | 44.639 | -113.569 | 122.027 | 0.055 | -160.972 | |
| | 80 | -369.781 | -46.432 | 372.684 | 0.000 | 45.198 | 0.935 |
| 82 | | -174.767 | -27.577 | 176.930 | | | |
| | 77 | -117.812 | -39.863 | 124.374 | 4.538 | -4.120 | |
| | 83 | -46.888 | 21.973 | 51.782 | 0.327 | -6.325 | |
| | 96 | -10.067 | -9.688 | 13.971 | 0.020 | -10.620 | |
| 83 | | -48.782 | 0.472 | 48.784 | | | |
| | 82 | 47.215 | -28.298 | 55.046 | 0.327 | -6.325 | |
| | 84 | -24.650 | 13.612 | 28.159 | 0.559 | -3.801 | |
| | 85 | -71.348 | 15.158 | 72.940 | 2.408 | 1.468 | |
| 84 | | -71.639 | 8.036 | 72.088 | | | |
| | 83 | 25.209 | -17.413 | 30.639 | 0.559 | -3.801 | |
| | 85 | -96.850 | 25.450 | 100.138 | 3.173 | 4.327 | |
| 85 | | -24.000 | 10.823 | 26.328 | | | |
| | 83 | 73.756 | -13.691 | 75.016 | 2.408 | 1.468 | |

