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Load Flow Analysis Of Ieee14 Bus System Using MATLAB

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Abstract—**The power system analysis and design is generally done by using power flow analysis .This analysis is carried out at the state of planning, operation, control and economic scheduling .they are useful in determining the magnitude and phase angle of load buses, and active and reactive power flows over transmission lines, and active and reactive powers that are injected at the buses.**

For this work the gauss-seidel method is used for numerical analysis. The objective of this project is to develop a MATLAB program to calculate voltages, active and reactive power at each bus for IEEE 14 bus systems. At first IEEE 5 bus system is calculated by using hand calculations and compared with MATLAB Program results and then IEEE 14 bus system MATLAB program is executed with the input data. This type of analysis is useful for solving the power flow problem in different power systems which will useful to calculate the unknown quantities.

Index Terms— **Power Flow Studies (PFS), Guass-Siedel (GS) method, and voltage magnitudes (V), active power (P) & reactive power (Q)**

I. INTRODUCTION

Load flow studies are used to ensure that electrical power transfer from generators to consumers through the grid system is stable, reliable and economic. Conventional techniques for solving the load flow problem are iterative using the Gauss-Seidel methods Load flow analysis forms an essential prerequisite for power system studies. Considerable research has already been carried out in the development of computer programs for load flow analysis of large power systems. However, these general purpose programs may encounter convergence difficulties when a radial distribution system with a large number of buses is to be solved and, hence, development of a special program for radial distribution studies becomes necessary.

There are many solution techniques for load flow analysis. The solution procedures and formulations can be precise or approximate, with values adjusted or unadjusted, intended for either on-line or off-line application, and designed for either single-case or multiple-case applications. Since an engineer is always concerned with the cost of products and services, the efficient optimum economic operation and planning of electric power generation system have always occupied an important position in the electric power industry. With large interconnection of the electric networks, the energy crisis in the world and continuous rise in prices, it is very essential to reduce the running charges of the electric energy. A saving in the operation of the system of a small percent represents a significant reduction in operating cost as well as in the quantities of fuel consumed. The classic problem is the economic load dispatch of generating systems to achieve minimum operating cost.

II. POWER FLOW OVER VIEW

- Power flow analysis is very important in planning stages of new networks or addition to existing ones like adding new generator sites, meeting increase load demand and locating new transmission sites.
- The load flow solution gives the nodal voltages and phase angles and hence the power injection at all the buses and power flows through interconnecting power channels.
- It is helpful in determining the best location as well as optimal capacity of proposed generating station, substation and new lines
- It determines the voltage of the buses. The voltage level at the certain buses must be kept within the closed tolerances.
- System transmission loss minimizes.
- Economic system operation with respect to fuel cost to generate all the power needed
- The line flows can be known. The line should not be overloaded, it means, we should not operate the close to their stability or thermal limits.

III. POWER FLOW ANALYSIS

BUS CLASSIFICATION:
A bus is a node at which one or many lines, one or many loads and generators are connected. In a power system each node or bus is associated with 4 quantities, such as magnitude of voltage, phage angle of voltage, active or true power and reactive power in load flow problem two out of these 4 quantities are specified and remaining 2 are required to be determined through the solution of equation. Depending on the quantities that have been specified, the buses are classified into 3 categories.
Buses are classified according to which two out of the four variables are specified

- **Load bus**:

No generator is connected to the bus. At this bus the real and reactive power are specified. It is desired to find out the voltage magnitude and phase angle through load flow solutions. It is required to specify only Pd and Qd at such bus as at a load bus voltage can be allowed to vary within the permissible values.

- **Generator bus or voltage controlled bus**: Here the voltage magnitude corresponding to the generator voltage and real power Pg corresponds to its rating are specified. It is required to find out the reactive power generation Qg and phase angle of the bus voltage.
- **Slack (swing) bus**: For the Slack Bus, it is assumed that the voltage magnitude |*V*| and voltage phase *Θ* are known, whereas real and reactive powers Pg and Qg are obtained through the load flow solution.

