EEE 306 PROJECT REPORT

Comparison Between Load Flow using Classical Newton Raphson and Simplified Newton Raphson

Submitted By:

Group 02

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A1

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Abstract:

In this project, we wanted to implement simplified Newton Raphson for solving load flow using MATLAB along with the classical one and then compare both models. In PSAF, we compute the load flow using general Newton Raphson formula. If we use a lot of bus data and try to simulate it, the software takes some times to give the output report. On the other hand, if we implement the system using simplified Newton Raphson, the output report will not take too much time. So, we can also implement this system at the low configuration PCs easily.

The standard NR power flow method is one of the most powerful algorithms, which has long history of development, and is widely used to develop commercial power-flow solution software. Although the standard NR power flow method is very efficient and commonly used for the power flow calculation to formulate iterative Jacobian updating matrix equations requires complicated formulae and long expressions. However, essential difference between NR and SNR (simplified newton-raphson) is that the proposed algorithm is to find roots of the current mismatch equations instead of those of the power mismatch equations. This approach can simplify a very long and complicated mathematical formula to a very simplistic and short mathematical expression. With this simplification, reduction of the overall execution time is expected.

THEORY AND DESCRIPTION OF PROJECT:

Algorithm for Newton Raphson Load Flow method

1) 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)

2) *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.*

3) *If the convergence criterion is not satisfied , evaluate elements of the jacobian matrix.*

4) *Solve for corrections of voltage angles and magnitudes.*

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

Case 1 **(PV bus changes to PQ bus)** : In step 2 if reactive power limits of generator bus are violated (i.e. Qg is greater than Qmax or Qg is less than Qmin), PV bus is changed to PQ bus during that iteration and the value of Q is taken as its upper/lower limit Qmax/Qmin depending on type of violation.

Case 2 **(PQ bus changes to PV bus)** : In step 5, if the voltage limits of PQ bus are violated (i.e. |V| is greater than |V max| or |V| is less than |V min|), PQ bus is changed to PV bus during that iteration and the value of V is taken as its upper/lower limit |Vmax|/|Vmin| depending on type of violation.

Necessary Equations:

$$P_i = |V_i|^2 G_{ii} + \sum_{\substack{n=1 \\ n\neq i}}^{N} |V_i V_n Y_{in}| \cos(\theta_{in} + \delta_n - \delta_i)$$

$$Q_i = -|V_i|^2 B_{ii} + \sum_{\substack{n=1 \\ n\neq i}}^{N} |V_i V_n Y_{in}| \sin(\theta_{in} + \delta_n - \delta_i)$$

Using the above two formula ,we computed the "Calculated Values"**($P_{i,calc}$,$Q_{i,calc}$)** of real and reactive power flowing through the transmission line from bus i.

The power mismatches for typical load bus (i),

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

$$= (P_{gi} - P_{di}) - P_{i,calc}$$

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

$$= (Q_{gi} - Q_{di}) - Q_{i,calc}$$

P_{gi} = scheduled real power being generated at bus (i)

P_{di} = scheduled real power demand by load at bus (i)

Therefore, net power being injected at bus (i),

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

Similarly,

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

the updated formulas for the starting values of the state variables are,

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

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

Expressions for the elements of the Jacobian sub matrix are easily found by differentiating the appropriate term in the following equation

$$\mathbf{P_i = |V_i|^2 G_{ii} + \sum_{\substack{n=1 \\ n\neq i}}^{N} |V_i\, V_n\, Y_{in}|\cos(\theta_{in} + \delta_n - \delta_i)}\ \mathbf{...(1)}$$

When the variable *n* equals the particular value *j*, only one of the cosine terms in the summation of the above Equation contains $\boldsymbol{\delta j}$. So, we obtain the typical off-diagonal ($\boldsymbol{i \neq j}$) elements of J11,

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

Every term in summation of Eq. (1) contains $\boldsymbol{\delta}_i$. So, the typical diagonal ($\boldsymbol{i = j}$) element of J11

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

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

In a quite similar manner, we can derive formulas for the elements of sub-matrix J21 as,

Off-diagonal elements:

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

Diagonal elements:

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

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

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

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

The off-diagonal elements of sub-matrix J22 are

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

$$= \frac{\partial Pi}{\partial \delta j}$$

The Diagonal elements of sub-matrix J22 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, $i \neq j$

$$M_{ij} \triangleq \frac{\partial Pi}{\partial \delta j} = |V_j|\frac{\partial Qi}{\partial |Vj|}$$

$$N_{ij} \triangleq \frac{\partial Qi}{\partial \delta j} = -|V_j|\frac{\partial Pi}{\partial |Vj|}$$