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|---|---|---|---|---|---|---|
| | 84 | 100.022 | -21.123 | 102.228 | 3.173 | 4.327 |
| | 86 | 52.874 | -9.425 | 53.707 | 1.004 | -1.892 |
| | 88 | -7.676 | 6.624 | 10.139 | 0.030 | -5.270 |
| | 89 | -242.976 | 48.441 | 247.757 | 14.933 | 98.205 |
| 86 | | -51.468 | -33.948 | 61.655 | | |
| | 85 | -51.869 | 7.533 | 52.414 | 1.004 | -1.892 |
| | 87 | 0.401 | -41.480 | 41.482 | 0.401 | -6.445 |
| 87 | | 0.000 | 35.035 | 35.035 | | |
| | 86 | 0.000 | 35.035 | 35.035 | 0.401 | -6.445 |
| 88 | | -555.073 | 126.162 | 569.230 | | |
| | 85 | 7.706 | -11.894 | 14.172 | 0.030 | -5.270 |
| | 89 | -562.797 | 138.068 | 579.485 | 47.989 | 241.778 |
| 89 | | 607.000 | -4213.548 | 4257.046 | | |
| | 85 | 257.908 | 49.764 | 262.665 | 14.933 | 98.205 |
| | 88 | 610.786 | 103.710 | 619.528 | 47.989 | 241.778 |
| | 90 | -21.226 | 11.781 | 24.276 | 0.355 | -10.245 |
| | 90 | -41.517 | 20.382 | 46.250 | 0.590 | -20.681 |
| | 92 | 322.622 | -19.855 | 323.232 | 9.275 | 35.250 |
| | 92 | 101.566 | -14.047 | 102.533 | 3.674 | 5.668 |
| 90 | | -163.000 | -1676.961 | 1684.864 | | |
| | 89 | 21.581 | -22.027 | 30.837 | 0.355 | -10.245 |
| | 89 | 42.107 | -41.063 | 58.815 | 0.590 | -20.681 |
| | 91 | 98.183 | -21.679 | 100.547 | 2.375 | 3.254 |
| 91 | | -10.000 | -9.773 | 13.983 | | |
| | 90 | -95.808 | 24.932 | 98.999 | 2.375 | 3.254 |
| | 92 | 85.808 | -34.705 | 92.560 | 3.042 | 2.976 |
| 92 | | -65.000 | -2461.004 | 2461.862 | | |
| | 89 | -313.347 | 55.105 | 318.155 | 9.275 | 35.250 |
| | 89 | -97.892 | 19.714 | 99.858 | 3.674 | 5.668 |
| | 91 | -82.766 | 37.681 | 90.940 | 3.042 | 2.976 |
| | 93 | 420.827 | 12.126 | 421.002 | 42.051 | 133.718 |
| | 94 | 249.408 | 2.525 | 249.421 | 27.525 | 82.012 |
| | 100 | 136.098 | -10.086 | 136.471 | 11.048 | 39.987 |
| | 102 | 601.633 | 59.125 | 604.531 | 41.343 | 184.861 |
| 93 | | -334.135 | 101.708 | 349.272 | | |
| | 92 | -378.776 | 121.592 | 397.814 | 42.051 | 133.718 |
| | 94 | 44.631 | -19.877 | 48.857 | 0.531 | -1.928 |
| 94 | | -244.936 | 7.223 | 245.043 | | |
| | 92 | -221.883 | 79.488 | 235.691 | 27.525 | 82.012 |
| | 93 | -44.100 | 17.949 | 47.613 | 0.531 | -1.928 |
| | 95 | 41.156 | 9.547 | 42.249 | 0.243 | -1.360 |
| | 96 | 19.797 | -10.448 | 22.385 | 0.126 | -4.121 |
| | 100 | -39.913 | -89.308 | 97.821 | 1.549 | -7.507 |
| 95 | | -42.510 | -33.341 | 54.025 | | |
| | 94 | -40.914 | -10.907 | 42.343 | 0.243 | -1.360 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 96 | -1.596 | -22.434 | 22.490 | 0.079 | -2.619 |
| 96 | | -101.094 | -32.012 | 106.042 | | |
| | 80 | -82.331 | -36.803 | 90.182 | 2.815 | 3.653 |
| | 82 | 10.087 | -0.932 | 10.130 | 0.020 | -10.620 |
| | 94 | -19.672 | 6.327 | 20.664 | 0.126 | -4.121 |
| | 95 | 1.675 | 19.814 | 19.885 | 0.079 | -2.619 |
| | 97 | -10.854 | -20.418 | 23.123 | 0.078 | -4.421 |
| 97 | | -141.639 | -33.474 | 145.540 | | |
| | 80 | -152.571 | -49.470 | 160.390 | 4.561 | 17.665 |
| | 96 | 10.932 | 15.996 | 19.375 | 0.078 | -4.421 |
| 98 | | -158.934 | -39.662 | 163.808 | | |
| | 80 | -139.285 | -26.134 | 141.715 | 4.525 | 14.136 |
| | 100 | -19.649 | -13.527 | 23.856 | 0.174 | -9.426 |
| 99 | | -42.000 | 4.730 | 42.266 | | |
| | 80 | -53.269 | -7.321 | 53.770 | 1.147 | -7.417 |
| | 100 | 11.269 | 12.051 | 16.499 | 0.054 | -4.551 |
| 100 | | 215.000 | 171.467 | 275.002 | | |
| | 92 | -125.050 | 50.073 | 134.702 | 11.048 | 39.987 |