Gauss iterative method using Ybus:-

The solution of the load flow problem is initiated by assuming voltages for all buses except the slack bus, where the voltage is specified and remains fixed. Then currents are calculated for all buses except slack bus s from the loading equation

$$Ip = \frac{P_p - jQ_p}{E_p^*} \qquad p = 1,2,.....,n \quad p \neq s$$

.... (1)

Where n is the number of buses in the network .The performance of the network can be obtained from the equation

$$I_{BUS} = Y_{BUS}\, E_{BUS}$$

.... (2)

Selecting the ground as the reference bus, a set of (n-1) simultaneous equations can be written in the form

$$E_p = \frac{1}{Y_{pp}}\left(I_p - \sum_{\substack{q=1\\ q\neq p}}^{n} Y_{pq}E_q\right)$$

$$p = 1,2,.....,n$$

$$p \neq s \qquad .... (3)$$

The bus currents calculated from equation (1), the slack bus voltage, and the estimated bus voltages are substituted in to EQ (3) to obtain a new set of bus voltages. The new voltages are used inEQ (8.3.1) to re calculate bus currents from a subsequent solution of EQ (3). This process is continued until changes in all bus voltages are negligible. After the voltage solution has been obtained, the power at the slack bus and line flows can be calculated.

The network EQ (3) and the bus loading EQ (1) can be combining to obtain

$$E_p = \frac{1}{Y_{pp}}\left(\frac{P_P - jQ_P}{E_P^*} - \sum_{\substack{q=1\\ q\neq p}}^{n} Y_{pq}E_q\right)$$

$$p = 1,2,.....,n$$

$$p \neq s \qquad .... (4)$$

This involves only bus voltages as variables. Formulating the load flow problem in this manner results in asset of non-linear equations that can be solved by an iterative method. A significant reduction in the computing time for a solution will be obtained by performing as many arithmetic operations as possible before initiating the iterative calculation .Letting

$$\frac{1}{Y_{pp}} = L_p$$

Equation (4) can be written

$$Ep = \frac{(p_p - jQ_p)L_p}{E_p^*} - \sum_{\substack{q=1\\ q\neq p}}^{n} Y_{pq}L_pE_q$$

.... (5)

Letting

$$\left(P_p - jQ_p\right)L_p = KL_p$$

And

$$Y_{pq}L_{PQ} = YL_{PQ}$$

Then, the bus voltage equation (5) becomes

$$Ep = \frac{KLp}{E_p^*} - \sum_{\substack{q=1\\ q\neq p}}^{n} YL_{pq}E_q$$

.... (6)

The normal procedure for a load flow study is to assume a balanced system and to use a single-phase representation equivalent to the positive sequence network. Since there is no mutual coupling, the bus admittance matrix can be formed by inspection and many of its elements will be zero. Selecting bus 2 as the slack bus in the system shown in the fig IEEE 5 BUS SYSTEM, the formulas for the gauss iterative solutions are **Gauss-sidle iterative method using Ybus** The bus voltage EQ (6) also can be solved by the gauss-seidle iterative method (glimn and Stagg 1957) in this method the new calculated voltage immediately replaces and is used in the solution of the subsequent equations. For the system shown in fig of IEEE 5 BUS SYSTEM(8.1)

$$E_1^{k+1} = \frac{KL1}{E_1^k} - YL_{12}E_2 - YL_{13}E_3^k - YL_{14}E_4^k$$

$$E_2 = Specified \quad fixed \ \ value$$

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$$E_3^{k+1} = \frac{KL_3}{(E_3^k)^*} - YL_{31}E_1^k - YL_{35}E_5^k$$