Diagonal elements, $i = j$

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

$$N_{ii} \triangleq \frac{\partial Qi}{\partial \delta i} = -|V_i|\frac{\partial Pi}{\partial |Vi|} == -N_{ii} - 2|V_i|^2 G_{ii}$$

The matrix equation for the system

$$
\left[\begin{array}{cccc|cccc}
M_{22} & M_{23} & M_{24} \ldots & M_{2n} & N_{22}+2|V_2|^2G_{22} & -N_{23} & -N_{24} \;\ldots & -N_{2n} \\
M_{32} & M_{33} & M_{34} \ldots & M_{3n} & -N_{32} & N_{33}+2|V_3|^2G_{33} & -N_{34} \;\ldots & -N_{3n} \\
\ldots & \ldots & \ldots & \ldots\ldots & \ldots. & \ldots.. & \ldots. & \ldots.. \\
M_{n2} & M_{n3} & M_{n4} & M_{nn} & -N_{n2} & -N_{n3} & -N_{n4} \ldots. & N_{nn}+2|V_n|^2G_{nn} \\
\hline
N22 & N23 & N24\ldots & N2n & -M_{22}-2|V_2|^2B_{22} & M_{23} & M_{24} \;\ldots & M_{2n} \\
N32 & N33 & N34\ldots.. & N3n & M_{32} & -M_{33}+2|V_3|^2B_{33} & M_{34} \;\ldots & M_{3n} \\
\ldots & \ldots & \ldots & \ldots.. & \ldots. & \ldots.. & \ldots. & \ldots.. \\
N_{n2} & N_{n3} & N_{n4} & N_{nn} & M_{n2} & M_{n3} & M_{n4} \ldots. & M_{nn}+2|V_n|^2B_{nn}
\end{array}\right]
X
\begin{bmatrix}
\Delta\delta_2 \\ \Delta\delta_3 \\ \Delta\delta_4 \\ \ldots.. \\ \Delta\delta_n \\ \frac{\Delta|V2|}{|V2|} \\ \frac{\Delta|V3|}{|V3|} \\ \frac{\Delta|V4|}{|V4|} \\ \ldots.. \\ \frac{\Delta|Vn|}{|Vn|}
\end{bmatrix}
=
\begin{bmatrix}
\Delta P_2 \\ \Delta P_3 \\ \Delta P_4 \\ \ldots\ldots. \\ \Delta P_n \\ \Delta Q_2 \\ \Delta Q_3 \\ \Delta Q_4 \\ \ldots \\ \Delta Q_n
\end{bmatrix}
$$

For Voltage-controlled buses:

• In the polar form of power-flow equations voltage controlled buses are easily taken into account

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

• Hence,the $(n-1)^{th}$ column of the jacobian is always multiplied by 0, and it may be removed

• Furthermore, since Qn is not specified, the mismatch ΔQn cannot be defined, so we must omit the $(n-1)^{th}$ row of the Jacobian matrix. Of course, Qn can be calculated after the power-flow solution become available

Simplified Newton–Raphson power flow method:

Given that an n-bus power system, which bus number 1 is assigned to be a slack bus of constant voltage magnitude and zero phase angle. Considering the kth bus, current balance equations characterizing this bus can be expressed as follows

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

where $I_{gen,k}$ denotes generator current at bus k, $I_{dem,k}$ denotes load current at bus k, V_k denotes phasor voltage at bus k, Y_{ki} denotes 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 (1) into a function of powers as follows

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

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

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

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

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

(4) and (5) are real and imaginary parts of the current mismatch at bus k. The mismatches will be zero when all unknown bus voltages are successfully solved. To find a set of voltage solutions by using the NR method, these two equations must be expanded by Taylor series as follows

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

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

where s denotes the slack bus. With n 1 unknowns of complex variables and n 1 complex current mismatch equations, a compact matrix form used to update the voltage solution can be expressed as follows

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

Hence, elements of the Jacobian matrices can be derived in the similar manner as those of the standard NR method and are summarized in (9)–(16). Sub-matrix J_1

$$\frac{\partial G_k}{\partial \delta_i} = -|V_i Y_{ki}| \sin(\theta_{ki} + \delta_i) \quad \text{for } k \neq i \tag{9}$$

$$\frac{\partial G_k}{\partial \delta_k} = -|V_k Y_{kk}| \sin(\theta_{kk} + \delta_k) + \left|\frac{S_{sch,k}}{V_k}\right| \sin(-\varphi_k + \delta_k) \tag{10}$$

