Load Flow Analysis by Gauss-Seidel Method

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Abstract- Optimum Power Flow (OPF) studies to minimize either the power distribution losses and the cost of power drawn from the substation, without affecting on the voltage regulation. This paper discusses the concept of the continuation Gauss-Seidel method to be used with load flow analysis control for stability of large power systems. This method preserves load flow equations and hence can achieve better accuracy, which is verified by the case studies of an IEEE-5 busses system.

Indexed Terms- Load Flow, Gauss-Seidel, OPF and Power System.

I. INTRODUCTION

OPF studies are considered an important for planning to construct the power system and can be reach to the operation of the power system at the stable of the entire voltages, active and reactive power. At the stability in the power system, the power generation equalized with the load values with consideration for the line losses. Furthermore, the demand power is constant value for the load, that's flow by transmission line. So, the power flow studies are very completed from load flow studies. OPF can obtain the voltage angles and magnitudes at all busses in the system at steady state operation. Also, the active and reactive power flow through each TL can be calculated [1] [2]. OPF studies can be compute the steady state condition, the over load and under load. Researchers studied many different solutions have been proposed to solve the OPF problems for examples; using advanced power converter technologies [3], using the Jaya Algorithm (JA) one from methods that's used with OPF [4] and realized OPF problem by means of Particle Swarm Optimization (PSO) algorithm with consideration Static Var Compensation (SVC) system and Static Synchronous Compensator (STATCOM) [5], a stand- alone Renewable Energy (RE) system based on Energy Storage (ES) [6], multi-objective Evolutionary Algorithm (EA) for high levels of penetration from Distributed Generations (DG) [7]. Gravitational Search Algorithm (GSA) is used to solve the OPF problem in a power system [8]. In this paper discusses the active and reactive power calculations regarding to load flow that's can be simply simulated by IEEE- 5 busses, also discusses Gauss-Seidel Method to be used with load flow studies.

II. POWER FLOW ANALYSIS

The nodal analysis equations for the power system can be used to driven the OPF basic equations [9]. Equation (1) the matrix for N -buses system.

$$\begin{bmatrix} I_1 \\ \vdots \\ I_N \end{bmatrix} = \begin{bmatrix} Y_{11} & \cdots & Y_{1N} \\ \vdots & \ddots & \vdots \\ Y_{N1} & \cdots & Y_{NN} \end{bmatrix} \begin{bmatrix} V_1 \\ \vdots \\ V_N \end{bmatrix} \quad (1)$$

Yij: Elements of the bus admittance matrix
Vi: Buses voltages
Ii: Currents value at each node
So, Equation (2) followed to node at bus i.

$$I_i = \sum_{j=1}^{n} Y_{ij} V_j \quad (2)$$

Per-unit value at Bus i for active and reactive power and current injected into the system at that bus:

$$S_i = V_i I_i^* = P_i + JQ_i \quad (3)$$

Vi : per-unit voltage at the bus
Ii*: complex conjugate of the per-unit current injected at the bus
Pi and Qi: per-unit real and reactive powers.

$$I_i^* = \frac{(P_i + jQ_i)}{V_i}$$

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

$$(P_i - jQ_i) = V_i^* \sum_{j=1}^{n} Y_{ij} V_j = \sum_{j=1}^{n} Y_{ij} V_j V_i^* \quad (4)$$

Can be simulate:

$Y_{ij} = |Y_{ij}|\angle\theta_{ij}$, and $V_i = |V_i|\angle\delta_i$

$$(P_i - jQ_i) = \sum_{j=1}^{n} |Y_{ij}||V_i||V_j|\angle(\theta_{ij} + \delta_j - \delta_i) \quad (5)$$

$$P_i = \sum_{j=1}^{n} |Y_{ij}||V_i||V_j| COS(\theta_{ij} + \delta_j - \delta_i) \quad (6)$$

$$Q_i = \sum_{j=1}^{n} |Y_{ij}||V_i||V_j| sin(\theta_{ij} + \delta_j - \delta_i) \quad (7)$$

So, 4 variables that's required to compute the power flow parameters P, Q, V.

2.1 Load Flow Data

Activepoweratbus-icanbewrittenbyPGi,also,reactive powercanbedenotedbyQGi.

P and Q consumed at the ith bus can be denoted by PLi and QLi.

So, the active power injected in bus-i is

$P_{i,inj}$ □ P_{Gi} □ P_{Li} (8)

Pi,calc.isthecalculatedpowerbytheloadflowprogram. So, the different between the actual injected and computedvalues:

$$\Delta P_i = P_{i,inj} - P_{i,calc} = P_{Gi} - P_{Li} - P_{i,calc} \quad (9)$$

Also, the different between Q injected and calculated values:

$$\Delta Q_i = Q_{i,inj} - Q_{i,calc} = Q_{Gi} - Q_{Li} - Q_{i,calc} \quad (10)$$

Load flow study is use to minimize the above two different. With noted that, active and reactive power in equation (9) and equation (10) computed from equation (6) and equation (7). However, the voltage magnitudes angles are not known a priori, an iterative procedure must be used to estimate the bus magnitude voltages and angles in order to calculate the mismatches. It is expected that different □Pi and □Qi that's reduces with each iteration and the load flow is said to have converged when the mismatches of all the buses become less than a verysmallnumber[10-13].