$$E_4^{k+1} = \frac{KL_4}{(E_4^k)^*} - YL_{41}E_1^k - YL_{46}E_6^k$$

$$E_5^{k+1} = \frac{KL_5}{(E_5^k)^*} - YL_{52}E_2 - YL_{53}E_3^k$$

$$E_6^{k+1} = \frac{KL_6}{(E_6^k)^*} - YL_{62}E_2 - YL_{64}E_3^k$$

IV CASE STUDIES

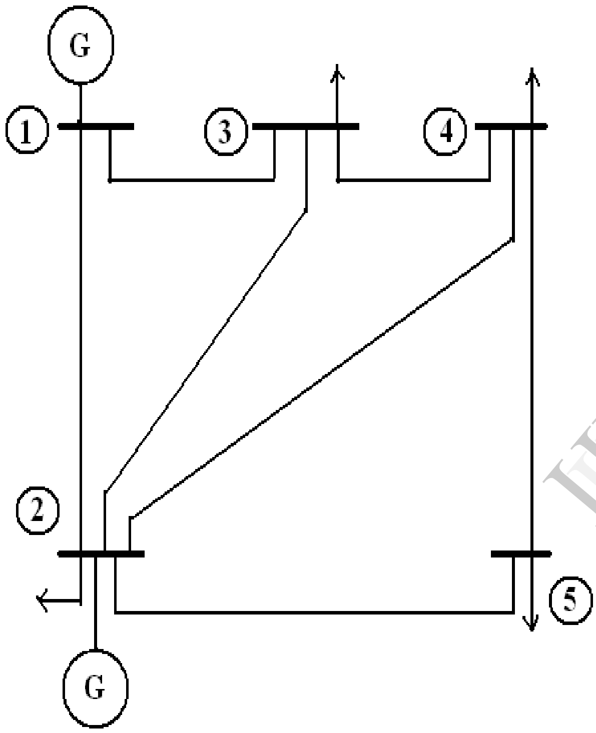

Figure 1: Sample 5-Bus System.

Case:1 IEEE 5 bus

A sample 5 bus system is used for this case,the input data of 5 bus is taken from the reference[].The hand calculations are done by using guass-seidel equations to calculate voltages ,active and reactive powers at each bus for every iteration.

A matlab program is written to calculate the voltages ,active power and reactive power at every bus in the system for every iteration.The input data for the program is given with input file name.

To verify the effectiveness of MATLAB program,both MATLAB results and hand calculations results are compared .It is found that ,These two results are equal.The input data for sample 5 bus system is given in appendix.

The MATLAB results & Hand calculations are

Iteration count k	Bus voltages			
	Bus 2	Bus 3	Bus 4	Bus 5
0	1.0 + j0.0	1.0 + j0.0	1.0 + j0.0	1.0 + j0.0
1	1.05253 + j0.00406	1.00966 − j0.01289	1.01579 − j0.02635	1.02727 − j0.07374
2	1.04528 − j0.03015	1.02154 − j0.04227	1.02451 − j0.06353	1.01025 − j0.08932
3	1.04732 − j0.03618	1.02637 − j0.07153	1.02394 − j0.08326	1.01712 − j0.09826
4	1.04964 − j0.04730	1.02395 − j0.08289	1.02268 − j0.09079	1.01575 − j0.10787
5	1.04749 − j0.05016	1.02300 − j0.08693	1.02148 − j0.09393	1.01315 − j0.10782
6	1.04708 − j0.05057	1.02195 − j0.08877	1.02036 − j0.09473	1.01316 − j0.10873
7	1.04678 − j0.05127	1.02106 − j0.08901	1.01977 − j0.09493	1.01256 − j0.10908
8	1.04639 − j0.05120	1.02070 − j0.08913	1.01945 − j0.09501	1.01224 − j0.10893
9	1.04630 − j0.05123	1.02048 − j0.08918	1.01927 − j0.09502	1.01219 − j0.10904
10	1.04623 − j0.05126	1.02036 − j0.08917	1.01920 − j0.09504	1.01211 − j0.10904

BUS VOLTAGES AT THE END OF 10 ITEATIONS

E(1)=(1.060000)+j(0.000000)

E(2)=(1.046249)+j(-0.051279)

E(3)=(1.020376)+j(-0.089174)

E(4)=(1.019215)+j(-0.095041)

E(5)=(1.012128)+j(-0.109042)

The Line Power Flows are:

Ppq(1)(2)=88.822114 MW	Qpq(1)(2)=-8.684865 MVAr
Pqp(2)(1)=-87.412785 MW	Qqp(2)(1)=6.250251 MVAr
Ppq(1)(3)=40.696820 MW	Qpq(1)(3)=1.126016 MVAr
Pqp(3)(1)=-39.506563 MW	Qqp(3)(1)=-2.987044 MVAr
Ppq(2)(3)=24.674725 MW	Qpq(2)(3)=3.539738 MVAr
Pqp(3)(2)=-24.323822 MW	Qqp(3)(2)=-6.779800 MVAr
Ppq(2)(4)=27.925725 MW	Qpq(2)(4)=2.963475 MVAr
Pqp(4)(2)=-27.484747 MW	Qqp(4)(2)=-5.930740 MVAr
Ppq(2)(5)=54.822293 MW	Qpq(2)(5)=7.360576 MVAr
Pqp(5)(2)=-53.697096 MW	Qqp(5)(2)=-7.185329 MVAr
Ppq(3)(4)=18.930215 MW	Qpq(3)(4)=-5.155906 MVAr
Pqp(4)(3)=-18.894450 MW	Qqp(4)(3)=3.166250 MVAr
Ppq(4)(5)=6.340671 MW	Qpq(4)(5)=-2.277924 MVAr
Pqp(5)(4)=-6.309887 MW	Qqp(5)(4)=-2.840041 MVAr

