A Simple Solution For Power Flow Problem Using Gauss-Seidel Method In MATLAB

Dr. Lokanatha Dhall Samanta, Professor, Dept. of Electrical Engineering, S.I.E.T., Dhenkanal

Ramesh Chandra Panda, Asst. Professor, Dept. of Mechanical Engineering, S.I.E.T., Dhenkanal

***Abstract*:**

Power flow studies, commonly referred to as load flow are the backbone of power system that focuses on design., economic operation ,protection, control of existing system, planning its future expansion, exchange power between the utilities and analyses transient stability and contingency study. In power system power are known rather than current, thus the resulting equations in terms of power is known as the power flow or load flow equations, become non-linear and are solved by iterative techniques namely Gauss –Seidel method, Newton-Raphson method. and Newton's Fast Decoupled method. The Gauss-Seidel method is an iterative algorithm for solving a set of non- linear algebraic equations. The relationship between network bus voltages and currents may be represented by either loop equations or node equations. Node equations are normally preferred because the numbers of independent node equations are smaller than the number of independent loop equations. This paper illustrates a simple example of 3-bus power system where solution results of both numerical as well as MATLAB-based Gauss-siedel method were compared and found both are in close agreement.

Key words: Power flow, Gauss-Seidel, Newton-Raphson, Fast- Decoupled, transient, contingency

I INTRODUCTION

Electrical energy is an indispensable ingredient for the industrial and all-round growth of any country. It is the most popular form of energy; as it can be transported easily at high efficiency with reasonable cost and symmetrically steady state, certainly, the most important means of operation of a power system.

Power flow studies, usually referred to as load flow are the backbone of power system analysis and design [1]. 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 Newton-Raphson (N.R) or the Gauss-Seidel (G.S) methods. The load flow solution techniques bring extra mathematical hurdles, including matrix representation (with complex number coefficients), iterative methods and probability functions. The

N.R method and G.S method can be compared when both use Y_{BUS} as their network model [2]. The N.R method needs more memory when rectangular co-ordinates are used and hence polar forms are preferred. Further time taken per iteration is larger for a typical larger system 7 times more than G.S method. The N.R. method involves complex programming and large computer memory, even when compact storage scheme is used for Jacobian and admittance matrix. On the other hand the G.S. method works well when programmed using Rectangular co-ordinates, requires smallest number of arithmetic operations to complete iteration due to the sparsity of network. It involves the most utilization of core memory and ease of programming and iteration time is appreciably less compared to N.R method for a large power system [3].G.S. method is referred to as Successive Displacement Method. The difference between the two methods is that the Jacobi uses the value derived from previous steps where as G.S. uses the latest updated value during the iteration. The second unknown value can be obtained from the first unknown and similarly the third unknown value is obtained from first and second and so on[4, 5, 6].

Some paper discusses a reformulation of the least distance problems bounded by the inequality constraints as an unconstrained convex minimization problem equivalent to some system of piece wise linear equations. The proposed G.S method solves the problem easily for implementation when the number of rows of matrix is lesser than the column and proved to have the linear convergence [7].

For attaining an iterative solution of a system of thermal-radiation transfer equations for radiation, absorption and scattering media, the application of G.S diagonal element isolation method has been tested. This has been proved useful for modeling the transfer of neutrons and γ-rays [8].

In a novel research work two iterative methods of solving system of linear equations have been compared, the iterative methods are used for solving sparse and dense system of linear equation and the methods were being considered are: Jacobi method and Gauss-Seidel method. The results show that Gauss-Seidel method is more efficient than Jacobi method by considering maximum number of iteration required to converge and accuracy [9].

G.S method is very well accepted iterative technique for solution of linear system of algebraic equations. It can be applied to any converging matrix with non-zero elements on diagonal.

Gauss-Seidel is considered superior over Gauss Jacobi Method. In this method, just like any other iterative method, an approximate solution of the given equations is assumed, and iteration is carried on until the intended degree of accuracy is achieved.

