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Experiment # 03

Implementation of Guass-Siedel method for Multivariable System

Objectives:

- This manual describes how to solve power –flow (load flow) problems using Guass-Siedel iterative techniques.
- Student will model a power system in PWS and perform load flow analysis by using Guass-Siedel iterative method for Multivariable System.

Introduction:

Load flow analysis is the study conducted to determine the steady state operating condition of the given power system under given conditions. Many numerical algorithms have been developed and Gauss Seidel method is one of such algorithms. The Gauss–Seidel method is also a point-wise iteration method and bears a strong resemblance to the Jacobi method, but with one notable exception. In the Gauss–Seidel method, instead of always using previous iteration values for all terms of the right-hand side, whenever an updated value becomes available, it is immediately used. The non-linear load flow equation is given by:

$$\boxed{V_p^{k+1} = \frac{1}{Y_{pp}}\left[\frac{P_p - j\,Q_p}{(V_p^{k})^*} - \sum_{q=1}^{p-1} Y_{pq} V_q^{k+1} - \sum_{q=p+1}^{n} V_q^{k}\right]}$$

The reactive power of bus-p is given by:

$$\boxed{Q_p^{k+1} = (-1) \times \mathrm{Im}\left[(V_p^{k})^* \left[\sum_{q=1}^{p-1} Y_{pq} V_q^{k+1} + \sum_{q=p}^{n} Y_{pq} V_q^{k}\right]\right]}$$

Task #01:

Use Guass-Siedel method to find the solution of following equations

$$X_1+X_1X_2=10$$

$$X_1+X_2=6$$

Perform five iterations with following initial estimates

a) $X_1^0=1$ and b) $X_2^0=2$

Hand Calculation:

$$X_1+X_1X_2=10 \text{ ------ (I)}$$

$X_1 = \frac{10}{1+X2}$ -------(a)

$$X_1+X_2=6 \text{----------- (II)}$$

$X_2 = 6-X_1$------------(b)

By using Initial estimate in equation (a) and (b)

1st iteration:

$$X_1 = \frac{10}{1+2} = \frac{10}{3} = 3.33$$

$$X_2 = 6-3.33 = 2.67$$

2nd iteration:

$$X_1 = \frac{10}{1+2.67} = \frac{10}{3.67} = 2.72$$

$$X_2 = 6-2.72 = 3.27$$

3rd iteration:

$$X_1 = \frac{10}{1+3.27} = \frac{10}{4.27} = 2.34$$

$$X_2 = 6-2.34 = 3.65$$

4th iteration:

$$X_1 = \frac{10}{1+3.65} = \frac{10}{4.65} = 2.15$$

$$X_2 = 6-2.15 = 3.84$$

5th iteration:

$$X_1 = \frac{10}{1+3.84} = \frac{10}{4.84} = 2.066$$

$$X_2 = 6-2.066 = 3.933$$

Task #02:

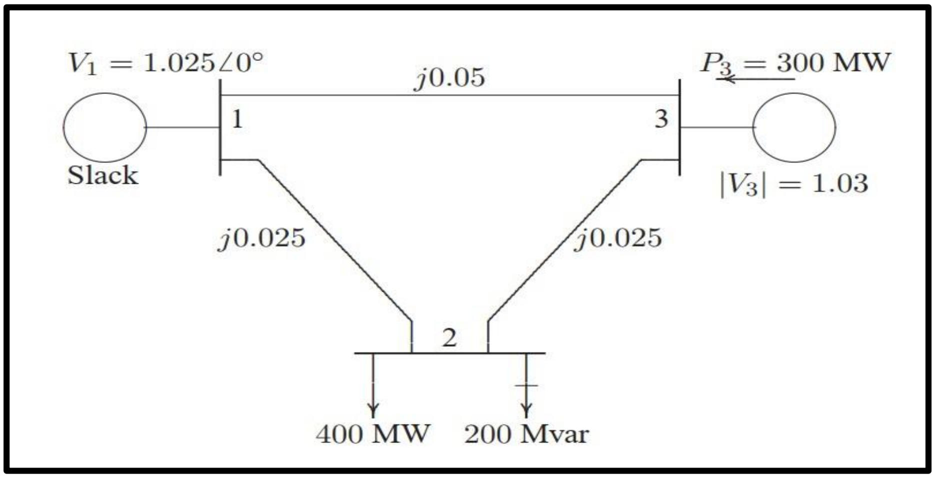

Figure 1: Power System to Analyze

The figure shown above is the one-line diagram of a simple three-bus power system with generation at buses 1 and 3.the voltages at bus 1 is V1=1.025 ∠0 ° pu. Voltages magnitude at bus 3 is fixed at 1.03pu with a real power generation of 300MW.A load consisting of 400MW and 200MVar is taken from bus 2. Line impedances are marked in per unit on a 100-MVA base.

- Using Gauss Seidel method and initial estimate of $V2^{(0)}$ =1+0j and $V3^{(0)}$ =1.03+0j and keeping |V3|=1.03 pu, determine the phasor values of V2 and V3. Perform three iterations. (Hand Calculation)
- Also simulate the above circuit in power World Simulator and match your hand calculations with the result obtained from PWS.

Using PWS

- Draw the one-line diagram in PWS.
- In the Run Mode, go to Tools ⟶Solve ⟶Gauss Seidel Power Flow. This will give you the result of the bus voltages after performing all iterations.
- To check your results iteration, go to Tools ⟶Simulator Option ⟶Common Option ⟶ Check 'Do Only for One Iteration'. Now repeat the above step to get results for each iteration.
- While doing single iteration you will hear warning sound until the solution converges
- The detailed result of each iteration can be viewed through log in the Tools selection.

Theoretical Calculation:

$$\boldsymbol{Y\ bus} = \begin{bmatrix} Y11 & -Y12 & -Y13 \\ -Y21 & Y22 & -Y23 \\ -Y31 & -Y32 & Y33 \end{bmatrix}$$

R= 0Ω

X = j0.05 (from bus 1 to bus 3)

X = j0.025 (from bus 1 to bus 2 and bus 2 to bus 3)

$$Y = \frac{1}{R+jX}$$

$\mathbf{Y_{12}}$ = -Y_{21} = $\frac{1}{j0.025}$ = -40j

$\mathbf{Y_{13}}$ = -Y_{31} = $\frac{1}{j0.05}$ = -20j

$\mathbf{Y_{23}}$ = -Y_{32} = $\frac{1}{j0.025}$ = -40j

$\mathbf{Y_{11}}$ = Y_{12} + Y_{13}= -40j – 20j = -60j

$\mathbf{Y_{22}}$ = Y_{21} + Y_{23}= -40j – 40j = -80j

$\mathbf{Y_{33}}$ = Y_{31} + Y_{32}= -20j – 40j = -60j

By putting all values in above Ybus matrix

$$\boldsymbol{Y\ bus} = \begin{bmatrix} -60j & 40j & 20j \\ 40\mathrm{j} & -80j & 40j \\ 20j & 40j & -60j \end{bmatrix}$$

Given that

$$V_1 = 1.025\angle 0^\circ \text{ pu}$$

$$V_2^{(0)} = 1 + 0j$$

$$V_3^{(0)} = 1.03 + 0j$$

$$|V_3| = 1.03 \text{ pu}$$

$$P_3^{sch} = \frac{400 - 0}{100} = 4 \text{ pu}$$

$$S_2^{ch} = \frac{-(400 + j200)}{100} = (-4 - 2j) \text{ pu}$$

By using gauss siedel method

$$V_i = \frac{\frac{P_i - jQ_i}{Y_{ii}}}{V_i^*} - \sum_{\substack{p=1 \\ p\neq i}}^{n} \frac{Y_{ip}}{Y_{ii}} \cdot V_p$$

