Bangladesh University of Engineering and Technology

Department of Electrical and Electronic Engineering

Project Report

Load Flow Analysis of a 9 Bus System Using Newton Raphson Method

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Project Title: Load Flow Analysis by Newton-Raphson Method

Abstract:

In this project, we intended to apply the classical and streamlined Newton-Raphson method to solve load flow problem using MATLAB and PSAF and compare the models.

In PSAF, the generic Newton-Raphson formula is used to calculate the load flow. The software requires some time to produce the output report if we try to replicate the bus using a lot of bus data. On the other hand, the output won't take too long to be calculated if we construct the system using a simpler version of Newton-Raphson. Therefore, we can simply implement this system on PCs with modest configuration.

One of the most potent algorithms, the standard NR power flow technique has a lengthy history of research and is frequently used to create commercial power flow solution software. Despite the fact that the conventional NR power flow approach is incredibly effective and frequently utilized for the power flow calculation, complex formulas and lengthy expressions are needed for Jacobian updating matrix equations. The key distinction between Newton-Raphson (NR) and SNR (simplified Newton-Raphson) is that the proposed technique looks for roots of current mismatch equations rather than power mismatch equations. With this method, a highly intricate and lengthy mathematical formula can be reduced to a very short and simple mathematical phrase. It is anticipated that the overall execution time would decrease with this simplification.

Newton-Raphson Method:

Algorithm:

The voltage and angle (|v| and δ) at slack bus are fixed, assume |v| and δ at all PQ buses and δ at PV buses. (Generally flat voltage start is assumed, i.e. |v| = 1.0 and δ = 0)

↓

Compute ΔPi (for PV and PQ buses) and ΔQi (for all PQ buses).If all the values are less than prescribed tolerance, stop the iterations, calculate slack bus powers (P1 and Q1) and print the entire power flow solution including line flows

↓

Examine the elements of the Jacobian matrix if the convergence requirement is not met.

↓

Solve for corrections of voltage angles and magnitudes.

↓

Update voltage angles and magnitudes by adding the corresponding changes to the previous values and return to step 2.

Two Special Cases:

- *PV Bus Changes to PQ Bus:* In second step, if $Q<Q_{min}$ or $Q>Q_{max}$, i.e., reactive power limit is violated, PV bus is changed to PQ bus during that iteration & $Q_{new} = Q_{max}$ or $Q_{new} = Q_{min}$ based on the violation.

- *PQ Bus Changes to PV Bus:* In final step, if $|V|<|V|_{min}$ or $|V|>|V|_{max}$, i.e., voltage limit is violated, PQ bus is changed to PV bus during that iteration & $|V|_{new} = |V|_{max}$ or $|V|_{new} = |V|_{min}$ based on the violation.

Related Formulas:

$$S_i = P_i + jQ_i = V_i \sum_{k=1}^{n} V_{ik} V_k \text{ ....(1)}$$

$$S_i = \sum_{k=1}^{n} (V_i\, V_k\, Y_{ik}) \underline{/(\delta_i} - \delta_k - \theta_{ik}) \dots \dots (2)$$

$$P_i = \sum_{k=1}^{n} (V_i\, V_k\, Y_{ik}) \cos(\delta_i - \delta_k - \theta_{ik}) \dots \dots (3)$$

$$Q_i = \sum_{k=1}^{n} (V_i\, V_k\, Y_{ik}) \sin(\delta_i - \delta_k - \theta_{ik}) \dots \dots (4)$$

Equation (3) and (4) can also be written as,

$$P_i = V_i V_i Y_{ii} \cos\theta_{ii} + \sum_{\substack{k=1 \\ k \neq 1}}^{n} (V_i\, V_k\, Y_{ik}) \cos(\delta_i - \delta_k - \theta_{ik}) \dots \dots (5)$$

$$Q_i = -V_i V_i Y_{ii} \cos\theta_{ii} + \sum_{\substack{k=1 \\ k \neq 1}}^{n} (V_i\, V_k\, Y_{ik}) \sin(\delta_i - \delta_k - \theta_{ik}) \dots \dots (6)$$

Using the two above mentioned formulas, $P_{i,calc}$ & $Q_{i,calc}$ is determined. Then, power mistmatch ΔP_i & ΔQ_i is calculated by using this formula:

$$\Delta P_i = P_{sch,i} - P_{i,calc}$$

$$\Delta Q_i = Q_{sch,i} - Q_{i,calc}$$

$$P_{sch,i} = P_{gi} - P_{di}$$

$$Q_{sch,i} = Q_{gi} - Q_{di}$$

P_{gi} = Scheduled real power being generated at bus i

P_{di} = Scheduled real power demand by load at bus i

Q_{gi} = Scheduled reactive power being generated at bus i

Q_{di} = Scheduled reactive power demand by load at bus i

Formulas related to determine the values of state variables:

$$\delta_i^{(k+1)} = \delta_i^{(k)} + \Delta\delta_i^{(k)}$$

$$|V_i|^{(k+1)} = |V_i|^{(k)} + \Delta|V_i|^{(k)} = |V_i|^{(k)}\left(1 + \frac{\Delta|V_i|^{(k)}}{|V_i|^{(k)}}\right)$$

In case of equation (3) & equation (4), when the variable k equals the particular value j, only one of the cosine terms in the summation of the above equation contains δ_j. So we obtain the typical off-diagonal ($i \neq j$) elements,

$$\frac{\partial Pi}{\partial \delta j} = - |V_i V_j Y_{ij}| \sin(\theta_{ii} + \delta_j - \delta_i)$$

$$\frac{\partial Qi}{\partial \delta j} = - |V_i V_j Y_{ij}| \cos(\theta_{ii} + \delta_j - \delta_i)$$

Every term in summation of equation (3) and equation (4) contains δ_i. So the typical diagonal element ($i = j$),

$$\frac{\partial Pi}{\partial \delta i} = \sum_{\substack{n=1 \\ n\neq i}}^{N} |V_i V_n Y_{in}| \,\mathrm{Sin}(\theta_{in} + \delta_n - \delta_i)$$

$$= \sum_{\substack{n=1 \\ n\neq i}}^{N} \frac{\partial Pi}{\partial \delta n}$$

$$\frac{\partial Qi}{\partial \delta i} = \sum_{\substack{n=1 \\ n\neq i}}^{N} |V_i V_n Y_{in}| \cos(\theta_{in} + \delta_n - \delta_i)$$

$$= - \sum_{\substack{n=1 \\ n\neq i}}^{N} \frac{\partial Qi}{\partial \delta n}$$

The off-diagonal elements of sub-matrix J12 are easily found by first finding the expression for derivative $\frac{\partial \mathrm{Pi}}{\partial |\mathrm{Vj}|}$ and then multiplying bt |Vj| as

$$|V_j|\frac{\partial Pi}{\partial |Vj|} = |V_j|\,|V_i Y_{ij}| \cos(\theta_{ii} + \delta_j - \delta_i)$$