| | 94 | 41.462 | 81.801 | 91.709 | 1.549 | -7.507 |
| | 98 | 19.823 | 4.102 | 20.243 | 0.174 | -9.426 |
| | 99 | -11.215 | -16.603 | 20.036 | 0.054 | -4.551 |
| | 101 | 2.376 | 40.716 | 40.785 | 0.498 | -4.563 |
| | 103 | 146.551 | -13.239 | 147.148 | 3.143 | -1.261 |
| | 104 | 67.436 | 6.849 | 67.783 | 1.938 | -2.585 |
| | 106 | 73.617 | 17.769 | 75.732 | 3.324 | 0.048 |
| 101 | | -40.642 | -36.922 | 54.909 | | |
| | 100 | -1.878 | -45.279 | 45.318 | 0.498 | -4.563 |
| | 102 | -38.764 | 8.357 | 39.654 | 0.406 | -3.936 |
| 102 | | -521.103 | 113.433 | 533.306 | | |
| | 92 | -560.290 | 125.736 | 574.225 | 41.343 | 184.861 |
| | 101 | 39.170 | -12.292 | 41.054 | 0.406 | -3.936 |
| 103 | | 17.000 | 20.429 | 26.577 | | |
| | 100 | -143.408 | 11.978 | 143.908 | 3.143 | -1.261 |
| | 104 | 37.706 | 5.046 | 38.042 | 0.662 | -6.155 |
| | 105 | 51.847 | 3.363 | 51.956 | 1.383 | -4.176 |
| | 110 | 70.856 | 0.043 | 70.856 | 1.854 | -0.933 |
| 104 | | -38.000 | -21.912 | 43.865 | | |
| | 100 | -65.498 | -9.433 | 66.173 | 1.938 | -2.585 |
| | 103 | -37.044 | -11.200 | 38.700 | 0.662 | -6.155 |
| | 105 | 64.542 | -1.279 | 64.554 | 0.413 | -0.393 |
| 105 | | -31.000 | 55.983 | 63.993 | | |
| | 103 | -50.464 | -7.539 | 51.024 | 1.383 | -4.176 |
| | 104 | -64.128 | 0.886 | 64.135 | 0.413 | -0.393 |
| | 106 | 18.683 | 53.832 | 56.982 | 0.481 | -0.867 |
| | 107 | 29.042 | -15.932 | 33.125 | 0.519 | -7.618 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 108 | 35.867 | 24.736 | 43.569 | 0.525 | -2.135 |
| 106 | | -66.332 | -103.388 | 122.837 | | |
| | 100 | -70.293 | -17.722 | 72.493 | 3.324 | 0.048 |
| | 105 | -18.202 | -54.699 | 57.648 | 0.481 | -0.867 |
| | 107 | 22.163 | -30.967 | 38.081 | 0.687 | -6.737 |
| 107 | | -50.000 | 32.543 | 59.658 | | |
| | 105 | -28.523 | 8.313 | 29.710 | 0.519 | -7.618 |
| | 106 | -21.477 | 24.230 | 32.378 | 0.687 | -6.737 |
| 108 | | -12.801 | -35.700 | 37.925 | | |
| | 105 | -35.342 | -26.871 | 44.397 | 0.525 | -2.135 |
| | 109 | 22.541 | -8.828 | 24.208 | 0.064 | -1.245 |
| 109 | | -17.332 | -41.669 | 45.130 | | |
| | 108 | -22.476 | 7.584 | 23.721 | 0.064 | -1.245 |
| | 110 | 5.144 | -49.253 | 49.521 | 0.675 | -2.071 |
| 110 | | -39.000 | -46.087 | 60.374 | | |
| | 103 | -69.002 | -0.976 | 69.009 | 1.854 | -0.933 |
| | 109 | -4.469 | 47.182 | 47.393 | 0.675 | -2.071 |
| | 111 | -35.584 | -27.221 | 44.802 | 0.416 | -2.707 |
| | 112 | 70.055 | -65.072 | 95.614 | 2.055 | -7.427 |
| 111 | | 36.000 | 24.514 | 43.554 | | |
| | 110 | 36.000 | 24.514 | 43.554 | 0.416 | -2.707 |
| 112 | | -68.000 | 57.645 | 89.146 | | |
| | 110 | -68.000 | 57.645 | 89.146 | 2.055 | -7.427 |
| 113 | | -6.000 | 177.061 | 177.163 | | |
| | 17 | -0.058 | 165.879 | 165.879 | 2.333 | 6.095 |
| | 32 | -5.942 | 11.182 | 12.663 | 0.180 | -10.367 |
| 114 | | -8.613 | -84.531 | 84.969 | | |
| | 32 | -8.613 | -84.277 | 84.716 | 1.015 | 1.425 |
| | 115 | -0.000 | -0.254 | 0.254 | -0.000 | -0.509 |
| 115 | | -21.729 | -72.390 | 75.581 | | |
| | 27 | -21.729 | -72.136 | 75.337 | 0.964 | 0.494 |
| | 114 | -0.000 | -0.254 | 0.254 | -0.000 | -0.509 |
| 116 | | -184.000 | 816.916 | 837.381 | | |
| | 68 | -184.000 | 816.916 | 837.381 | 2.318 | -6.459 |
| 117 | | -19.692 | -16.660 | 25.794 | | |
| | 12 | -19.692 | -16.660 | 25.794 | 0.195 | -6.144 |
| 118 | | -82.821 | -18.934 | 84.958 | | |
| | 75 | -39.953 | -24.264 | 46.744 | 0.344 | -1.060 |
| | 76 | -42.868 | 5.329 | 43.198 | 0.342 | -1.317 |