Figure (1) shows simplified system, which is a 3 buses load and 2 generator buses. Bus-1 defined as the slack bus while taking bus-5 as the P-V bus. Other busses are defined as P-Q buses. The data for the line charging and impedances admittances are shown in table (1). Table (2) is the results from table (1) for the Ybus matrix. The sources and internal impedances are not considered in table (2). Where, Ybus matrix for load flow studies considered with the bus voltages.

Table (3) shows the bus voltages and their angles, power generated and power consumed. Voltage and their angles in busses 2,3 and 4 are initial data used for starting the load flow program. The active and reactive power generated at bus 1, 5 and the reactive power generated at the P-V bus are unknown. Therefore, each of these quantitiesareindicatedbyadash(□).Where, theirinitial estimates are not required quantities for load flow calculations. With noted that, the slack bus simulatedin figure(1)withoutloadswhiletheP-Vbus5hasalocalload andthisisindicatedpower consumed to load in table (3).

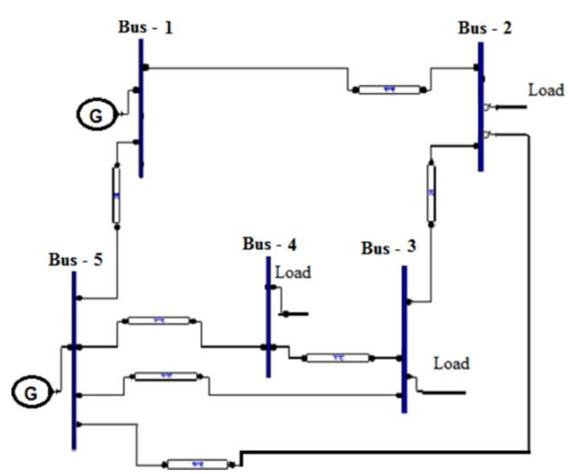

Figure 1: IEEE- 5 busses used for load flow studies

Table 1: Transmission line charging and impedance for IEEE-5 busses in figure (1)

Transmission Line	Line charging (Y/2)	Impedance
Bus -1 to Bus -5	0.02 □90□	0.25 □78.69□
Bus -1 to Bus -2	0.03 □90□	0.10 □78.69□
Bus -2 to Bus -5	0.02 □90□	0.25 □78.69□
Bus -2 to Bus -3	0.025 □90□	0.20 □78.69□
Bus -3 to Bus -5	0.01 □90□	0.41 □78.69□
Bus -3 to Bus -4	0.02 □90□	0.25 □78.69□
Bus -4 to Bus -5	0.075 □90□	0.51 □78.69□

Table 2: Ybus matrix of the system IEEE- 5 busses in figure (1)

	Bus -1	Bus -2	Bus -3	Bus -4	Bus -5
1	13.6791 □-78.649□	9.8058 □101.31□	0	0	3.92236 □101.309□
2	9.8058 □101.31□	18.5575 □-78.6448□	4.90222 □101.311□	0	3.92236 □101.309□
3	0	4.90222 □101.311□	11.2228 □-78.6352□	3.92236 □101.309□	2.45141 □101.311□
4	0	0	3.92236 □101.309□	5.7903 □-78.5061□	1.96118 □101.309□
5	3.92236 □101.309□	3.92236 □101.309□	2.45141 □101.311□	1.96118 □101.309□	12.1347 □-78.5745□

Table 3: Bus voltages and their angles, power generated and power consumed

Bus no.	Bus voltage		Power consumed to load		Power generated	
	Per-unit magnitude value - (pu)	Angle (degree)	Active P (MW)	Reactive Q (MVAr)	Active P (MW)	Reactive Q (MVAr)
Bus -1	1.05	0	0	0	□	□
Bus -2	1	0	96	62	0	0
Bus -3	1	0	35	14	0	0
Bus -4	1	0	16	8	0	0
Bus -5	1.02	0	24	11	48	□

III. GAUSS-SEIDEL ANALYSES FOR LOAD FLOW

Equation (6) and equation (7) are the basic equations for power flow calculations. At the power system contain N busses, so, P - Q busses number is np and the P – V for the generator busses is ng. The voltage magnitudes and their angles for P - Q buses and P - V buses are unknown values, so, number of 2np+ng quantities to be computed. The 2np numbers are the known value of active and reactive power for the P - Q buses, the 2ng numbers of active powers and magnitudes voltage for the P - V buses and voltage magnitude and their angle for the slack bus [11-14].