The diagonal elements of sub-matrix J12 are

$$|V_i|\frac{\partial Pi}{\partial |Vi|} = |V_i|\left[2|V_i|G_{ii} + \sum_{\substack{n=1 \\ n\neq i}}^{N} |V_n Y_{in}| \cos(\theta_{in} + \delta_n - \delta_i)\right]$$

The off-diagonal elements of sub-matrix J12 are

$$|V_i|\frac{\partial Qi}{\partial |Vi|} = -\frac{\partial Pi}{\partial \delta i} - 2|V_i|^2 B_{ii} = Q_i - |V_i|^2 B_{ii}$$

The above results can be written in the following manner:

Off-diagonal elements (i ≠ j)	Diagonal elements (i=j)
$M_{ij} \triangleq \frac{\partial Pi}{\partial \delta j} = |V_j|\frac{\partial Qi}{\partial |Vj|}$	$M_{ii} \triangleq \frac{\partial Pi}{\partial \delta i} = |V_i|\frac{\partial Qi}{\partial |Vi|} = -M_{ii} - 2|V_i|^2 B_{ii}$
$N_{ij} \triangleq \frac{\partial Qi}{\partial \delta j} = -|V_j|\frac{\partial Pi}{\partial |Vj|}$	$N_{ii} \triangleq \frac{\partial Qi}{\partial \delta i} = -|V_i|\frac{\partial Pi}{\partial |Vi|} == -N_{ii} - 2|V_i|^2 G_{ii}$

The matrix equation for the system:

$$\left[\begin{array}{ccc|ccc}
M_{22} & M_{23} & M_{24} & N_{22} + 2|V_2|^2 G_{22} & -N_{23} & -N_{24} \\
M_{32} & M_{33} & M_{34} & -N_{32} & N_{33} + 2|V_3|^2 G_{33} & -N_{34} \\
M_{42} & M_{43} & M_{44} & -N_{42} & -N_{43} & N_{44} + 2|V_4|^2 G_{44} \\
\hline
N_{22} & N_{23} & N_{24} & -M_{22} - 2|V_2|^2 B_{22} & M_{23} & M_{24} \\
N_{32} & N_{33} & N_{34} & M_{32} & -M_{33} - 2|V_3|^2 B_{33} & M_{34} \\
N_{42} & N_{43} & N_{44} & M_{42} & M_{43} & -M_{44} - 2|V_4|^2 B_{44}
\end{array}\right]$$

$$\times \left[\begin{array}{c}
\Delta\delta_2 \\ \Delta\delta_3 \\ \Delta\delta_4 \\ \hline \Delta|V_2| / |V_2| \\ \Delta|V_3| / |V_3| \\ \Delta|V_4| / |V_4|
\end{array}\right] = \left[\begin{array}{c}
\Delta P_2 \\ \Delta P_3 \\ \Delta P_4 \\ \hline \Delta Q_2 \\ \Delta Q_3 \\ \Delta Q_4
\end{array}\right]$$

Voltage Controlled Bus:

Voltage-controlled buses are simply considered in the polar form of power-flow equations.

If bus (n) is voltage-controlled, then Vn has a specified constant value, i.e., ΔVn/Vn = 0 is always true

As a result, the Jacobian's (n-1)th column is always multiplied by 0, and it may be eliminated.

We must also exclude the (n-1)th row of the Jacobian matrix since the mismatch Qn cannot be determined because Qn is not provided. Naturally, Qn can be determined after the power-flow solution is provided.

Simplified Newton-Raphson power flow method:

Given that there are n buses in a power system, bus 1 is designated as a slack bus with constant voltage magnitude and zero phase angle. The following is how the current balancing equations for the kth bus may be described:

$$(I_{gen,k} - I_{dem,k}) - \sum_{i=1}^{n} Y_{ki} V_i = 0$$

$I_{gen,k}$ = generator current at bus k

$I_{dem,k}$ = load current at bus k

V_k = phasor voltage at bus k

Y_{ki} = the kth-row and ith-column element of the system bus admittance matrix.

In practice, loads in electrical power systems are in form of powers, therefore it is convenient to rewrite the above mentioned equation into a function of powers as follows:

$$F_k = \left(\frac{S_{gen,k} - S_{dem,k}}{V_k}\right)^* - \sum_{i=1}^{n} Y_{ki} V_i = 0 \tag{2}$$

Define $F_k = G_k + jH_k$ be the current mismatch at bus k,

$V_k = |V_k| \angle \delta_k$

$Y_{ki} = |Y_{ki}| \angle \theta_{ki}$ is

$S_{gen,k} - S_{dem,k} = S_{sch,k} = |S_{sch,k}| \angle \varphi_k$

Substitute the above expressions into (2), thus

$$F_k = \left|\frac{S_{sch,k}}{V_k}\right| \angle(-\varphi_k + \delta_k) - \sum_{i=1}^{n} |Y_{ki} V_i| \angle(\theta_{ki} + \delta_i) = 0 \tag{3}$$

$$G_k = \left|\frac{S_{sch,k}}{V_k}\right| \cos(-\varphi_k + \delta_k) - \sum_{i=1}^{n} |Y_{ki} V_i| \cos(\theta_{ki} + \delta_i) = 0 \tag{4}$$

$$H_k = \left|\frac{S_{sch,k}}{V_k}\right| \sin(-\varphi_k + \delta_k) - \sum_{i=1}^{n} |Y_{ki} V_i| \sin(\theta_{ki} + \delta_i) = 0 \tag{5}$$

To find a set of voltage solutions by using the NR method, equation (4) & equation (5) must be expanded by Taylor series as follows,

$$G_k = \sum_{\substack{i=1 \\ i \neq s}}^{n} \frac{\partial G_k}{\partial \delta_i} \Delta\delta_i + \sum_{\substack{i=1 \\ i \neq s}}^{n} \frac{\partial G_k}{\partial |V_i|} \Delta|V_i| \tag{6}$$

$$H_k = \sum_{\substack{i=1 \\ i \neq s}}^{n} \frac{\partial H_k}{\partial \delta_i} \Delta\delta_i + \sum_{\substack{i=1 \\ i \neq s}}^{n} \frac{\partial H_k}{\partial |V_i|} \Delta|V_i| \tag{7}$$

Here, s denotes the slack bus. With (n-1) number of unknown complex variables and (n-1) number of current mismatch equations, a compact matrix form can be expressed as follows,

$$\begin{bmatrix} G \\ H \end{bmatrix} = \begin{bmatrix} \frac{\partial G}{\partial \delta} & \frac{\partial G}{\partial |V|} \\ \frac{\partial H}{\partial \delta} & \frac{\partial H}{\partial |V|} \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} \tag{8}$$

Elements of Jacobian matrix can be derived in the similar manner.