**Total loss 505.123 -44**

# CHAPTER 5

# CONCLUSION

A Mat lab simulation program was used to express the Gauss-Seidel method of power flow analysis to calculate the line flow and line losses in a given power grid system.

The result obtained in this study reveals some slight mismatch with the margin of accuracy considered. This originated from the fact that at certain point in the course of calculation the matrix order of the line data and bus data file. Also handling a large data (118 bus) needs a lot of estimate since it’s a recurrence technique. This has a tendency of altering the accuracy of the program because it requires a large number of iteration to converge.

Further research in this field will require a more viable Mat lab program to handle huge amount of data.

# APPENDIX

# APPENDIX A

## lfgauss.m

```
%   Power flow solution by Gauss-Seidel method
%   Copyright (c) 1998 by  H. Saadat
% Revision 1 (Aug. 99) Modified to include two or more parallel lines
Vm=0; delta=0; yload=0; deltad =0;
nbus = length(busdata(:,1));
kb=[ ];Vm=[ ]; delta=[ ]; Pd=[ ]; Qd=[ ]; Pg=[ ]; Qg=[ ]; Qmin=[ ];
Qmax=[ ];  % Added (6-8-00)
Pk=[ ]; P=[ ]; Qk=[ ]; Q=[ ]; S=[ ]; V=[ ]; % Added (6-8-00)
for k=1:nbus
n=busdata(k,1);
kb(n)=busdata(k,2); Vm(n)=busdata(k,3); delta(n)=busdata(k, 4);
Pd(n)=busdata(k,5); Qd(n)=busdata(k,6); Pg(n)=busdata(k,7); Qg(n) =
busdata(k,8);
Qmin(n)=busdata(k, 9); Qmax(n)=busdata(k, 10);
Qsh(n)=busdata(k, 11);
if Vm(n) <= 0  Vm(n) = 1.0; V(n) = 1 + j*0;
else delta(n) = pi/180*delta(n);
V(n) = Vm(n)*(cos(delta(n)) + j*sin(delta(n)));
P(n)=(Pg(n)-Pd(n))/basemva;
Q(n)=(Qg(n)-Qd(n)+ Qsh(n))/basemva;
S(n) = P(n) + j*Q(n);
end
DV(n)=0;
end
num = 0; AcurBus = 0; converge = 1;
Vc = zeros(nbus,1)+j*zeros(nbus,1); Sc =
zeros(nbus,1)+j*zeros(nbus,1);
while exist('accel')~=1
accel = 1.3;
end
while exist('accuracy')~=1
accuracy = 0.001;
end
while exist('basemva')~=1
basemva= 100;

end
while exist('maxiter')~=1
```

```
maxiter = 100;
end
%%%% added for parallel lines (Aug. 99)
mline=ones(nbr,1);
for k=1:nbr
for m=k+1:nbr
if((nl(k)==nl(m)) & (nr(k)==nr(m)));
mline(m)=2;
elseif ((nl(k)==nr(m)) & (nr(k)==nl(m)));
mline(m)=2;
else, end
end
end
%%%   end of statements for parallel lines (Aug. 99)
iter=0;
maxerror=10;
while maxerror >= accuracy & iter <= maxiter
iter=iter+1;
for n = 1:nbus;
YV = 0+j*0;
for L = 1:nbr;
if (nl(L) == n & mline(L) == 1), k=nr(L);   %modified to handle
parallel lines (Aug. 99)
YV = YV + Ybus(n,k)*V(k);
elseif (nr(L) == n & mline(L)==1), k=nl(L); %modified to handle
parallel lines (Aug. 99)
YV = YV + Ybus(n,k)*V(k);