At start iterative calculation, there are some assumed values for the unknown values. The process continues till errors between all the known and actual quantities reduce below a pre-specified value. At Gauss-Seidel load flow, by assuming the initial busses voltage of the ith by Vi (0), i=2, □, n. This method shows the voltage for the ith bus at the 0th iteration. Also, the voltage after first iteration will be denoted by Vi (1). In Gauss-Seidel method the load buses and voltage-controlled buses are treated differently. In both types of buses, it simulates by use the equations complex power that's showed in equation (5). The active and reactive power injected at any busses can expand equation (5) as:

$$P_{i,inj} - jQ_{i,inj} = V_i^* \sum_{k=1}^{n} Y_{ik} V_k = V_i^* [Y_{i1}V_1 + Y_{i2}V_2 + \cdots + Y_{ii}V_i + \cdots + Y_{in}V_n] \quad (11)$$

Equation (11) can write as:

$$V_i = \frac{1}{Y_{ii}} \left[\frac{P_{i,inj} - jQ_{i,inj}}{V_i^*} - Y_{i1}V_1 - Y_{i2}V_2 - \cdots - Y_{in}V_n \right] \quad (12)$$

The outline for this procedure can be denoted with the help of the system, that's showed in figure (1), related to data for this system that's showed in table (1), table (2) and table (3). With noted that the active and reactive powers are computed in MW and MVar. The per unit quantities for these quantities from the base of 100 MVA is chosen.

IV. UPDATING LOAD BUS VOLTAGES

The start calculations from bus-2 of load bus, the active and reactive power into this bus is known. So, equation (13) can be defined from equation (12)

V. THE NEW VALUES FOR P - V BUS VOLTAGES

The reactive power in bus – 5 is undefined, and from table (3) the active power can be specified for the P – V. [14]. So, to update the magnitude voltage in bus -5, its need to estimate the reactive power in bus – 5.

From equation (11) can be written in equation (16)

The generation power value in bus - 5 is 48 MW, the power injected by this bus is 24 MW and consequently the injected power P5, inj in this case is taken as 0.24 per unit. The voltage is calculated as V4 (1) = 1.0169 □□ 0.8894□. However, the voltage magnitude of the obtained above is not equal to the magnitude given in table (3). So, by force the magnitude voltage to be equal to that specified by equation (20).

The voltage magnitude will fix at 1.02 Pu, while retaining the phase of □ 0.8894□.

VI. CONVERGENCE OF THE ALGORITHM

From table (3) the total number of 4 active and 3 reactive powers are known. Now, its required to compute each of real and reactive power from equation (6) and equation (7), by using the magnitude voltages and their angles values obtained after each iteration. The mismatches power calculated from equation (9) and equation (10). The process is assumed to have converged when each of □P2, □P3, □P4, □P5, □Q2, □Q3 and □Q4 is below a small pre-specified value. From equation (12), the update voltage value for bus-i is written by equation (21)

Where, □ is a constant for the acceleration factor. □ value is below 2.0 for the convergence to occur [14] [15]. The updated bus voltages after the 1st iteration is shown in table (4). Where, the number of iterations required for the algorithm to converge for different values of □. That's shows the algorithm converges in the least number of iterations at □ value is 1.4 to maximum number at □ value is 2. With noted, the algorithm will start to diverge at larger values of acceleration factor are chosen.

Table 4: The updated bus voltages after the 1st by Gauss-Seidel method

□	Bus voltages After 1st iteration (per unit)				Iterations for convergence
	Bus -1 (V)	Bus -3 (V)	Bus -4 (V)	Bus -5 (V)	
1	0.9927□ □ 2.6□	0.9883 □□ 2.83□	0.9968□ □ 3.48□	1.02 □□ 0.89□	28
2	0.9874□ □ 5.22□	0.9766 □□ 8.04□	0.9918□ □ 14.02□	1.02□ □ 4.39□	860
1.8	0.9883□ □ 4.7□	0.9785 □□ 6.8□	0.9903□ □ 11.12□	1.02□ □ 3.52□	54
1.6	0.9893□ □ 4.17□	0.9807 □□ 5.67□	0.9909□ □ 8.65□	1.02□ □ 2.74□	24
1.4	0.9903□ □ 3.64□	0.9831 □□ 4.62□	0.9926□ □ 6.57□	1.02□ □ 2.05□	14
1.2	0.9915□ □ 3.11□	0.9857 □□ 3.68□	0.9947□ □ 4.87□	1.02□ □ 1.43□	19

CONCLUSION

The proposed of load flow study by different techniques to updates the conventional generation and to reach the optimum stability operation system for the new plants. Gauss-Seidel method can provide control of voltage magnitude and their angle. Therefore, it can be utilized to effectively increase power transfer capability of the existing power in transmission lines, reduce operational and investment costs. Gauss-Seidel method is clear that discussed in this paper to reduce the power losses by improving the voltage values in the system. Also, this paper shows the updated voltage value by use the simple system for IEEE – 5 busses system by fix the voltage magnitude at Bus – 5 and after 1st iteration we noted the voltage become 0.9947 at bus -4 and so on in all busses.

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