Sub-matrix	Equation
J_1	$\frac{\partial G_k}{\partial \delta_i} = -\lvert V_i Y_{ki} \rvert \sin(\theta_{ki} + \delta_i) \quad \text{for } k \neq i$ $\frac{\partial G_k}{\partial \delta_k} = -\lvert V_k Y_{kk} \rvert \sin(\theta_{kk} + \delta_k) + \lvert \frac{S_{sch,k}}{V_k} \rvert \sin(-\varphi_k + \delta_k)$
J_2	$\frac{\partial G_k}{\partial \lvert V_i \rvert} = \lvert Y_{ki} \rvert \cos(\theta_{ki} + \delta_i) \quad \text{for } k \neq i$ $\frac{\partial G_k}{\partial \lvert V_k \rvert} = \lvert Y_{kk} \rvert \cos(\theta_{kk} + \delta_k) + \left\lvert \frac{S_{sch,k}}{V_k^2} \right\rvert \cos(-\varphi_k + \delta_k)$
J_3	$\frac{\partial H_k}{\partial \delta_i} = \lvert V_i Y_{ki} \rvert \cos(\theta_{ki} + \delta_i) \quad \text{for } k \neq i$ $\frac{\partial H_k}{\partial \delta_k} = \lvert V_k Y_{kk} \rvert \cos(\theta_{kk} + \delta_k) - \left\lvert \frac{S_{sch,k}}{V_k} \right\rvert \cos(-\varphi_k + \delta_k)$
J_4	$\frac{\partial H_k}{\partial \lvert V_i \rvert} = \lvert Y_{ki} \rvert \sin(\theta_{ki} + \delta_i) \quad \text{for } k \neq i$ $\frac{\partial H_k}{\partial \lvert V_k \rvert} = \lvert Y_{kk} \rvert \sin(\theta_{kk} + \delta_k) + \left\lvert \frac{S_{sch,k}}{V_k^2} \right\rvert \sin(-\varphi_k + \delta_k)$

In the NR method, (8) is iteratively solved for Dd & D|V|. If a specified norm of the current mismatches G and H is smaller than maximum mismatch allowance, the voltage solution is successfully obtained. Otherwise, the current voltage solution at iteration h must be updated for the next iteration h+1, as shown below:

$$\begin{bmatrix} \delta \\ \lvert V \rvert \end{bmatrix}^{h+1} = \begin{bmatrix} \delta \\ \lvert V \rvert \end{bmatrix}^{h} + \begin{bmatrix} \Delta\delta \\ \Delta \lvert V \rvert \end{bmatrix}^{h}$$

To compare the effectiveness of the proposed NR method against the standard NR method, expressions of the Jacobian matrix elements of J_1, J_2, J_3 & J_4, the calculated real and imaginary current matrix elements of G & H and the calculated real and reactive power matrix elements of P_{cal} & Q_{cal} need to be evaluated.

Single Line Diagram:

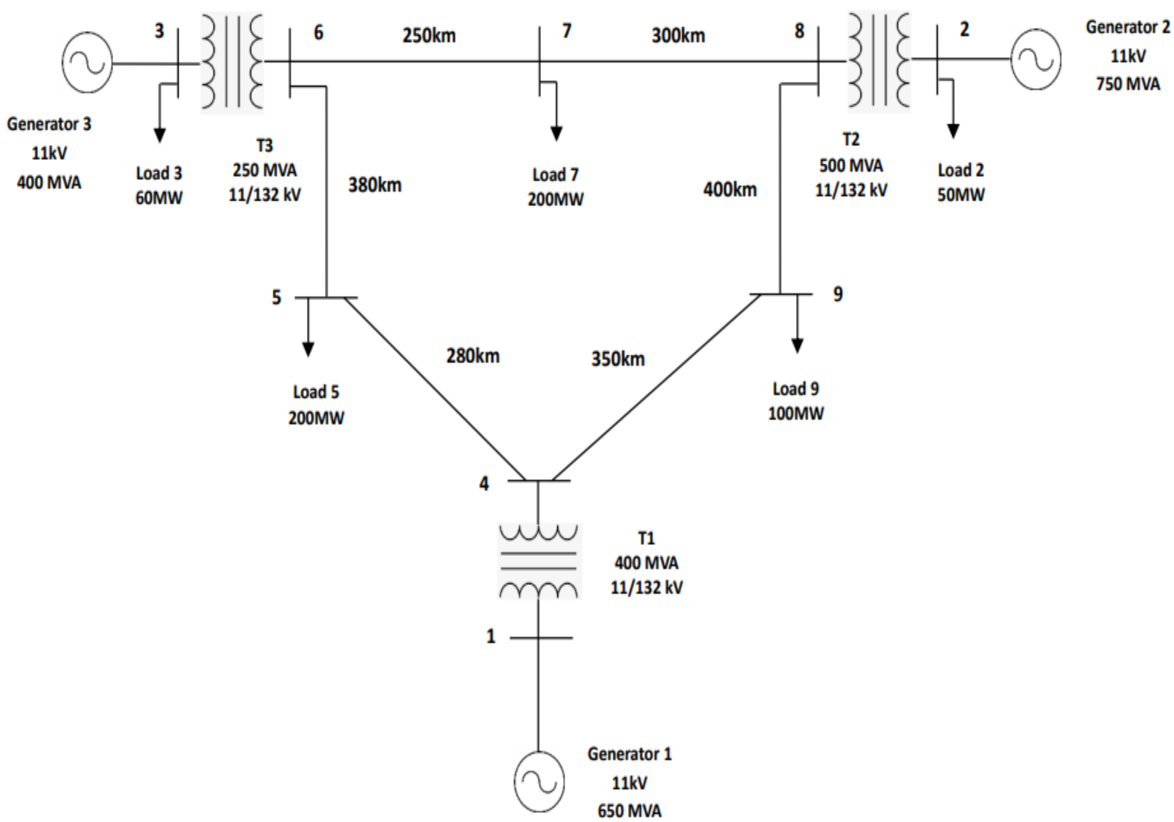


Fig. IEEE 9 Bus System

There are 3 generators, 3 transformers, 5 loads and 9 buses. Generators operate at 11 kV and the transmission lines are at 132 kV. Transformers are used to connect the generators to power grid. Bus 1,2,3 are connected to generators, hence they are considered PV buses. Bus 1 is taken as slack bus whose voltage angle is to be taken as reference during load flow analysis. Bus 4,5,6,7,8,9 are PQ buses. Lengths of all lines are greater than 250 km so we will apply long line transmission model. System base apparent power is 100 MVA.

Now, we will perform load flow analysis on this power system both using MATLAB and PSAF.

MATLAB Code:

Our MATLAB implementation consists of several functions and .m files. They are-

1. **main.m**

Executes the main command and shows the simulation result.

2. **bus_data.m**

Contains information about slack/PV/PQ bus, initial bus voltage and angle, generated real and reactive power, load real and reactive power etc. for the system that is to be analyzed. User needs to provide this data.

3. **line_data.m**

Contains information about the line connection between buses and their loading limits and length.

4. **line_parameters.m**

Contains information about resistance, reactance, susceptance for long transmission line.

5. **y_bus.m**

Builds the bus admittance matrix.

6. **newton_raphson.m**

Contains the main code for newton Raphson method.

Main function calls and executes other functions to complete the analysis.