Sub-matrix J_2

$$\frac{\partial G_k}{\partial |V_i|} = |Y_{ki}| \cos(\theta_{ki} + \delta_i) \quad \text{for } k \neq i \qquad (11)$$

$$\frac{\partial G_k}{\partial |V_k|} = |Y_{kk}| \cos(\theta_{kk} + \delta_k) + \left| \frac{S_{sch,k}}{V_k^2} \right| \cos(-\varphi_k + \delta_k) \qquad (12)$$

Sub-matrix J_3

$$\frac{\partial H_k}{\partial \delta_i} = |V_i Y_{ki}| \cos(\theta_{ki} + \delta_i) \quad \text{for } k \neq i \qquad (13)$$

$$\frac{\partial H_k}{\partial \delta_k} = |V_k Y_{kk}| \cos(\theta_{kk} + \delta_k) - \left| \frac{S_{sch,k}}{V_k} \right| \cos(-\varphi_k + \delta_k) \qquad (14)$$

Sub-matrix J_4

$$\frac{\partial H_k}{\partial |V_i|} = |Y_{ki}| \sin(\theta_{ki} + \delta_i) \quad \text{for } k \neq i \qquad (15)$$

$$\frac{\partial H_k}{\partial |V_k|} = |Y_{kk}| \sin(\theta_{kk} + \delta_k) + \left| \frac{S_{sch,k}}{V_k^2} \right| \sin(-\varphi_k + \delta_k) \qquad (16)$$

In the NR method, (8) is iteratively solved for Dd and 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 in (17)

$$\begin{bmatrix} \delta \\ |V| \end{bmatrix}^{h+1} = \begin{bmatrix} \delta \\ |V| \end{bmatrix}^{h} + \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix}^{h} \quad (17)$$

To compare the effectiveness of the proposed NR method against the standard NR method, expressions of the Jacobian matrix elements of J1, J2, J3 and J4, the calculated real and imaginary current matrix elements of G and H, and the calculated real and reactive power matrix elements of Pcal and Qcal need to be evaluated as described in the next section.

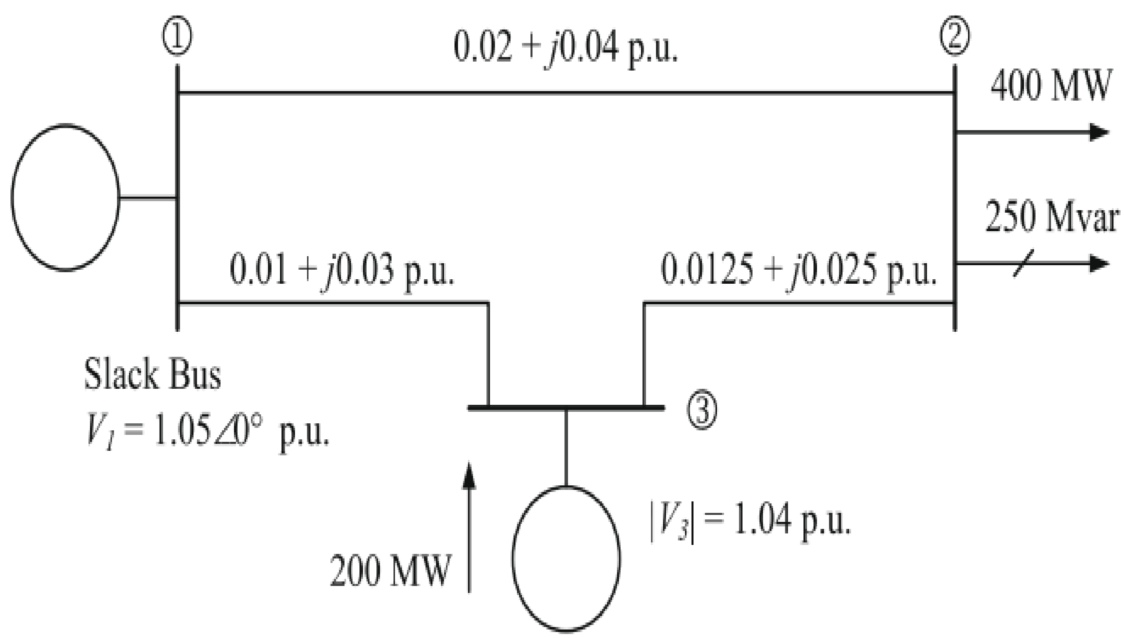

Fig. 3. Single-line diagram of a simple 3-bus power system [1].

