A Methodical Load Flow Analysis

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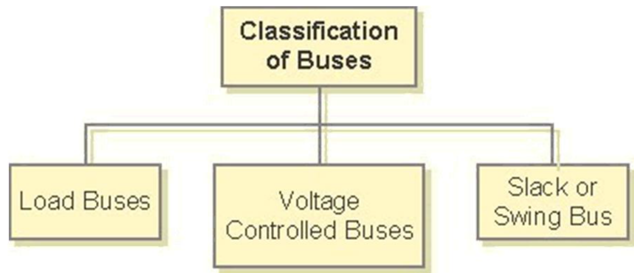
Abstract**—***Load flow calculation is one of the most basic problems in power engineering. The repetitive solution of a large set of linear equations in load flow problem is one of the most time consuming parts. Load flows are calculated using the traditional method such as Gauss Seidel or Newton Raphson methods. Gauss Seidel algorithm is an iterative numerical procedure and in this method the number of iteration depends on the acceleration factor (α). Here we attempt to choose the appropriate acceleration factor (α) so as to minimize the number of iteration and get the result in minimum required time. In this paper, a Fuzzy based efficient approach with MATLAB is used to evaluate the voltages at different buses by using Gauss Seidel Method for the Solutions of Non Linear differential equations. Different areas will be highlighted wherever possible based on the author's own knowledge and experience. In conclusion and future scenario, the trend of various methods for the analysis of Load Flow Problem along with some possible research and development areas will be highlighted.*

Keywords**—** MATLAB, Fuzzy Logic, Gauss Seidel, Various buses.

I. INTRODUCTION

Power flow analysis is a very important and basic tool in the field of power system engineering. It is used in the planning and design stages as well as during the operational stages of a power system [1-2]. In a three phase ac power system P and Q flows from the generators to the load through various buses and lines which is called as power flow or load flow [3]. Power flow analysis provide mathematical approach for determination of P,Q,V, □ power flow through different lines , generators and loads under steady state condition. PFA is used to determine the steady state operating condition of a power system [4,5] .It is widely used by power distribution authorities during the planning and operation of power distribution system.

Each bus in the system has four variables: voltage magnitude, voltage angle, real power and reactive power. During the operation of the power system, each bus has two known variables and two unknowns. Generally, the bus must be classified as one of the following bus types:



II. LOAD FLOW EQUATIONS

LF is required when

· There is a significant plant expansion
· New local generation is or is proposed to be added
· New utility feed has been installed
· New large motors have been added to the system
· New transformers have been installed
· Addition of significant loads [6][7]

1. Equations for active and reactive power flows.
2. Transmission line loss.

$I_{Bus} = Y_{Bus} V_{Bus}$

I_{Bus} is the n*1 column matrix representing n bus currents.

V_{Bus} is the n*1 column matrix representing n bus voltages.

Y_{Bus} is the n*n square matrix representing n^2 bus admittances.

$$I_i = \sum_{k=1}^{n} Y_{ik} V_k \quad (1)$$

$$P_i = \sum_{k=1}^{n} |V_i| |V_k| |Y_{ik}| \cos(\delta_i - \delta_k + \gamma_{ik}) \quad (2)$$

$$Q_i = \sum_{k=1}^{n} |V_i| |V_k| |Y_{ik}| \sin(\delta_i - \delta_k + \gamma_{ik}) \quad (3)$$

$$V_i = 1/Y_{ii}\left[(P_i - jQ_i)/V_i^* - \sum_{\substack{k=1 \\ k\neq i}}^{n} Y_{ik} V_{ik}\right] \quad (4)$$

Problems regarding steady state and transient analysis of power systems mainly require iterative solutions of large sets of equations representing system components [8]. The load flow calculation is one of the most basic problems in power engineering. The repetitive solution of a large set of linear equations in the load flow problem is one of the most time consuming parts of power system simulations.

The main disadvantage of all these sophisticated methods is the large number of calculations which are needed on account of factorization, refactorisation and computations on the jacobian matrix.

Traditionally, load flows are calculated using the Gauss Seidel and Optimal Load Flow (or Newton Raphson) methods. In this paper we have shown as to how the number of iteration is dependent on acceleration factor (α) and how a choice of correct acceleration factor (α) gives the optimum result in minimum iteration applying Gauss Seidel Method.

The Gauss Seidel algorithm is an iterative numerical procedure which attempts to find a solution to the system of linear equations by repeatedly solving the linear system until the iteration solution is within a predetermined acceptable bound of error. The number of iteration for the solution to be within a predetermined acceptable bound of error depends upon the acceleration factor (α). By choosing the correct value of 'α' we can achieve the optimum solution in minimum number of iterations.

In this paper we have tried to choose optimum values of acceleration factor (α) so as to achieve the solution in minimum number of iterations using MATLAB with Fuzzy Model.