II POWER /LOAD FLOW STUDIES

A load flow study is the determination of voltage, current, real power and reactive power at various points in an electric network which concerns with Load flow analysis, Short circuit analysis or fault calculations as well as Stability analysis [10]. The systems being planned are to be optimal with respect to cost, performance and operating efficiency. For this better planning The main objective of load flow analysis is to identify the potential problems in terms of unacceptable voltage condition, overloading, decreasing reliability or any failure of the transmission system to meet performance criteria. They also help to determine the best size and favorable locations for the power capacitors both for improvement of the power factor also raising the bus voltage of the electrical network. There are 4 variables that are associated with each bus are: real / active power (P), reactive power (Q), Voltage magnitude (V) and phase angle (δ)

III POWER / LOADFLOW PROBLEMS

Three major problems encountered in this mode of operation are listed below in their hierarchical order, Load or power flow problemOptimal load scheduling problem and Systems control problem. The most common formulation of the Load Flow problem requires all input variables (PQ at loads, PV at generators) to be specified as deterministic values. Each set of specified values corresponds to one system state, which depends on some set of system conditions. Thus, when the input conditions are uncertain, there is a need for numerous scenarios to be analyzed. A load flow approach that could directly incorporate uncertainty into the solution process has been long recognized as useful. The results from such analysis would be expected to give solutions over the range of the uncertainties, i.e., solutions that are sets of values or regions instead of single operating points.

IV POWER FLOW SOLUTIONS [1, 4]

The Gauss-Seidel method is an iterative algorithm for solving a set of non- linear algebraic equations. The relationship between network bus voltages and currents may be represented by either loop equations or node equations. Node equations are normally preferred because the number of independent node equation is smaller than the number of independent loop equations.

The basic power flow nonlinear equations are

$$P_i = \sum_{k=1}^{n} |Y_{ik} V_i V_k| \cos(\theta_{ik} + \delta_k - \delta_i) \quad \text{.}$$

…… .(1)

$$Q_i = -\sum_{k=1}^{n} |Y_{ik} V_i V_k| \sin(\theta_{ik} + \delta_k - \delta_i)$$

……. (2)

Knowing the real and reactive power injected at any bus.

$$P_{i,inj} - jQ_{i,inj} = V_i^* \sum_{k=1}^{n} Y_{ik} V_k = V_i^* [Y_{i1} V_1 + Y_{i2} V_2 + \cdots + Y_{ii} V_i + \cdots + Y_{in} V_n]$$

. …. (3)

$$V_i = \frac{1}{Y_{ii}} \left[\frac{P_{i,inj} - jQ_{i,inj}}{V_i^*} - Y_{i1} V_1 - Y_{i2} V_2 - \cdots - Y_{in} V_n \right]$$ **… (4)**

It can be seen that even though the real power is specified for the P-V bus, its reactive power is unknown. Therefore to update the voltage of this bus, we must first estimate the reactive power of the k^{th}iteration type of buses i.e.

$$Q_{i,inj}^{(k)} = -\mathrm{Im}\left[V_i^{*(k-1)} \left\{ Y_{i1} V_1 + Y_{i2} V_2^{(k)} + \cdots + Y_{ii} V_i^{(k-1)} + \cdots + Y_{in} V_n^{(k-1)} \right\} \right]$$

…… (5)

Here, we have written a program code for **Gauss-Seidel method in MATLAB-10 version** that thrashes out its theoretical background through a flow chart and investigated the outcome of MATLAB program with a numerical outcome of a power system based 3-bus system. The flow diagram for G.S. method is shown in figure 1.