The power-flow solution by the proposed NR method is demonstrated in a simple 3-bus power system as shown in Fig. 3. The obtained result can be compared with the solution given in example 6.10 in [1]. The bus admittance matrix can be described by

$$Y_{bus} = \begin{bmatrix} 53.8517\angle -68.20^\circ & 22.3607\angle 116.57^\circ & 31.6228\angle 108.43^\circ \\ 22.3607\angle 116.57^\circ & 58.1378\angle -63.43^\circ & 35.7771\angle 116.57^\circ \\ 31.6228\angle 108.43^\circ & 35.7771\angle 116.57^\circ & 67.2310\angle -67.25^\circ \end{bmatrix}$$

From (4) and (5), the expressions for real current mismatches at bus 2 and 3, and imaginary current mismatch at bus 2 are

$$G_2 = \left|\frac{S_{sch,2}}{V_2}\right| \cos(-\varphi_2 + \delta_2) - \sum_{i=1}^{3} |Y_{2i}V_i| \cos(\theta_{2i} + \delta_i)$$

$$G_3 = \left|\frac{S_{sch,3}}{V_3}\right| \cos(-\varphi_3 + \delta_3) - \sum_{i=1}^{3} |Y_{3i}V_i| \cos(\theta_{3i} + \delta_i)$$

$$H_2 = \left|\frac{S_{sch,2}}{V_2}\right| \sin(-\varphi_2 + \delta_2) - \sum_{i=1}^{3} |Y_{2i}V_i| \sin(\theta_{2i} + \delta_i)$$

Elements of the Jacobian matrix are obtained by the following equations

$$\frac{\partial G_2}{\partial \delta_2} = -|V_2 Y_{22}| \sin(\theta_{22} + \delta_2) + \left|\frac{S_{sch,2}}{V_2}\right| \sin(-\varphi_2 + \delta_2)$$

$$\frac{\partial G_2}{\partial \delta_3} = -|V_3 Y_{23}| \sin(\theta_{23} + \delta_3)$$

$$\frac{\partial G_2}{\partial |V_2|} = |Y_{22}| \cos(\theta_{22} + \delta_2) + \left|\frac{S_{sch,2}}{V_2^2}\right| \cos(-\varphi_2 + \delta_2)$$

$$\frac{\partial G_3}{\partial \delta_2} = -|V_2 Y_{32}| \sin(\theta_{32} + \delta_2)$$

$$\frac{\partial G_3}{\partial \delta_3} = -|V_3 Y_{33}| \sin(\theta_{33} + \delta_3) + \left|\frac{S_{sch,3}}{V_3}\right| \sin(-\varphi_3 + \delta_3)$$

$$\frac{\partial G_3}{\partial |V_2|} = |Y_{32}| \cos(\theta_{32} + \delta_2)$$

$$\frac{\partial H_2}{\partial \delta_2} = |V_2 Y_{22}| \cos(\theta_{22} + \delta_2) - \left|\frac{S_{sch,2}}{V_2}\right| \cos(-\varphi_2 + \delta_2)$$

$$\frac{\partial H_2}{\partial \delta_3} = |V_3 Y_{23}| \cos(\theta_{23} + \delta_3)$$

$$\frac{\partial H_2}{\partial |V_3|} = |Y_{23}| \sin(\theta_{23} + \delta_3)$$

With 100 MVA base, the scheduled power in per-unit can be written as,

$$S_{sch,2} = -4.0 - j2.5 \text{ p.u.}$$

The slack bus voltage V1 is 1.050 p.u., starting with initial guess voltages V2 = 1.000 p.u. and V3 = 1.040 p.u., thus

$$\begin{aligned} Q_{cal,3} = & -|V_3V_1Y_{31}|\sin(\theta_{31}+\delta_1-\delta_3) \\ & -|V_3V_2Y_{32}|\sin(\theta_{32}+\delta_2-\delta_3) \\ & -|V_3^2Y_{33}|\sin(\theta_{33}) = 1.0192 \text{ p.u.} \end{aligned}$$

$$S_{sch,3} = 2.0 + j1.0192 \text{ p.u.}$$

The current mismatch of the initial state can be obtained as follows. Compute the Jacobian matrix with the initial guess voltage solution, the updating equation of the first iteration becomes,

$$\begin{bmatrix} -2.8600 \\ 1.3831 \\ 0.2200 \end{bmatrix} = \begin{bmatrix} 54.50 & -33.28 & 22.00 \\ -32.00 & 63.50 & -16.00 \\ 30.00 & -16.64 & -49.50 \end{bmatrix} \begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta|V_2| \end{bmatrix}^0$$