Input Data:

(a) Bus Data

Type: 1. Slack Bus, 2. PV Bus, 3. PQ Bus

PG: Real Power Generation

QG: Reactive Power Generation (initial assumption)

PL: Real Power Load

QL: Reactive Power Load

Qmin/Qmax: Reactive power generation limit

Bus No	Type	Voltage Mag. (pu)	Voltage Angle	PG	QG	PL	QL	Qmin	Qmax
1	1	1.00	0	0	0	0	0	0	0
2	2	1.00	0	500	0	50	5	-300	400
3	2	1.00	0	200	0	60	8	-100	140
4	3	1.00	0	0	0	0	0	0	0
5	3	1.00	0	0	0	200	20	0	0
6	3	1.00	0	0	0	0	0	0	0
7	3	1.00	0	0	0	200	50	0	0
8	3	1.00	0	0	0	0	0	0	0
9	3	1.00	0	0	0	100	30	0	0

Since bus 1 is slack bus, its voltage is fixed at 1<0. And due to flat start, initial assumption of other bus voltage is also 1<0.

(b) Line data

R (pu) / km = 0.0000534034 ohm

X (pu) / km = 0.000106003 ohm

(B/2) (pu) / km = 0.0000641*0.5 ohm

Line	Length (km)
L45	280
L49	350
L56	380
L67	250
L78	300
L89	400

Output Data Analysis:

(a) Summary Report

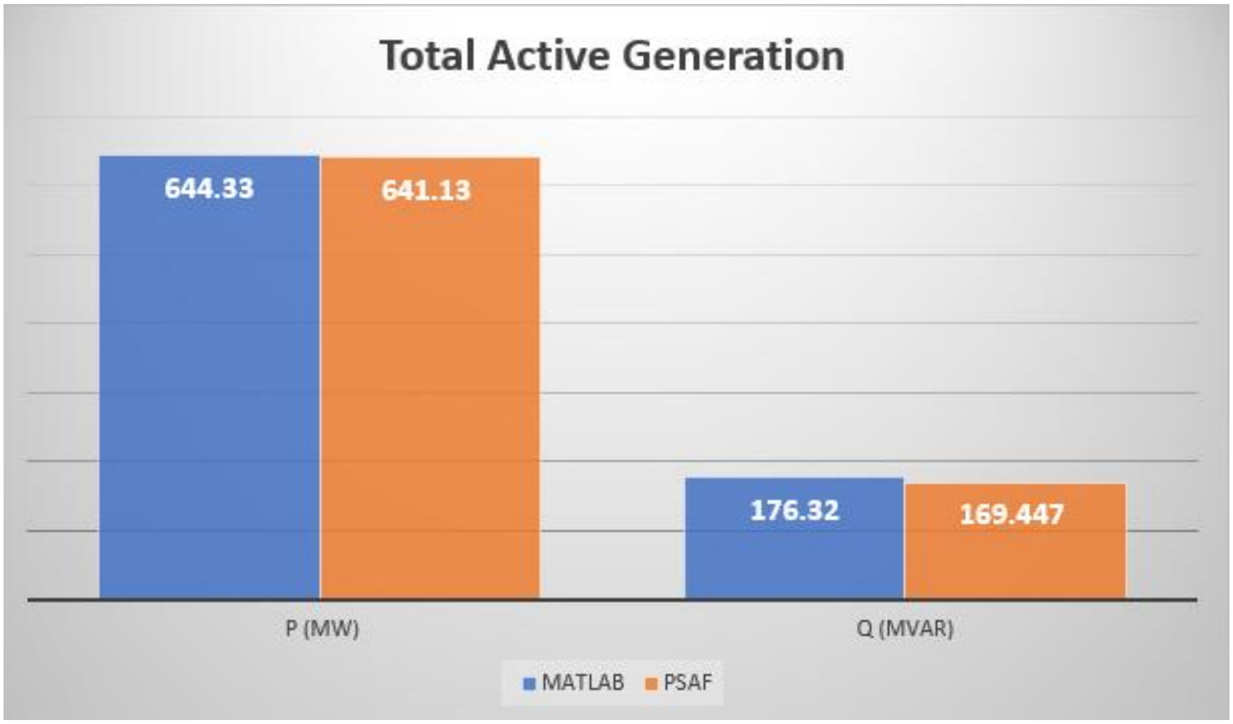
PSAF

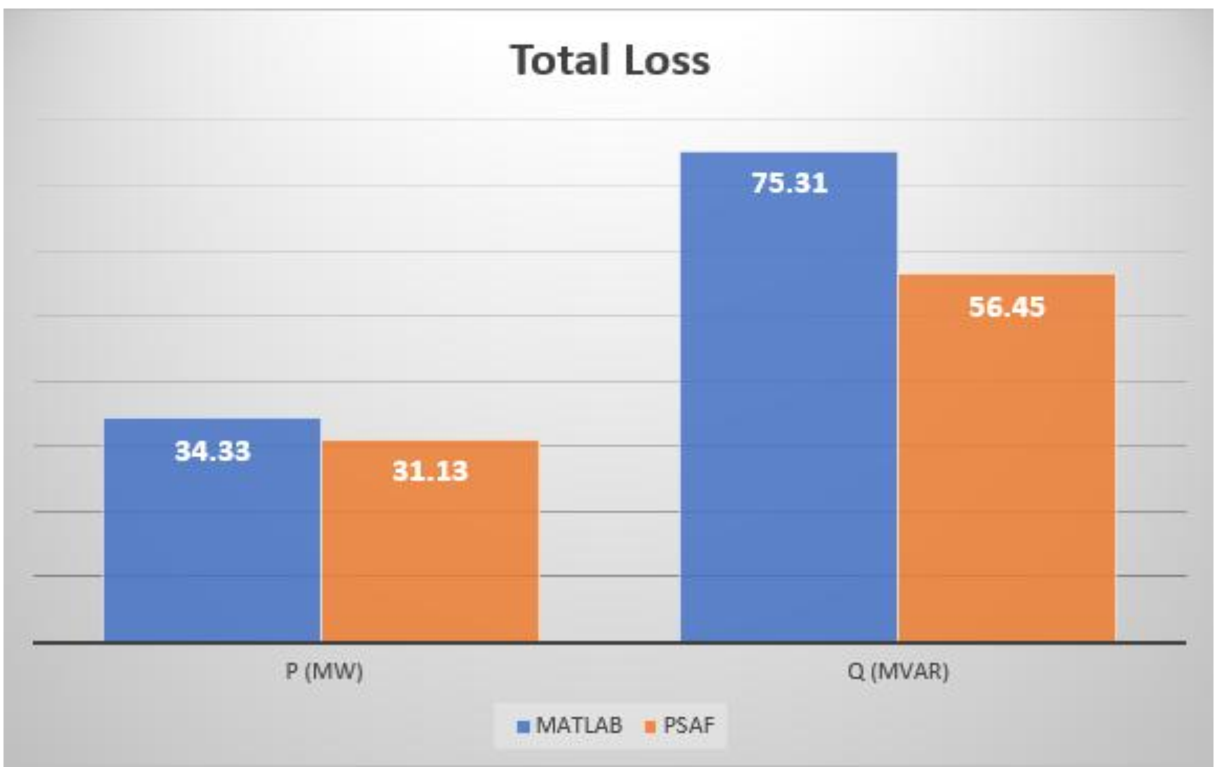
COMPLETE SUMMARY REPORT		
Summary Data	**Active Power**	**Reactive Power**
Total generation	**641.130**	**169.447**
Spinning reserve	978.870	
Static Load	610.000	113.000
Shunt loads	0.000	0.000
Motor loads	0.000	0.000
Total load	**610.000**	**113.000**
Line / cable losses	30.450	48.242
Transformer losses	0.680	8.205
Total losses	**31.130**	**56.447**
Mismatches	0.000	0.000

Total active generation is 641.13 MW and 169.447 MVAR. Since total load is 610 MW and 113 MVAR, excess of the generated power will turn out to be loss which is 31.13 MW and 56.45 MVAR.