V FLOW CHART [2]

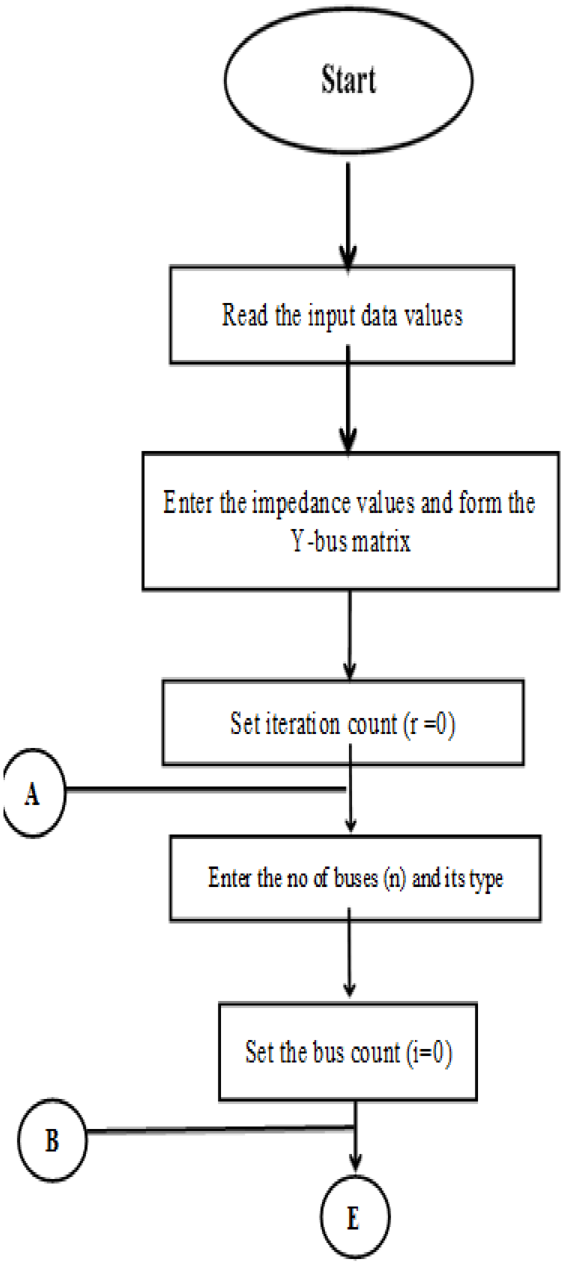
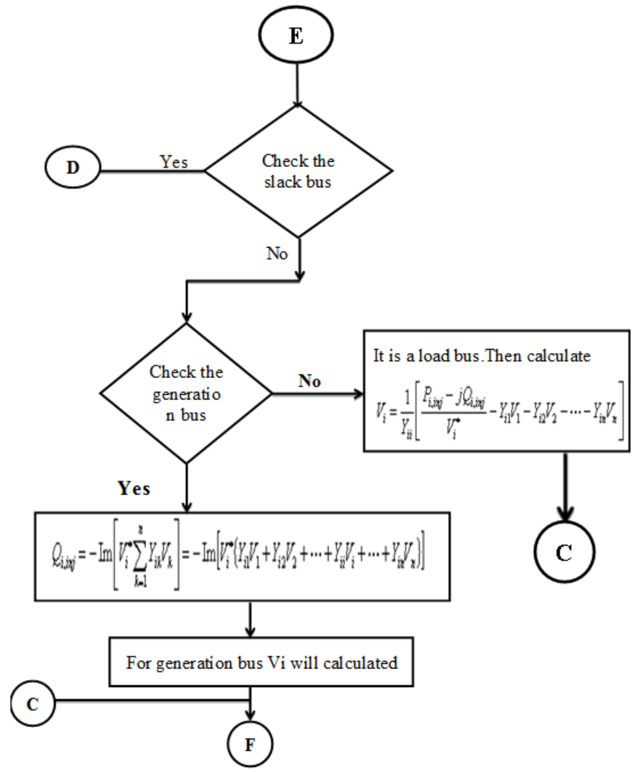
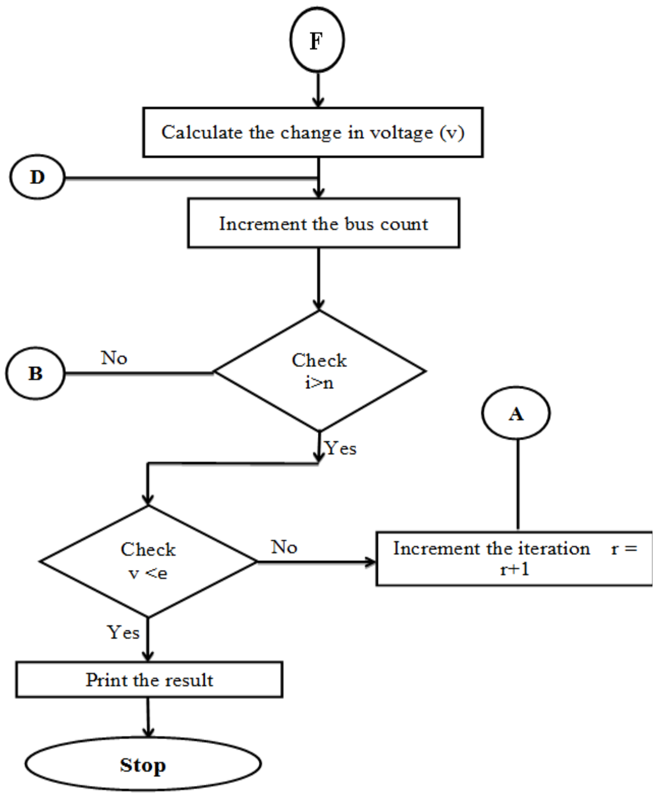