Thus, the updated bus voltages for the first iteration are:

$$\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta|V_2| \end{bmatrix}^0 = \begin{bmatrix} -0.0460 \\ -0.0088 \\ -0.0294 \end{bmatrix} \rightarrow \begin{bmatrix} \delta_2 \\ \delta_3 \\ |V_2| \end{bmatrix}^1 = \begin{bmatrix} \delta_2 \\ \delta_3 \\ |V_2| \end{bmatrix}^0 + \begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta|V_2| \end{bmatrix}^0$$

$$\begin{bmatrix} \delta_2 \\ \delta_3 \\ |V_2| \end{bmatrix}^1 = \begin{bmatrix} 0.0 \\ 0.0 \\ 1.00 \end{bmatrix} + \begin{bmatrix} -0.046 \\ -0.0088 \\ -0.0294 \end{bmatrix} = \begin{bmatrix} -0.046 \text{ rad} \\ -0.0088 \text{ rad} \\ 0.9706 \text{ p.u.} \end{bmatrix}$$

For the second iteration, the updating equation becomes,

$$\begin{bmatrix} -0.0408 \\ 0.0241 \\ -0.0826 \end{bmatrix} = \begin{bmatrix} 54.3425 & -33.4251 & 19.4624 \\ -31.7416 & 63.2414 & -14.5117 \\ 26.8874 & -16.3466 & -50.2945 \end{bmatrix} \begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta|V_2| \end{bmatrix}^1$$

And

$$\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta|V_2| \end{bmatrix}^1 = \begin{bmatrix} -0.0011 \\ 0.0001 \\ 0.0010 \end{bmatrix} \rightarrow \begin{bmatrix} \delta_2 \\ \delta_3 \\ |V_2| \end{bmatrix}^2 = \begin{bmatrix} \delta_2 \\ \delta_3 \\ |V_2| \end{bmatrix}^1 + \begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta|V_2| \end{bmatrix}^1$$

$$\begin{bmatrix} \delta_2 \\ \delta_3 \\ |V_2| \end{bmatrix}^2 = \begin{bmatrix} -0.046 \\ -0.0088 \\ 0.9706 \end{bmatrix} + \begin{bmatrix} -0.0011 \\ 0.0001 \\ 0.0010 \end{bmatrix} = \begin{bmatrix} -0.0471 \text{ rad} \\ -0.0087 \text{ rad} \\ 0.9716 \text{ p.u.} \end{bmatrix}$$

For the third iteration, the updating equation becomes,

$$\begin{bmatrix} 6.71 \times 10^{-5} \\ 4.03 \times 10^{-4} \\ -6.3 \times 10^{-6} \end{bmatrix} = \begin{bmatrix} 54.4238 & -33.4238 & 19.4172 \\ -31.7908 & 63.2908 & -14.4766 \\ 26.8492 & -16.3493 & -50.3215 \end{bmatrix} \begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta|V_2| \end{bmatrix}^2$$

therefore,

$$\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta|V_2| \end{bmatrix}^2 = \begin{bmatrix} 7.23 \times 10^{-6} \\ 1.02 \times 10^{-5} \\ 6.80 \times 10^{-7} \end{bmatrix} \rightarrow \begin{bmatrix} \delta_2 \\ \delta_3 \\ |V_2| \end{bmatrix}^3 = \begin{bmatrix} \delta_2 \\ \delta_3 \\ |V_2| \end{bmatrix}^2 + \begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta|V_2| \end{bmatrix}^2$$

For the third iteration, the updating equation becomes,

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Power flow solution for the example.