MATLAB

Total active generation is 644.3274 MW and 176.3175 MVAR. Hence total loss is 34.3274 MW and 75.3098 MVAR.





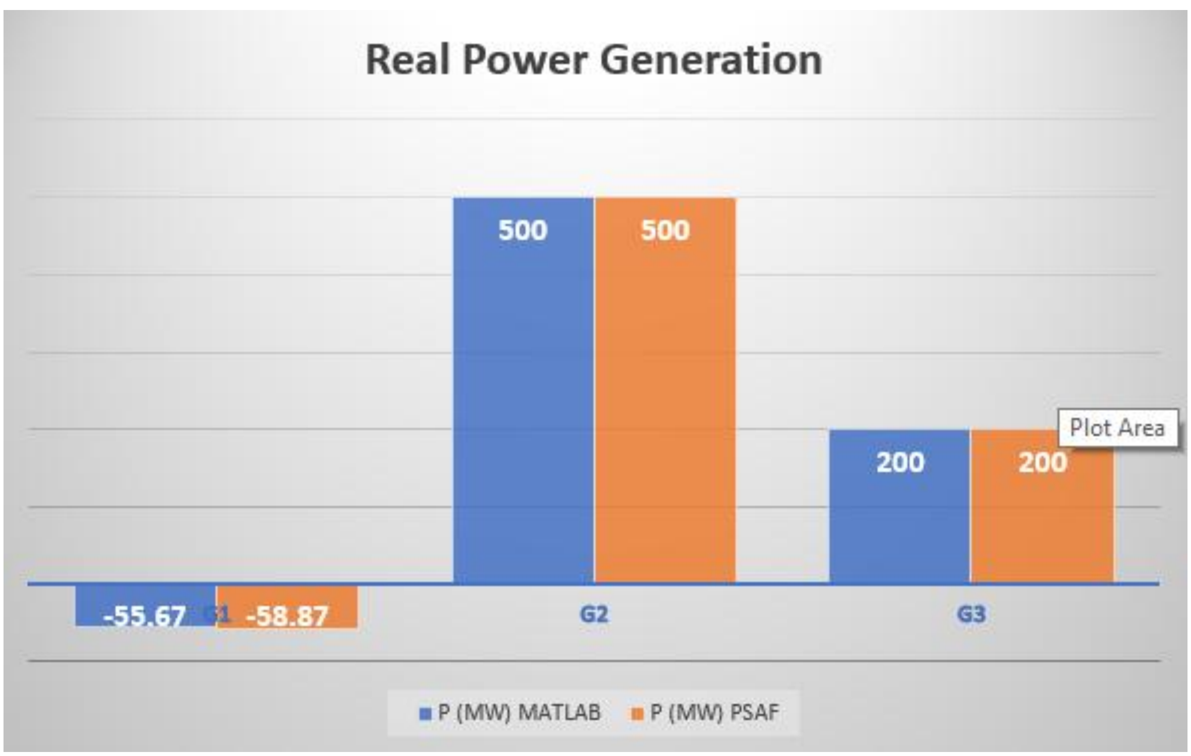
(b) Generator Report

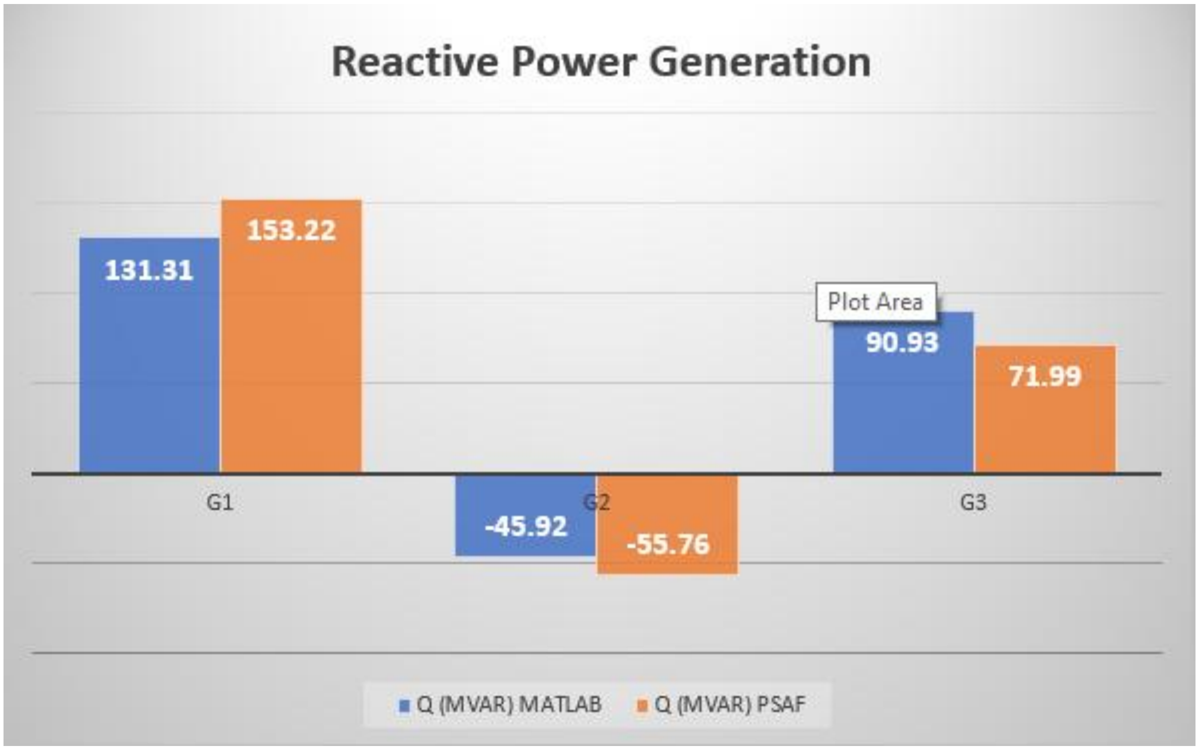
PSAF

ID	Connected to bus	Type	MVA Rating	kV Nominal	P (MW)	Q (MVAR)	S (MVA)	PF(%)
G1	B1	Swing	650	11	-58.87	153.22	164.14	-35.9
G2	B2	Voltage Controlled	750	11	500	-55.76	503.1	99.4
G3	B3	Voltage Controlled	400	11	200	71.99	212.56	94.1