end
end
Sc = conj(V(n))*(Ybus(n,n)*V(n) + YV) ;
Sc = conj(Sc);
DP(n) = P(n) - real(Sc);
DQ(n) = Q(n) - imag(Sc);
if kb(n) == 1
S(n) =Sc; P(n) = real(Sc); Q(n) = imag(Sc); DP(n) =0; DQ(n)=0;
Vc(n) = V(n);
elseif kb(n) == 2
Q(n) = imag(Sc); S(n) = P(n) + j*Q(n);

if Qmax(n) ~= 0
Qgc = Q(n)*basemva + Qd(n) - Qsh(n);
if abs(DQ(n)) <= .005 & iter >= 10 % After 10 iterations
if DV(n) <= 0.045                % the Mvar of generator buses are
if Qgc < Qmin(n),             % tested. If not within limits Vm(n)
Vm(n) = Vm(n) + 0.005;        % is changed in steps of 0.005 pu
```

```
DV(n) = DV(n)+.005;            % up to .05  pu in order to bring
elseif Qgc > Qmax(n),          % the generator Mvar within the
Vm(n) = Vm(n) - 0.005;         % specified limits.
DV(n)=DV(n)+.005; end
else, end
else,end
else,end
end
if kb(n) ~= 1
Vc(n) = (conj(S(n))/conj(V(n)) - YV )/ Ybus(n,n);
else, end
if kb(n) == 0
V(n) = V(n) + accel*(Vc(n)-V(n));
elseif kb(n) == 2
VcI = imag(Vc(n));
VcR = sqrt(Vm(n)^2 - VcI^2);
Vc(n) = VcR + j*VcI;
V(n) = V(n) + accel*(Vc(n) -V(n));
end
end
maxerror=max( max(abs(real(DP))), max(abs(imag(DQ))) );
if iter == maxiter & maxerror > accuracy
fprintf('\nWARNING: Iterative solution did not converged after ')
fprintf('%g', iter), fprintf(' iterations.\n\n')
fprintf('Press Enter to terminate the iterations and print the results
\n')
converge = 0; pause, else, end
end
if converge ~= 1
tech= ('                      ITERATIVE SOLUTION DID NOT CONVERGE');
else,
tech=('                     Power Flow Solution by Gauss-Seidel
Method');
end
k=0;
for n = 1:nbus
Vm(n) = abs(V(n)); deltad(n) = angle(V(n))*180/pi;
if kb(n) == 1
S(n)=P(n)+j*Q(n);
Pg(n) = P(n)*basemva + Pd(n);
Qg(n) = Q(n)*basemva + Qd(n) - Qsh(n);
k=k+1;
Pgg(k)=Pg(n);
elseif  kb(n) ==2
k=k+1;
```

```
Pgg(k)=Pg(n);
S(n)=P(n)+j*Q(n);
Qg(n) = Q(n)*basemva + Qd(n) - Qsh(n);
end
yload(n) = (Pd(n)- j*Qd(n)+j*Qsh(n))/(basemva*Vm(n)^2);
end
Pgt = sum(Pg);  Qgt = sum(Qg); Pdt = sum(Pd); Qdt = sum(Qd); Qsht =
sum(Qsh);
busdata(:,3)=Vm'; busdata(:,4)=delta
```

# APPENDIX B

# lfybus.m

```
function[Y]=ybus(zdata)
nl=zdata(:,1);nr=zdata(:,2);
R=zdata(:,3);X=zdata(:,4);
nbr=length(zdata(:,1));
nbus=max(max(nl),max(nr));
Z=R+j*X; %branch impedance
y=ones(nbr,1)./Z; %branch admittance
Y=zeros(nbus,nbus);   %initialise Y to 0
for k=1:nbr; %formation of the off diagonal elements
if nl(k)> 0 &  nr(k)> 0
Y(nl(k),nr(k))=Y(nl(k),nr(k))-y(k);
Y(nr(k),nl(k))=Y(nl(k),nr(k));
end
end
for n=1:nbus %formation of diagonal elements
for k=1:nbr
if nl(k)==n|nr(k)==n
Y(n,n)=Y(n,n)+y(k);
else,
end,end,end
```