Item	Standard NR [1]	Proposed NR
V_2 (p.u.)	$0.97168\angle-2.696°$	$0.97168\angle-2.698°$
V_3 (p.u.)	$1.04\angle-0.4988°$	$1.04\angle-0.4979°$
Q_3 (p.u.)	1.4617	1.4618
Max. mismatch	2.2×10^{-4} p.u. power	4.0×10^{-4} p.u. current

$$\begin{bmatrix} \delta_2 \\ \delta_3 \\ |V_2| \end{bmatrix}^2 = \begin{bmatrix} -0.0471 \\ -0.0087 \\ 0.9716 \end{bmatrix} + \begin{bmatrix} 7.23 \times 10^{-6} \\ 1.02 \times 10^{-5} \\ 6.80 \times 10^{-7} \end{bmatrix}$$

$$= \begin{bmatrix} -0.04709 \text{ rad} \\ -0.00869 \text{ rad} \\ 0.97168 \text{ p.u.} \end{bmatrix} = \begin{bmatrix} -2.698^{\circ} \\ -0.4979^{\circ} \\ 0.97168 \text{ p.u.} \end{bmatrix}$$

To assess the effectiveness of the proposed NR method, comparison with the third-iteration bus voltages obtained by the standard NR method is given in Table 2. Fig. 4 gives solution convergence of both methods. The numerical example shows that the standard NR and the proposed NR methods show similar solution convergence for the simple 3-bus test system. Some might say that this can imply the quadratic convergence of the simplified NR method as well as the standard NR method does. As can be seen, there is no significant difference between their convergences, the proposed NR method is expected to perform faster in obtaining the power-flow solution due to its simplification

Now we will describe different report parts.

Bus Report:

Here, we illustrated different parameter values for each bus. The parameters are: Bus ID, Voltage (in pu), Angle (Expressed in Degree), Generated Real Power (expressed in MW), Generated Reactive Power (expressed in MVAR), Load Real Power (expressed in MW), Load Reactive Power (expressed in MVAR).

Here, Generated Real Power corresponds to P_{gi} corresponding to the theory. Similarly, Generated Reactive Power corresponds to Q_{gi}, Load Real Power corresponds to P_{di} and Load Reactive Power corresponds to Q_{di}.

As Newton Raphson differential equation parameter, we calculated Voltage and Angle directly from Newton Raphson Method. It is the output result from the differential equations.

So, in one line, we got the first two parameter just by reiterating the equations given below until tolerance is less than 1×10^{-5}:

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

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

After we get the voltage and voltage angles, it is easy to calculate different powers. We used the equations given below for power calculation:

$$\text{For load(PQ) bus, } P_{di} \text{ is given.}$$

$$P_i = |Vi|^2 Gii + \sum_{\substack{n=1 \\ n \neq i}}^{N} |\, Vi\, Vn\, Yin \,| \cos(\theta in + \delta n - \delta i)$$

$$P_{gi} = P_i + P_{di}$$

$$Q_i = -\lvert Vi \rvert^2 Bii - \sum_{\substack{n=1 \\ n \neq i}}^{N} \lvert Vi\ Vn\ Yin \rvert \sin(\theta in + \delta n - \delta i)$$ $$Q_{gi} = Q_i + Q_{di}$$

For Generator(PV) Bus, P_{gi} and P_{di} are given.
For Generator(PV) Bus, Q_{di} is given. After getting $V's$ and $\delta's$ values, we can use the equations given below: $$Q_i = -\lvert Vi \rvert^2 Bii - \sum_{\substack{n=1 \\ n \neq i}}^{N} \lvert Vi\ Vn\ Yin \rvert \sin(\theta in + \delta n - \delta i)$$ $$Q_{gi} = Q_i + Q_{di}$$

For Real Power of Slack Bus, $Pg, slack = \Sigma Pdi - \Sigma Pgi + \Sigma\ (mag\ Iij)2Rij\ loss$
For Reactive Power of Slack Bus, Qg slack= ΣQdi- ΣQgi –Σcharging MVAR in all the lines + Σ (mag Iij)2Xij loss

All the load Real and Reactive Power is given values. So all the values for this part can be calculated and tabularized.

Generator Report:

In generator report, we illustrated different parameter values for each generator bus(excluding the slack bus). The parameters are: Generator ID, Bus ID, Generated Real Power (expressed in MW), Generated Reactive Power (expressed in MVAR), Apparent Power (expressed in MVA), Power Factor (expressed in %), Minimum Possible Generated Reactive Power(MVAR) and Maximum Possible Generated Reactive Power(MVAR).

The last two components (Qmin and Qmax) are the given values for a power system. So, we don't need to make any calculations for them.