II. CONVENTIONAL METHOD

The Gauss−Seidel method is one of the simplest iterative methods known. It is in use since early days of digital computer methods of analysis. It has advantages like it is simple, computation cost is less. It is a robust and reliable load flow method that provides convergence to extremely complex power flow systems [9].

In Gauss−Seidel method for an n bus system the bus voltages are calculated by the formula

$$V_i^{r+1} = \frac{1}{Y_{ii}}\left[I_i^r - \sum_{\substack{j=1 \\ j\neq i}}^{n} Y_{ij} V_j^r \right] \qquad (5)$$

.

Where the subscript i denotes the bus number and the superscript r denotes the iteration number, Y is the admittance matrix of the system. I is the bus current. V is the bus voltage. Again if for each bus i the complex power S_i is known then the bus current can be calculated as

$$I_i^r = \frac{S_i^*}{(V_i^k)^*} = \frac{P_i - jQ_i}{(V_i^k)^*} \qquad (6)$$

Where P and Q are the real and the reactive power of the bus

respectively and V* is the complex conjugate of the bus voltage. Substituting equation (6) in equation (5) we get

$$V_i^{r+1} = \frac{1}{Y_{ii}}\left[\frac{P_i - jQ_i}{(V_i^k)^*} - \sum_{\substack{j=1 \\ j\neq i}}^{n} Y_{ij} V_j^r \right] \qquad (7)$$

This iteration in continued until the iteration solution in within a predetermined acceptable bound of error. Or in other words, the iteration stops if

$$\left| V_i^{r+1} - V_i^r \right| \leq \varepsilon \qquad (8)$$

Where ε is the tolerance condition. The rate of convergence of Gauss−Siedel method can be increased by applying an acceleration factor α at the end of each iteration. That is after obtaining the bus voltage

V_i^{k+1} the correction factor is calculated as follows

$$\Delta V_i^{r+1} = \alpha\left(V_i^{r+1} - V_i^r\right) \qquad (9)$$

$$V_i^{r+1}(acc) = V_i^r + \Delta V_i^{r+1} \qquad (10)$$

The value of voltage obtained in equation (10) is the new voltage of bus i after the (r+1)th iteration. In equation (9), α is the acceleration factor. Usually satisfactory range of acceleration factor is within 1 to 1.8. Proper selection of acceleration factor can reduce the number of iteration to a greater extent.

In this paper five bus system has been taken as shown

Bus Data	Bus No.	Load		Generation		Voltage	Remarks
		P	Q	P	Q		
	1	NS	NS	NS	NS	$1.2\angle 0$	Slack Bus
	2	0.4	0.3	0	0	NS	PQ Bus
	3	0.6	0.3	0	0	NS	PQ Bus
	4	0.6	0.3	0	0	NS	PQ Bus
	5	0.5	0.2	0	0	NS	PQ Bus

in Fig.1

The input data for five bus system has been shown in Table (1) and Table (2).

Table (1):

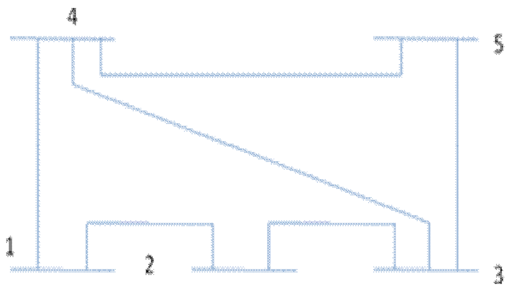


Fig.1

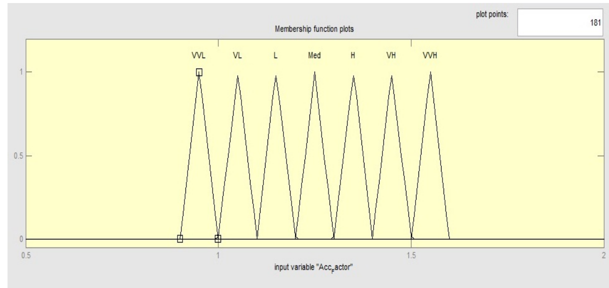


Fig.2 Membership Functions for Acceleration Factor

Table (2): Y_{BUS} Matrix

Y_{bus}	1	2	3	4	5
1	0.99 – j9.9	- 0.495 + j4.950	0	- 0.495 + j4.950	0
2	- 0.495 + j4.950	0.99 – j9.9	- 0.495 + j4.950	0	0
3	0	- 0.495 + j4.950	1.485 – j14.85	- 0.495 + j4.950	- 0.495 + j4.950
4	- 0.495 + j4.950	0	- 0.495 + j4.950	1.485 – j14.85	- 0.495 + j4.950
5	0	0	- 0.495 + j4.950	- 0.495 + j4.950	0.99 – j9.9