The line losses are:

Ploss(1)=1.409328 MW	Qloss(1)=-2.434615 MVAr
Ploss(2)=1.190257 MW	Qloss(2)=-1.861028 MVAr
Ploss(3)=0.350903 MW	Qloss(3)=-3.240062 MVAr
Ploss(4)=0.440978 MW	Qloss(4)=-2.967264 MVAr
Ploss(5)=1.125196 MW	Qloss(5)=0.175247 MVAr
Ploss(6)=0.035765 MW	Qloss(6)=-1.989657 MVAr
Ploss(7)=0.030784 MW	Qloss(7)=-5.117965 MVAr

Slack Bus Real Power Generation=129.518934 MW

Slack Bus Reactive Power Generation=-7.558849 MAVr

Case:2 IEEE 14 bus

The IEEE 14 bus system is simulated for voltages ,active and reactive powers at each bus.
The standard IEEE14 bus system is shown in figure.
A MATLAB program is used for IEEE 14 bus system with standard IEEE 14 bus system data input file.After simulating the program ,it didplays results ,i.e voltage ,active & Reactive powers and line losses .The results of MATLAB program for IEEE 14 bus system are

BUS VOLTAGES AT THE END OF 48 ITEATIONS

E(1)=(1.060000)+j(0.000000)
E(2)=(1.041071)+j(-0.090419)
E(3)=(0.985314)+j(-0.221865)
E(4)=(1.002309)+j(-0.181984)
E(5)=(1.008447)+j(-0.155282)
E(6)=(1.037393)+j(-0.261998)
E(7)=(1.033411)+j(-0.244615)
E(8)=(1.060686)+j(-0.251088)
E(9)=(1.020843)+j(-0.271512)
E(10)=(1.015241)+j(-0.273020)
E(11)=(1.022244)+j(-0.269053)
E(12)=(1.019093)+j(-0.273569)
E(13)=(1.014097)+j(-0.273800)
E(14)=(0.995706)+j(-0.285303)

The Line Power Flows are:

Ppq(1)(2)=156.317898 MW	Qpq(1)(2)=-20.255152 MVAr
Pqp(2)(1)=-152.051712 MW	Qqp(2)(1)=27.431249 MVAr
Ppq(2)(3)=73.087538 MW	Qpq(2)(3)=3.578016 MVAr
Pqp(3)(2)=-70.773582 MW	Qqp(3)(2)=1.545299 MVAr
Ppq(2)(4)=55.967986 MW	Qpq(2)(4)=-2.296184 MVAr
Pqp(4)(2)=-54.301066 MW	Qqp(4)(2)=3.371402 MVAr
Ppq(1)(5)=75.313365 MW	Qpq(1)(5)=3.492425 MVAr
Pqp(5)(1)=-72.567026 MW	Qqp(5)(1)=2.519567 MVAr
Ppq(2)(5)=41.385188 MW	Qpq(2)(5)=0.749092 MVAr
Pqp(5)(2)=-40.488427 MW	Qqp(5)(2)=-1.637334 MVAr
Ppq(3)(4)=-23.397752 MW	Qpq(3)(4)=2.785299 MVAr
Pqp(4)(3)=23.770984 MW	Qqp(4)(3)=-5.392707 MVAr
Ppq(4)(5)=-61.046827 MW	Qpq(4)(5)=15.619484 MVAr
Pqp(5)(4)=61.560360 MW	Qqp(5)(4)=-15.330086 MVAr
Ppq(5)(6)=43.904029 MW	Qpq(5)(6)=12.856263 MVAr
Pqp(6)(5)=-43.904029 MW	Qqp(6)(5)=-8.455568 MVAr
Ppq(4)(7)=27.926820 MW	Qpq(4)(7)=-9.401528 MVAr
Pqp(7)(4)=-27.926820 MW	Qqp(7)(4)=11.075128 MVAr
Ppq(7)(8)=0.010177 MW	Qpq(7)(8)=-16.900100 MVAr
Pqp(8)(7)=-0.010177 MW	Qqp(8)(7)=17.346207 MVAr
Ppq(4)(9)=16.024493 MW	Qpq(4)(9)=-0.309868 MVAr
Pqp(9)(4)=-16.024493 MW	Qqp(9)(4)=1.602588 MVAr
Ppq(7)(9)=28.061205 MW	Qpq(7)(9)=5.825814 MVAr
Pqp(9)(7)=-28.061205 MW	Qqp(9)(7)=-5.024598 MVAr
Ppq(9)(10)=5.244181 MW	Qpq(9)(10)=4.309034 MVAr
Pqp(10)(9)=-5.231047 MW	Qqp(10)(9)=-4.274147 MVAr
Ppq(6)(11)=7.332290 MW	Qpq(6)(11)=3.470636 MVAr
Pqp(11)(6)=-7.277693 MW	Qqp(11)(6)=-3.356303 MVAr
Ppq(6)(12)=7.769332 MW	Qpq(6)(12)=2.503193 MVAr
Pqp(12)(6)=-7.697799 MW	Qqp(12)(6)=-2.354312 MVAr
Ppq(6)(13)=17.727774 MW	Qpq(6)(13)=7.175947 MVAr
Pqp(13)(6)=-17.516427 MW	Qqp(13)(6)=-6.759739 MVAr
Ppq(9)(14)=9.452723 MW	Qpq(9)(14)=3.661815 MVAr
Pqp(14)(9)=-9.335661 MW	Qqp(14)(9)=-3.412809 MVAr
Ppq(10)(11)=-3.748790 MW	Qpq(10)(11)=-1.536134 MVAr
Pqp(11)(10)=3.760975 MW	Qqp(11)(10)=1.564657 MVAr
Ppq(12)(13)=1.612438 MW	Qpq(12)(13)=0.733450 MVAr
Pqp(13)(12)=-1.606212 MW	Qqp(13)(12)=-0.727817 MVAr
Ppq(13)(14)=5.628515 MW	Qpq(13)(14)=1.689408 MVAr
Pqp(14)(13)=-5.575015 MW	Qqp(14)(13)=-1.580481 MVAr