Fig. 1 Flow diagram for Gauss-Seidel power flow Solution





VI ILLUSTRATIVE EXAMPLE [1]

Figure 2.0 shows the one line diagram of a simple three bus power system

With generation at bus 1: The magnitude of voltage at bus 1 is adjusted to 1.05 per unit. The scheduled loads at buses 2 and 3 are as marked on the diagram. Line impedances are marked in per unit on a 100 MVA base with the line charging susceptance neglected.

(a)Numerical results and results using MATLAB for the Gauss Seidel method were obtained to determine the phasor values of the voltage AT the load buses 2 and 3(P-Q buses) accurate to four decimal places

(b)Similarly, following the same procedures, the line flows and line losses were also calculated showing the nature of line flows and losses close to three decimal places .

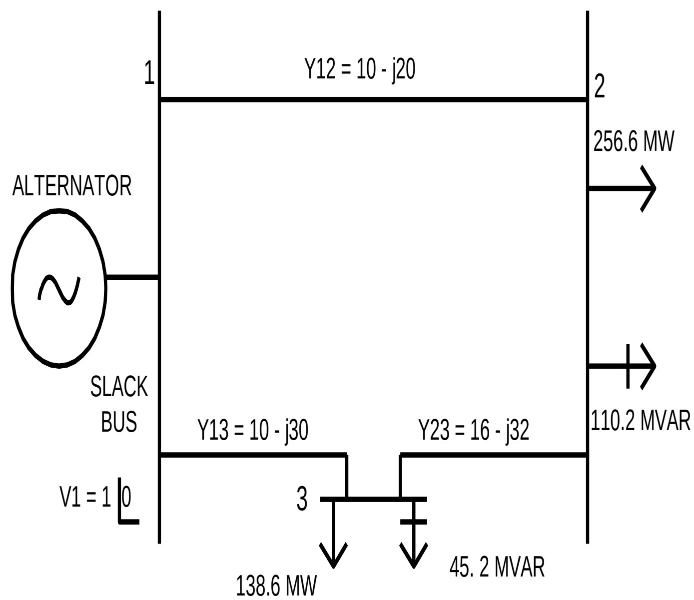


Fig. 2 Single Line diagram for a 3-bus system

VII TEST RESULTS

TABLE I COMPARISON OF VOLTAGES

TABLE II COMPARISION OF LINE FLOWS

Quantities / MethodS	S12 MVAR	S21 MVAR	S13 MVAR	S31 MVAR	S23 MVAR	S32 MVAR
Numerical Gauss-Seidel Method	1.995+0.840i	-1.989-0.82i	2.100+1.050i	-2.080-0.980i	-0.656-0.436i	0.660+0.442i
Gauss-Seidel method In MATLAB	1.986+0.826i	-1.975-0.8317i	2.089 +0.983i	-1.992 -0.976i	-0.6396 -0.4298i	0.6466 +0.428i