MATLAB

ID	P (MW)	Q (MVAR)	S (MVA)	PF(%)
G1	-55.67	131.31	142.62	-39.03
G2	500	-45.92	502.1	99.58
G3	200	90.93	219.7	91.03





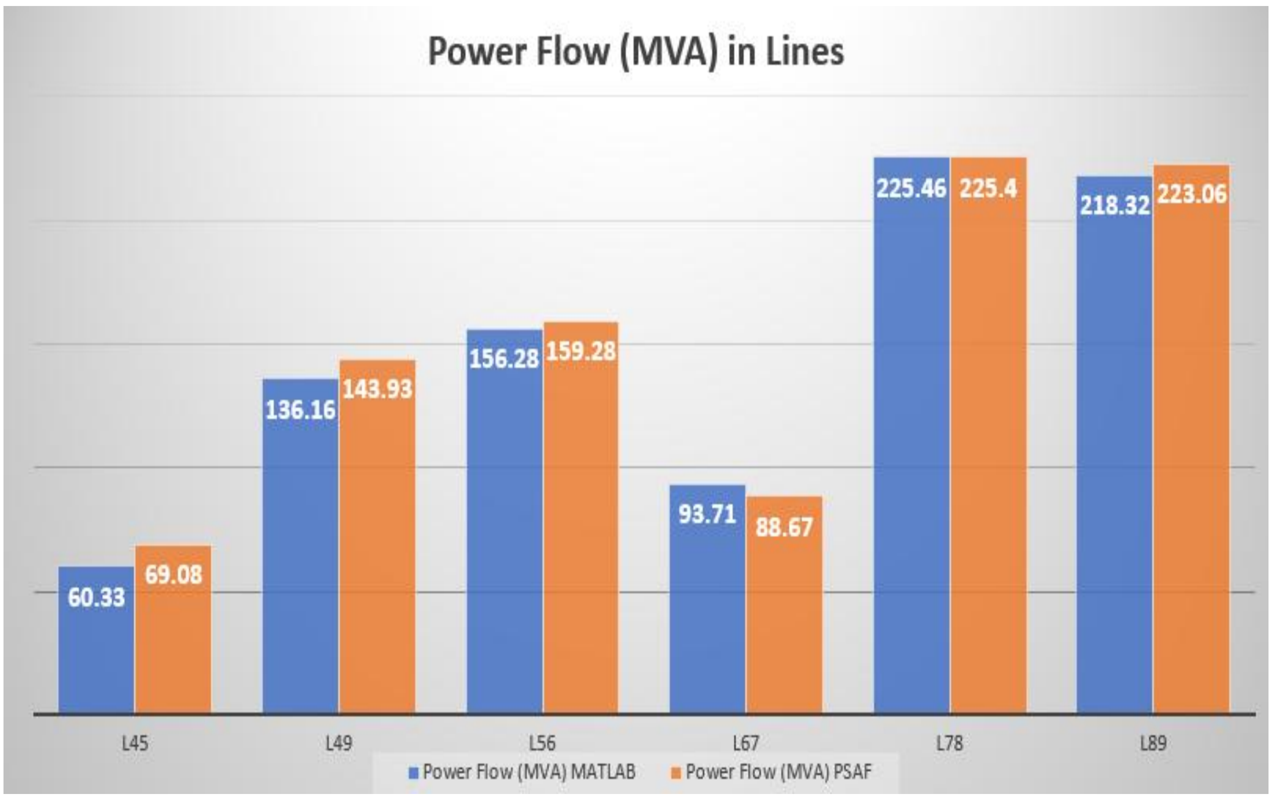
(c) Line Report

PSAF

Line ID	From Bus ( ) to Bus ( )	Length (km)	Power Flow (MVA)	Line Loss (MVA)
L45	4 to 5	280	69.08	0.79
L49	4 to 9	350	143.93	6.92
L56	5 to 6	380	159.28	10.11
L67	6 to 7	250	88.67	1.24
L78	7 to 8	300	225.4	17.5
L89	8 to 9	400	223.06	21.33

MATLAB

Line ID	Power Flow (MVA)	Line Loss (MVA)
L45	60.33	1.256
L49	136.16	8
L56	156.28	11.9
L67	93.71	2.66
L78	225.46	19.35
L89	218.32	22.91



(d) Bus Report

PSAF

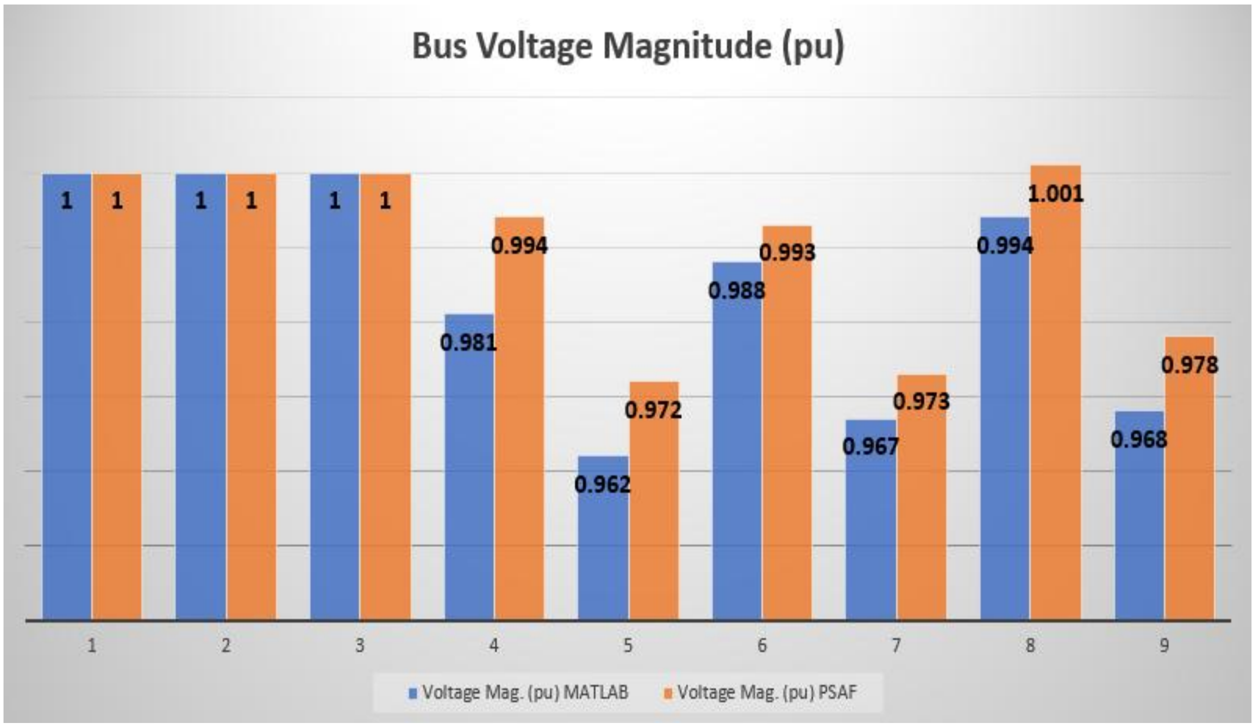
Bus No	Base kV	Voltage Mag. (pu)	Voltage Angle	PG	QG	PL	QL
1	11	1.00	0	-58.87	153.22	0	0
2	11	1.00	10.1	500	-55.76	50	5