# APPENDIX C

# busout.m

```
fprintf                Maximum Power Mismatch = %g \n', maxerror)
fprintf('              No. of Iterations = %g \n\n', iter)
head =['Bus   Voltage   Angle      ------Load------     ---Generation---
Injected'
'     No.   Mag.      Degree      MW         Mvar         MW         Mvar
Mvar '
       '
'];
disp(head)
for n=1:nbus
     fprintf(' %5g', n), fprintf(' %7.3f', Vm(n)),
     fprintf(' %8.3f', deltad(n)), fprintf(' %9.3f', Pd(n)),
     fprintf(' %9.3f', Qd(n)),  fprintf(' %9.3f', Pg(n)),
     fprintf(' %9.3f ', Qg(n)), fprintf(' %8.3f\n', Qsh(n))
end
    fprintf('      \n'), fprintf('    Total              ')
    fprintf(' %9.3f', Pdt), fprintf(' %9.3f', Qdt),
    fprintf(' %9.3f', Pgt), fprintf(' %9.3f', Qgt), fprintf('
%9.3f\n\n', Qsht)
```

# APPENDIX D

# lineflow.m

```
%  This program is used in conjunction with lfgauss or lf Newton
%  for the computation of line flow and line losses.
%
%  Copyright (c) 1998 H. Saadat
SLT = 0;
fprintf('\n')
fprintf('                              Line Flow and Losses \n\n')
fprintf('     --Line--  Power at bus & line flow    --Line loss--
Transformer\n')
fprintf('     from  to    MW      Mvar     MVA       MW      Mvar
tap\n')

for n = 1:nbus
busprt = 0;
   for L = 1:nbr;
       if busprt == 0
       fprintf('   \n'), fprintf('%6g', n), fprintf('      %9.3f',
P(n)*basemva)
       fprintf('%9.3f', Q(n)*basemva), fprintf('%9.3f\n',
abs(S(n)*basemva))

       busprt = 1;
       else, end
       if nl(L)==n      k = nr(L);
       In = (V(n) - a(L)*V(k))*y(L)/a(L)^2 + Bc(L)/a(L)^2*V(n);
       Ik = (V(k) - V(n)/a(L))*y(L) + Bc(L)*V(k);
       Snk = V(n)*conj(In)*basemva;
       Skn = V(k)*conj(Ik)*basemva;
       SL  = Snk + Skn;
       SLT = SLT + SL;
       elseif nr(L)==n  k = nl(L);
       In = (V(n) - V(k)/a(L))*y(L) + Bc(L)*V(n);
       Ik = (V(k) - a(L)*V(n))*y(L)/a(L)^2 + Bc(L)/a(L)^2*V(k);
       Snk = V(n)*conj(In)*basemva;
       Skn = V(k)*conj(Ik)*basemva;
       SL  = Snk + Skn;
       SLT = SLT + SL;
       else, end
         if nl(L)==n | nr(L)==n
```

```
        fprintf('%12g', k),
        fprintf('%9.3f', real(Snk)), fprintf('%9.3f', imag(Snk))
        fprintf('%9.3f', abs(Snk)),
        fprintf('%9.3f', real(SL)),
            if nl(L) ==n & a(L) ~= 1
            fprintf('%9.3f', imag(SL)), fprintf('%9.3f\n', a(L))
            else, fprintf('%9.3f\n', imag(SL))
            end
        else, end
  end
end
SLT = SLT/2;
fprintf('   \n'), fprintf('    Total loss                         ')
fprintf('%9.3f', real(SLT)), fprintf('%9.3f\n', imag(SLT))
clear Ik In SL SLT Skn Snk
```

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