The line losses are:

Ploss(1)=4.266185 MW	Qloss(1)=7.176097 MVAr
Ploss(2)=2.313956 MW	Qloss(2)=5.123314 MVAr
Ploss(3)=1.666920 MW	Qloss(3)=1.075218 MVAr
Ploss(4)=2.746339 MW	Qloss(4)=6.011992 MVAr
Ploss(5)=0.896762 MW	Qloss(5)=-0.888243 MVAr
Ploss(6)=0.373232 MW	Qloss(6)=-2.607408 MVAr
Ploss(7)=0.513533 MW	Qloss(7)=0.289398 MVAr
Ploss(8)=-0.000000 MW	Qloss(8)=4.400695 MVAr
Ploss(9)=0.000000 MW	Qloss(9)=1.673601 MVAr
Ploss(10)=0.000000 MW	Qloss(10)=0.446107 MVAr
Ploss(11)=0.000000 MW	Qloss(11)=1.292721 MVAr
Ploss(12)=0.000000 MW	Qloss(12)=0.801215 MVAr
Ploss(13)=0.013133 MW	Qloss(13)=0.034887 MVAr
Ploss(14)=0.054597 MW	Qloss(14)=0.114333 MVAr
Ploss(15)=0.071533 MW	Qloss(15)=0.148881 MVAr
Ploss(16)=0.211347 MW	Qloss(16)=0.416208 MVAr
Ploss(17)=0.117062 MW	Qloss(17)=0.249006 MVAr
Ploss(18)=0.012185 MW	Qloss(18)=0.028523 MVAr
Ploss(19)=0.006226 MW	Qloss(19)=0.005633 MVAr
Ploss(20)=0.053500 MW	Qloss(20)=0.108928 MVAr