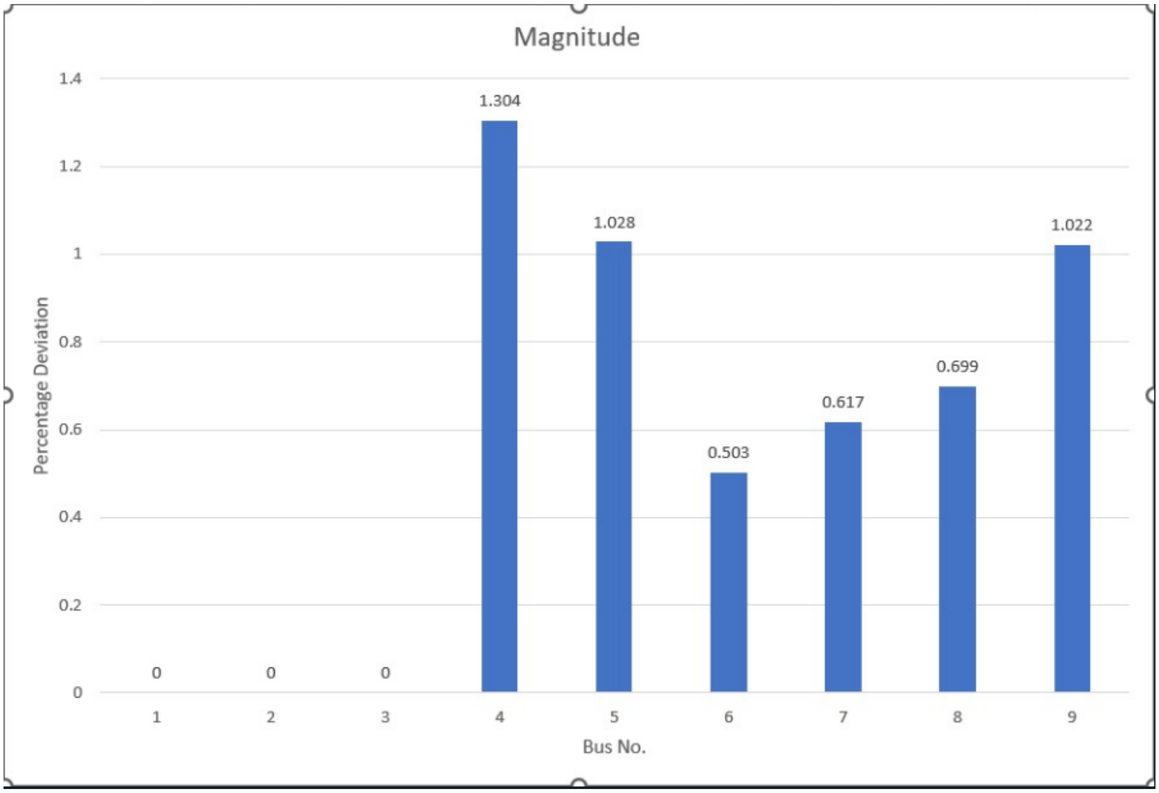
3	11	1.00	4.7	200	71.99	60	8
4	132	0.994	0.2	0	0	0	0
5	132	0.972	-0.2	0	0	200	20
6	132	0.993	4	0	0	0	0
7	132	0.973	5	0	0	200	50
8	132	1.001	9.5	0	0	0	0
9	132	0.978	3.5	0	0	100	30