TABLE III COMPARISION OF LINE LOSSES

Quantities / Methods	S12 MVAR	S13 MVAR	S23 MVAR
Numerical Gauss-Seidel Method	0.085+0.017i	0.05+0.15i	0.008+0.016i
Gauss-Seidel method In MATLAB	0.824 .009i	0.0476 + 0.143i	0.0075+.0149i

Quantities / Methods	V2 in p.u	V3 in p.u
Analytical Gauss-Seidel Method	0.9800 – 0.0600i	1.0000 – 0.0500i
Gauss-Seidel method in MATLAB	0.9873 - 0.0621i	1.014- 0.0497i

VIII CONCLUSION

In these studies the algorithm of load/power flow problem computation as well as its solution was realized through both numerical and MATLAB based analysis using Gauss-Seidel method. This algorithm is based on the distribution of the calculation of the bus voltage for any number of buses connected to the transmission and the distribution lines of power system.

From studying the results, it is clear that for large power system the suggested algorithm is effective. This algorithm reduces the execution time considerably compared to other sequential algorithm. The amount of communication overhead becomes insignificant as compared to the processing time when the size of the power circuit is considerably large. It can be easily found out the bus voltage of each bus by using this algorithm in MATLAB.

In this thesis we have considered a specific problem which has been solved using Numerical Gauss-seidel method and the same problem has been also solved using Gauss-Seidel method in MATLAB and found that both the results are in close agreement.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the contributions of Department of Electricaland Mechanical Engineering, Synergy Institute of Engineering and Technology, Dhenkanal for their work on the original version of this document.

REFERENCES

[1] John. J. Grainger & W. D. Stevenson, Jr, " *Power system analysis*", McGraw Hill Education, Private Limited, New Delhi.

[2] D. P. Kothari, I. J. Nagrath, "*Modern Power System Analysis"*, Tata McGraw-Hill Publishing Company Limited, New Delhi.

[3] Power flow by Gauss-Seidel method, *http://nptel.ac.in/courses/Webcourse-contents/IIT-KANPUR/power-system/ui/Course_home-4.htm*

[4] Hadi Saadat, "*Power system analysis",Tata Mc-Graw Hill Publishing Company Limited*, New Delhi.

[5] Raed Alqadi and Maher Khammash, "*A parallel Gauss-Seidel algorithm for the solution of load flow problem*", The international Arab journal of Informational Technology, Vol. 4, pp. 148-152, No.2, April 2007.

[6] Dr. B. R. Gupta, "*Power System Analysis and Design",* S. Chand and Company, Publication, New Delhi.

[7] W. Lz, P. M. Pardalos, C. G. Han, F. A. Potra, "*Gauss-Seidel Method for Least-Distance Problems"* Journal of Optimization Theory and Applications, Vol. 75, No. 3, pp.487-489, December 1992 .

[8] Snezhinsk, Chelyabinsk Oblast, "*Application of The Gauss-Seidel Iteration Process In The Diagonal Element Isolation Method For Thermal Radiation Transfer Problems"*, Atomic Energy, Vol.117, No.3, pp.156-160,January,2015

[9] A. I. Bakari, I.A.Dahiru, "*Comparision of Jacobi and Gauss-Seidel Iterative Methods for the Solutions of Systems of Linear Equations*", Asian Research Journal of Mathematics, Article no.ARJOM.34769 ISSN: 2456-477X, pp.1-7,2018.

[10] Sandeep Kaur and Dr. Raja Singh Khela, "*Power System Design & Stability Analysis*", International Journal of Advanced Research in Computer Science and Software Engineering, Vol. 4, Issue 1, pp. .January 2014.