We have a 'type' column in the given data, which shows the type of the bus (Slack, PQ or PV bus). So, we can easily find the generator buses. For generated buses, real power (P_{gi}) is given. So we need to calculate only the reactive powers. The reactive power is calculated using the formula given below:

$$Q_i = -|Vi|^2 Bii - \sum_{\substack{n=1 \\ n\neq i}}^{N} |\, Vi\ Vn\ Yin \,| \sin(\theta in + \delta n - \delta i)$$

$$Q_{gi} = Q_i + Q_{di}$$

Then we calculated apparent power from the real and reactive power generated. It became easy for us to find power factor after finding all these power values. The equations used for this process are give below:

$$S_{gi} = \sqrt{{P_{gi}}^2 + {Q_{gi}}^2}$$

$$pf = \frac{abs(P_{gi}) \times sgn(Q_{gi})}{\sqrt{{P_{gi}}^2 + {Q_{gi}}^2}} \times 100\%$$

Here, we used sign of Qgi to determine the lagging leading feature of power factor. The way we indicated the lagging leading feature is shown below:

Lagging: pf positive
Leading: pf negative

Here, the generator numbering method is done according to the order they appear in the data list. The algorithm for numbering is given below:

Finding generator bus locations(bus type == 2) ⟶ Approach to different buses ⟶ When a generator bus is got, location vector is summed up to the bus number position, this is the generator number.

Load Report:

For Load report, we illustrated 4 different parameter values along with load no and bus id for each load(PQ) bus and generator bus(PV) with loads. The parameters are: Load ID, Bus ID, Real Load Power (expressed in MW), Reactive Load Power (expressed in MVAR), Apparent Load Power (expressed in MVA), Power Factor of the load (expressed in %).

Once again for numbering, we used the same method as generator. But this time we didn't took the 'type' column data to determine load bus. Rather we used real and reactive load data column for each bus for determining whether our bus contains a load or not.

Generally, in a PV bus, along with generators there may contain some loads also. So, if we try to sort out load buses using type==3, then we will have a smaller number of load buses than we should really have. It happens because, we ignore the loads attached with the generator buses. As a result, for perfect load sensing we compared both real and reactive power in the load column and decided whether our bus is a load bus or not. For reader's convenience, we rewrite the algorithm again here with the required changes:

Finding load locations(real load power ~= 0 or reactive load power ~=0) ⟶ Approach to different buses ⟶ When a load is got, location vector is summed up to the bus number position, this is the load number.

For load buses, generally load real and reactive power are given. So, the only components we need to calculate are Apparent Load Power and Power Factor of the load. Here, the formula is the same as the generator bus. But for readers convenience, we rewrite the equations with proper notations here:

$$S_{di} = \sqrt{{P_{di}}^2 + {Q_{di}}^2}$$

$$pf = \frac{abs(P_{di}) \times sgn(Q_{di})}{\sqrt{{P_{di}}^2 + {Q_{di}}^2}} \times 100\%$$

Lagging: pf positive
Leading: pf negative

We also used the same pf convention here, to make things easily understandable. PF notations are also mentioned again in the above formula box.

Line Report:

In this line report part, we showed 7 different parameters apart from Line ID, Starting Bus(From Bus) and Ending Bus ID(To Bus). The 7 parameters are: Real Power Flowing from starting bus to ending bus (expressed in MW), Reactive Power Flowing from starting bus to ending bus (expressed in MVAR), Apparent Power Flowing from starting bus to ending bus (expressed in MVA), Power Factor of power flow (expressed in %), Loading of the line with respect to the Loading Limit (expressed in %), Real Power Losses in the line (expressed in MW), Reactive Power Losses in the line (expressed in MVAR).

In line data, we took each row as a line and thus got line number (Line ID). Starting and Ending bus are given in the data.

Now, we need to calculate real power flow. For finding real power flow in a line, we first need to loss in the line. To calculate the loss in the line, we first calculated the power flow through the line from starting bus to ending bus. Then we calculated power flow in the reverse direction i.e. from ending to starting bus. These two powers should be equal in magnitude but opposite in sign if there are no loss. But for losses, these powers are not equal. We get the differences as real power loss in the line. The formula-cum-algorithm is given below:

$$I_{ij} = \frac{V_i - V_j}{Z_{ij}}$$

$$P_{ij} + Q_{ij} = V_i I_{ij}^*$$

$$I_{ji} = \frac{V_j - V_i}{Z_{ji}} [Z_{ij} = Z_{ji}]$$

$$P_{ji} + Q_{ji} = V_j I_{ji}^*$$

$$P_{losses} = P_{ij} + P_{ji}$$

$$Q_{losses} = Q_{ij} + Q_{ji}$$

In the formula box above, we also calculated reactive power loss through the lines.