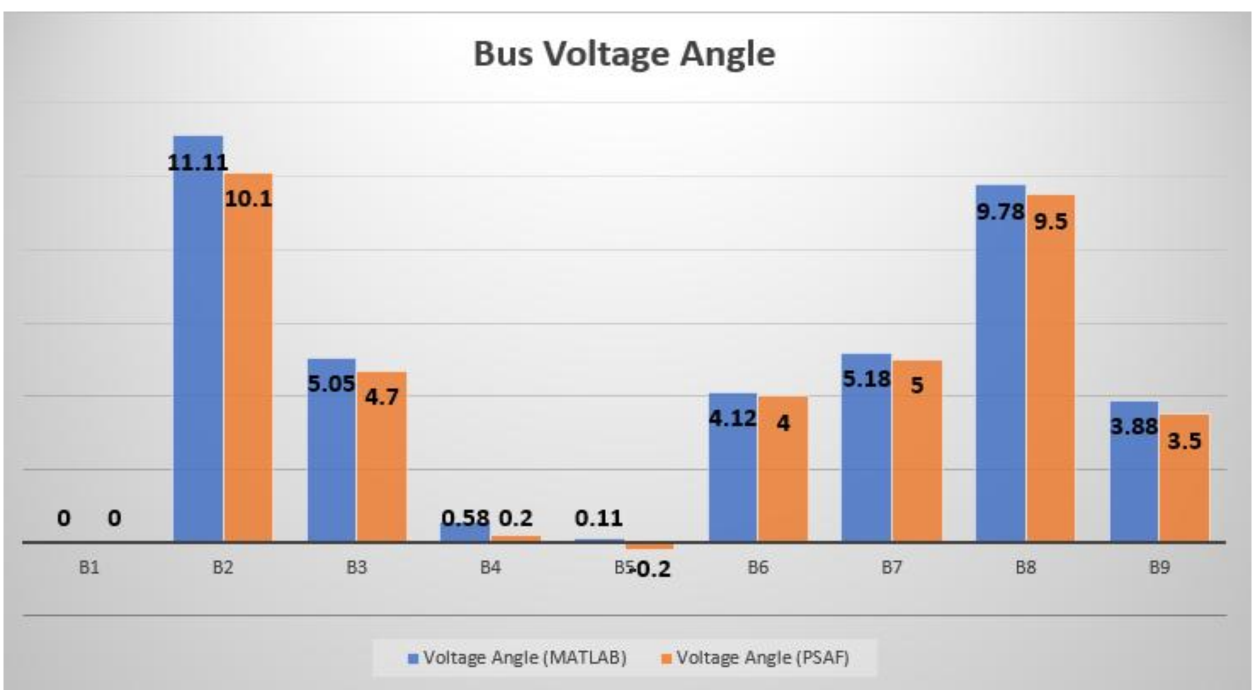
MATLAB

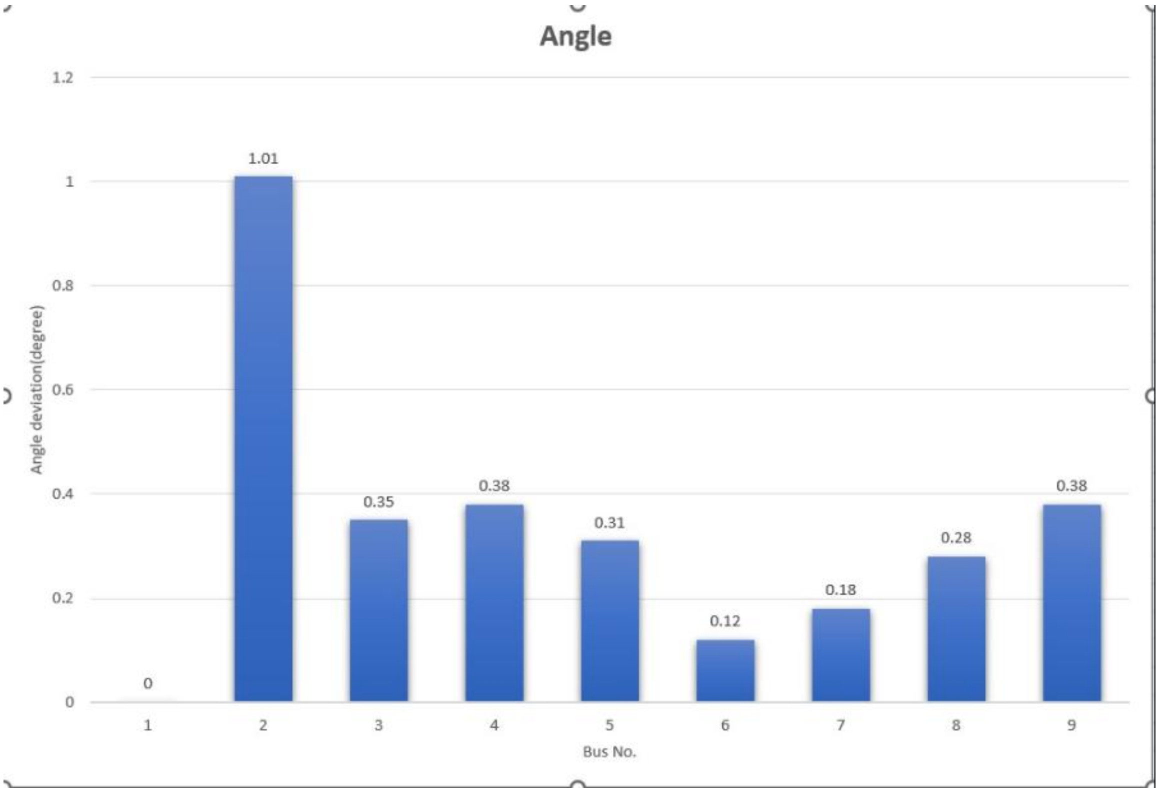
Bus No	Base kV	Voltage Mag. (pu)	Voltage Angle	PG	QG	PL	QL
1	11	1.00	0	-55.67	131.31	0	0
2	11	1.00	11.11	500	-45.92	50	5
3	11	1.00	5.05	200	90.93	60	8
4	132	0.9811	0.58	0	0	0	0

5	132	0.9622	0.11	0	0	200	20
6	132	0.9888	4.12	0	0	0	0
7	132	0.9673	5.18	0	0	200	50
8	132	0.9938	9.78	0	0	0	0
9	132	0.9677	3.88	0	0	100	30




Magnitude
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Percentage Deviation
1.304
1.028
1.022
0.699
0.617
0.503
0
0
0
1
2
3
4
5
6
7
8
9
Bus No.


Bus Voltage Angle
11.11
10.1
9.78
9.5
5.05
4.7
5.18
5
4.12
4
3.88
3.5
0
0
0.58
0.2
0.11
-0.2
B1
B2
B3
B4
B5
B6
B7
B8
B9
Voltage Angle (MATLAB)
Voltage Angle (PSAF)



(e) Abnormal Report:

PSAF

1. Buses outside voltage limit : Nil

2. Generators crossing reactive power limit: Nil

3. Overloaded lines: Line L78 and L89

OVERLOADED LINES & CABLES (WITHIN 100 %)

ID	Bus From	Bus To	Power Flow - [pu]	Loading Limit - [pu]	Emergency Loading Limit - [pu]
L78	B7	B8	2.317	1.829	1.943
L89	B8	B9	2.229	1.829	1.943

4. Underloaded lines: Line l45 and L67

UNDERLOADED LINES & CABLES (WITHIN 50 %)

ID	Bus From	Bus To	Power Flow - [pu]	Loading Limit - [pu]
L45	B4	B5	0.695	0.915
L67	B6	B7	0.893	0.915

5. Overloaded Transformer: Nil

6. Underloaded Transformer: X14

UNDERLOADED TRANSFORMERS (WITHIN 50 %)					
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]	
X14	B1	B4	164.138	200.000	

MATLAB

1. Buses outside voltage limit : Nil

2. Generators crossing reactive power limit: Nil

3. Overloaded lines: Line L78 and L89

Overloaded Lines and Cables

From Bus	To Bus	P MW	Q MVar	S Mvar	Loading Limit Mvar
7	8	-221.7649	40.6937	225.4676	195.0000
8	9	215.4422	-35.3736	218.3269	195.0000

4. Underloaded lines: Line l45 and L67

Underloaded Lines and Cables

From Bus	To Bus	P MW	Q MVar	S Mvar	Loading Limit Mvar
4	5	45.6162	39.4796	60.3281	195.0000
6	7	-20.5659	91.4245	93.7091	195.0000

5. Overloaded Transformer: Nil

6. Underloaded Transformer: X14

From Bus	To Bus	P MW	Q MVar	S Mvar	Loading Limit Mvar
1	4	-55.6726	131.3106	142.6251	400.0000

Possible reasons behind the difference of results from MATLAB and PSAF:

There are two possible reasons behind it.

1. Firstly, we considered equivalent circuit of the transformer.

2. Second, we only looked at the parameters (R,B,X) for positive sequences. Negative sequence computation was not performed.

Discussion:

A load flow analysis of a 9-bus-system can provide valuable information about the power distribution in the system. The Newton-Raphson method is a widely used algorithm for solving power flow problems, which can be implemented in MATLAB and PSAF. The objective of this analysis was to compare the results obtained from the two platforms, MATLAB and PSAF, in order to validate the accuracy of the calculations. The load flow analysis was performed to find the voltage magnitude and phase angle at each bus, which are necessary to determine the real and reactive power flowing in the transmission lines. Additionally, the load flow analysis was also used to identify the underloaded and overloaded lines in the system. This information is important for power system operators to understand the capacity utilization of the lines, and to make decisions about upgrades or reinforcements if necessary. To compare the results of the two platforms, the voltage angle and amplitude (per unit) were plotted for both MATLAB and PSAF output. The comparison of the results showed that both platforms gave relatively similar results, which indicates the validity of the calculations and the accuracy of the load flow analysis.