Comparison of Number of Iterations for different Acceleration Factors

Table (3): Final Result

S.N	Acceleration Factor	Number of Iterations	Result
1	1	14	More
2	1.1	13	Less
3	1.2	12	Less
4	1.3	10	Less
5	1.4	10	Less
6	1.5	11	More
7	1.6	14	More

III Fuzzy Model of the Load Flow Problem:

Here instead of using an arbitrary acceleration factor for the iteration, we will be using variable acceleration factor. Depending on the Acceleration Factor, Number of Iterations can be decided by using Fuzzy Logic. A membership functions for Acceleration factor has been shown in Fig.2 and the membership function for Number of Iterations is shown in Fig.3. And the fuzzy rules are shown in Table

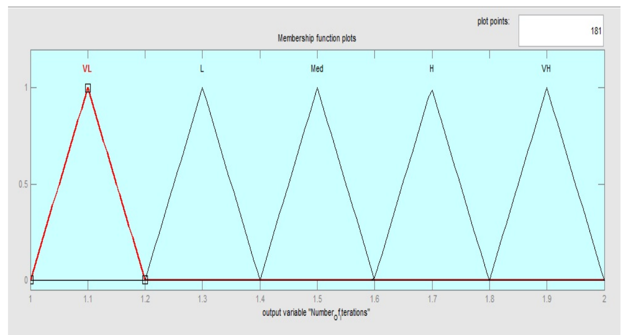


Fig.3 Membership Functions for Number of Iterations

Table (4): Fuzzy Rules

1. If (Acc_Factor is VVL) then (Number_Of_Iterations is VH) (1)
2. If (Acc_Factor is VL) then (Number_Of_Iterations is H) (1)
3. If (Acc_Factor is Med) then (Number_Of_Iterations is VL) (1)
4. If (Acc_Factor is H) then (Number_Of_Iterations is VL) (1)
5. If (Acc_Factor is VH) then (Number_Of_Iterations is L) (1)
6. If (Acc_Factor is VVH) then (Number_Of_Iterations is VH) (1)
7. If (Acc_Factor is L) then (Number_Of_Iterations is Med) (1)

Using the fuzzy rules of Table (4), Number of Iterations can be calculated using Acceleration Factor. Note that in this method the range of α has been taken from 1 to 1.9. This proposed method when applied to the five bus systems of Fig.1, the number of iteration required was nearly the Optimum. This has been summarized in the Table (3). More over this new method did not affect the final answer at all.

IV. CASE STUDY

Effect of acceleration factor on number of iteration for the five bus system using conditional method discussed earlier is as shown in the Table (1).
For Table (1) we can conclude that if the selection of acceleration factor for Gauss-Seidel method is correct then it can bring convergence in very little iteration.
By making its Fuzzy Logic Modal, Number of Iterations can be calculated based on the Acceleration Factor.
From the result of Table (3), we can conclude the method suggested gives optimum iteration and hence

the method suggested can give the result of the load flow study in minimum number of iteration.

V. CONCLUSION AND FUTURE SCENARIO

This paper begins with the discussion about the importance of Load Flow Analysis; particularly its role in Power System. From Table (3) we can conclude that if the selection of acceleration factor for Gauss-Seidel method is correct then it can bring convergence in very little iteration. We can conclude the method suggested gives optimum iteration and hence the method suggested can give the result of the load flow study in minimum number of iteration.

ACKNOWLEDGMENT

The authors wish to extend their appreciation to their Professors of Baba Banda Singh Bahadur Engineering College at Fatehgarh Sahib for permission to use these reviews in this paper.

REFERENCES

[1] Tinney W. G., and Hart C. E., "*Power flow solutions by Newton's method*," IEEE Trans. Power Apparatus Syst., Vol. 86, pp. 1449–1457, 1967.

[2] Stott B., and Alsac O., "Fast *decoupled load flow*," IEEE Trans. Power Apparatus Syst., Vol. 93, No. 3, pp. 859–869, 1974.

[3] D. P. Kothari, I.J.Nagrath, "*Power System Engineering* ", Tata McGraw Hill publication 2008

[4] Hadi Sadat, "*Power System Analysis*", Tata McGraw Hill publication

[5] Allen J. Wood and B.F. Wollenberg, "*Power Generation, Operation and Control*", John Wiley and Sons

[6] *Power System Engineering,* 20th Edition, I. J Nagrath & D. P Kothari, 2006

[7] Hadi Saddat, *Power System Analysis.* New york, New york: the mcgraw hill companies.

[8] BASSO,A., MINUSSI,C., and PADILHA, D.: '*Fast forward/fast backward substitution on vector computers*', IEEE Trans., 1999, PWS−14,(4),pp.1369−1373.

[9] GILBERT, G.M., BOUCHARD, D.E., and CHIGHANI, A.Y.: '*A comparison of load flow analysys using distflow,* Gauss−Seidel and optimal load flow algorithms.' IEEE Trans. 1998. pp. 850−853.

[10] *FLEXChip Signal Processor (MC68175/D)*, Motorola, 1996.