1st Iteration

$$V_2^{(1)} = \frac{\frac{-4 + j2}{-80j}}{1} - \sum_{p=1}^{3} \frac{Y_{ip}}{Y_{ii}} V_p$$

$$V_2^{(1)} = \frac{-4 + j2 + (-40j)(1.025) + (-40j)(1.03)}{(-80j)}$$

$$V_2^{(1)} = 1.0025 - 0.05j$$

or

$$\boxed{V_2^{(1)} = 1.003746 \angle -2.855^0}$$

$$Q_3^{sch} = V_3^{(0)} \left[V_3^{(0)} (y_{13} + y_{23}) - y_{13} V_1 - y_{23} V_2^{(1)} \right]$$

$$Q_3^{sch} = (1.03) \left[(1.03)(-60j) - (-20j)(1.025) - (-40j)(1.0025 - 0.05j) \right]$$

$$\boxed{Q_3^{sch} = 1.23}$$

Now, Using Gauss siedel formula

$$V_3^{(1)} = \frac{\frac{P_3^{sch} - Q_3^{sch}}{V_3^{(0)}} + y_{13} V_1 + y_{23} V_2^{(1)}}{y_{33}}$$

$$V_3^{(1)} = \frac{\frac{4 - 1.23j}{1.03} + (-20j)(1.025) + (-40j)(1.0025 - 0.05j)}{(-60j)}$$

$$V_3^{(1)} = 1.0299 - 0.031j$$

or

$$\boxed{V_3^{(1)} = 1.03 \angle 1.72^0}$$

2nd Iteration:

$$V_2^{(2)} = \frac{\frac{P_2 - jQ_2}{V_2^{(1)}} + y_{12}V_1 + y_{23}V_3^{(1)}}{y_{12} + y_{23}}$$

Putting values

$$V_2^{(2)} = \frac{\frac{-4+j2}{1.0025-0.05j} + (40j)(1.025) + (40j)(1.0299-0.031j)}{-(40j+40j)}$$

$$V_2^{(2)} = 1.005 - 0.0354j$$

or

$$\boxed{V_2^{(2)} = 1.005\angle{-2.02^\circ}}$$

Similarly

$$V_3^{(2)} = \frac{\frac{P_3 - jQ_3}{V_3^{(1)}} + y_{13}V_1 + y_{23}V_2^{(2)}}{y_{12} + y_{23}}$$

$$V_3^{(2)} = \frac{\frac{4-1.23j}{1.0299-0.031j} + (20j)(1.025) + (40j)(1.005\angle{-2.02^\circ})}{-(40j+40j)}$$

$$V_3^{(2)} = 1.03 + 0.08j$$

$$\boxed{V_3^{(2)} = 1.03\angle 4.48^\circ}$$

3rd Iteration:-

$$V_2^{(3)} = \frac{\frac{P_2 - jQ_2}{V_2^{(2)}} + y_{12}V_1 + y_{23}V_3^{(2)}}{-(y_{12} + y_{23})}$$

$$V_2^{(3)} = \frac{\frac{-4+j2}{1.005 - 0.03554j} + (40j)(1.025) + (40j)(1.03 + j0.08)}{-(40j + 40j)}$$

$$V_2^{(3)} = 1.004 - 0.0105j$$

$$\boxed{V_2^{(3)} = 1.004 \angle -0.602^\circ}$$

$$V_3^{(3)} = \frac{\frac{P_3 - jQ_3}{V_3^{(2)}} + y_{13}V_1 + y_{23}V_2^{(3)}}{y_{33}}$$

$$V_3^{(3)} = \frac{\frac{4 - 1.23j}{1.03 + j0.08} + (20j)(1.025) + (40j)(1.004 - 0.0105j)}{(0 - 80j)}$$

$$V_3^{(3)} = 1.03 + 0.055j$$

$$\boxed{V_3^{(3)} = 1.03 \angle 3.08^\circ}$$

Software Simulation:

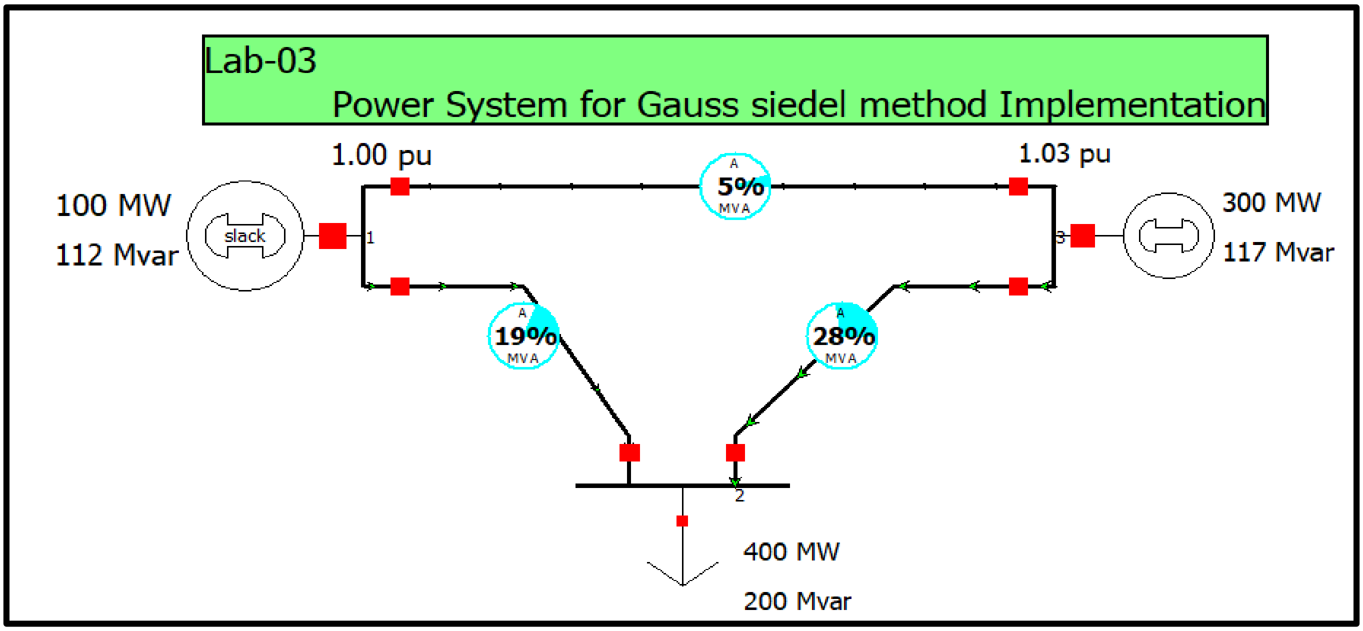

Figure 2: show the power system network simulation using gauss seidel method

Y-bus of given network:

	Number	Name	Bus 1	Bus 2	Bus 3
1	1	1	0.00 - j60.00	-0.00 + j40.00	-0.00 + j20.00
2	2	2	-0.00 + j40.00	0.00 - j80.00	-0.00 + j40.00
3	3	3	-0.00 + j20.00	-0.00 + j40.00	0.00 - j60.00

Figure 2: Ybus Matrix

System Information:

	Number	Name	Area Name	Nom kV	PU Volt	Volt (kV)	Angle (Deg)	Load MW	Load Mvar	Gen MW	Gen Mvar
1	1	1	1	138.00	1.00000	138.000	0.00			100.10	111.96
2	2	2	1	138.00	0.97290	134.260	-2.22	400.00	200.00		
3	3	3	1	138.00	1.00000	138.000	1.45			300.00	117.03

Figure 3: Output Data of given power system network

Conclusion:

By using this iterative method**:**

- ✓ We learned to implement the Guass-Siedel Method in load flow Analysis.
- ✓ We learned to find the unknown values of voltage and Angle of load bus.
- ✓ We learned to find the unknown values of Reactive power and Angle of voltage for Generator bus.