Slack Bus Real Power Generation=231.631263 MW

Slack Bus Reactive Power Generation=-16.762727 MAVr

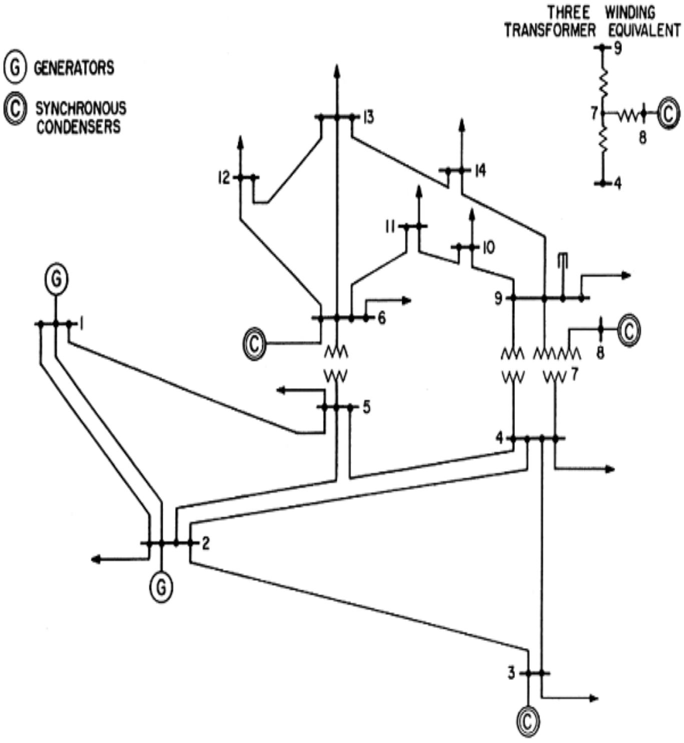

Figure 2: IEEE 14-Bus System.

In this paper, The IEEE 14 bus system is analyzed by using guass-seidel method. This is verified by calculating hand calculations by using the guass-seidel equations and MATLAB program for 5 bus sample system. Both these results are found equal .so this type of MATLAB programming is very useful for solving load flow problems. This MATLAB program can be applicable for any number of buses. The standard IEEE 14 bus input data is used for IEEE14bus system and sample 5 bus input data is used for 5 bus system. The future scope for this project can be extended with Newton-Raphson method and Fast Decoupled methods.

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APPENDIX

IEEE 5-Bus System input data

Bus code p	Assumed Bus Voltage	Generation		Load	
		MW	MVARs	MW	MVARs
1	1.06+j0.0	0	0	0	0
2	1.0+j0.0	40	30	20	10
3	1.0+j0.0	0	0	45	15
4	1.0+j0.0	0	0	40	5
5	1.0+j0.0	0	0	60	10

Bus Code p-q	Impedance Z_{pq}	Line Charging $Y'_{pq}/2$
1-2	0.02+j0.06	0.0+j0.030
1-3	0.08+j0.24	0.0+j0.025
2-3	0.06+j0.18	0.0+j0.020
2-4	0.06+j0.18	0.0+j0.020
2-5	0.04+j0.12	0.0+j0.015
3-4	0.01+j0.03	0.0+j0.010
4-5	0.08+j0.24	0.0+j0.025

IEEE 14-Bus System input data

Bus No	Bus Code	Voltage Magnitude	Angle Degrees	Load		Generator				Injected MVAR
				MW	MVAR	MW	MVAR	Qmin	Qmax	
1	1	1.06	0	30.38	17.78	40	-40	0	0	0
2	2	1.045	0	0	0	232	0	-40	50	0
3	2	1.01	0	131.88	26.6	0	0	0	40	0
4	0	1	0	66.92	10	0	0	0	0	0
5	0	1	0	10.64	2.24	0	0	0	0	0
6	2	1.07	0	15.68	10.5	0	0	-6	24	0
7	0	1	0	0	0	0	0	0	0	0
8	2	1.09	0	0	0	0	0	-6	24	0
9	0	1	0	41.3	23.24	0	0	0	0	0
10	0	1	0	12.6	8.12	0	0	0	0	0
11	0	1	0	4.9	2.52	0	0	0	0	0
12	0	1	0	8.54	2.24	0	0	0	0	0
13	0	1	0	18.9	8.12	0	0	0	0	0
14	0	1	0	20.86	7	0	0	0	0	0

Line Data of IEEE 14-Bus System

Sendind end Bus	Receiving end Bus	Resistance p.u.	Reactance p.u.	Half Susceptance p.u.	Tranformer tap
1	2	0.01938	0.05917	0.0264	1
2	3	0.04699	0.19797	0.0219	1
2	4	0.05811	0.17632	0.0187	1
1	5	0.05403	0.22304	0.0246	1
2	5	0.05695	0.17388	0.017	1
3	4	0.06701	0.17103	0.0173	1
4	5	0.01335	0.04211	0.0064	1
5	6	0	0.25202	0	0.932
4	7	0	0.20912	0	0.978
7	8	0	0.17615	0	1
4	9	0	0.55618	0	0.969
7	9	0	0.11001	0	1
9	10	0.03181	0.0845	0	1
6	11	0.09498	0.1989	0	1
6	12	0.12291	0.25581	0	1
6	13	0.06615	0.13027	0	1
9	14	0.12711	0.27038	0	1
10	11	0.08205	0.19207	0	1
12	13	0.22092	0.19988	0	1
13	14	0.17093	0.34802	0	1