Now total real power flowing from starting bus to ending bus is P_{ij}, when starting bus is i and ending bus is j. The power formula is summarized below:

$$\text{Real power flowing from starting bus, i to ending bus, j} = P_{ij} = P_{ji} + P_{losses}$$

$$\text{Reactive power flowing from starting bus, i to ending bus, j} = Q_{ij} = Q_{ji} + Q_{losses}$$

Again, apparent power flowing from one bus to another can also be calculated using the apparent power formula given above in generator. We are writing them again here with proper notations. Note that, apparent power passing from starting bus i to ending bus j is denoted by S_{ij}. All the formulas with pf notation is given below:

$$S_{ij} = \sqrt{{P_{ij}}^2 + {Q_{ij}}^2}$$

$$pf = \frac{abs(P_{ij}) \times sgn(Q_{ij})}{\sqrt{{P_{ij}}^2 + {Q_{ij}}^2}} \times 100\%$$

Lagging: pf positive
Leading: pf negative

The last component needed to be discussed is Loading of the line. In our line data, we have a loading limit (expressed in MVA) column for each of the line. After comparing the apparent power flowing in the line with its respective loading limit, we can find how much the line is loaded. We express this in percentage. The algorithm-cum-formula is given below:

$$\text{Loading of the line} = \frac{S_{ij}}{\text{Loading Limit}_{ij}} \times 100\%$$

Abnormal Report: Buses Outside Voltage Limit

Our first abnormal report is buses outside voltage limit. Here along with Bus No. we provided Loading Condition (Overloaded or Underloaded, mainly overloaded) and Percentage Loaded (Expressed in % -mainly overloaded).

Here, we solved the problem for flat start. We took this $1\angle 0°$ pu as base voltage of each line. After solving if we get any bus with a voltage magnitude greater than 1, then we termed that bus as a bus outside voltage limit. It's not really a warning, rather it is a reminder that the bus has a voltage which is greater than the base voltage or the bus is surpassing base voltage. We can see a lot of buses outside voltage limit for a big network like 57 buses. It is just a reminder only.

The algorithm for bus outside voltage limit part is given below:

$$\text{if } |\text{solved bus voltage}_\text{i}| > |\text{initial bus voltage}_\text{i}|$$
$$\text{the bus is outside voltage limit}$$
$$\text{Percent Loaded} = \frac{|\text{solved bus voltage}_\text{i}| - |\text{initial bus voltage}_\text{i}|}{|\text{initial bus voltage}_\text{i}|} \times 100\%$$

Abnormal Report: Generators at Reactive Limit

In this abnormal report, we provided Generator ID and Bus ID at which the generator is located. Apart from these, we gave 5 components. They are: Generated Real Power (expressed in MW), Generated Reactive Power (expressed in MVAR), Minimum Possible Generated Reactive Power (MVAR) and Maximum Possible Generated Reactive Power (MVAR), Percentage Outside Limit (expressed in %).

In Generator report part, we showed how we can get real power and reactive power that is generated from the generator. The 3rd and the 4th component are also got from data sheet. So we need to compute the rest one, Percentage Outside Limit.

The algorithm for this part is shown in the box below:

For Generator Buses

If Generated Reactive Power < Minimum Possible Generated Reactive Power

If Minimum Possible Generated Reactive Power is zero

Difference= Minimum Possible Generated Reactive Power − Generated Reactive Power

else

$$\text{Percentage}=\frac{\text{Minimum Possible Generated Reactive Power}-\text{Generated Reactive Power}}{\text{Minimum Possible Generated Reactive Power}}\times 100\%$$

Else if Generated Reactive Power > Maximum Possible Generated Reactive Power

If Maximum Possible Generated Reactive Power is zero

Difference= Generated Reactive Power − Maximum Possible Generated Reactive Power

else

$$\text{Percentage}=\frac{\text{Generated Reactive Power}-\text{Maximum Possible Generated Reactive Power}}{\text{Maximum Possible Generated Reactive Power}}\times 100\%$$

Here, creating Generator ID is the same as the one shown in generator report part.

Abnormal Report: Underloaded Lines and Cables

In underloaded lines and cables, we showed the starting and ending Bus ID for each line which are underloaded. Then we added 3 parameters, namely - Real Power Flowing from starting bus to ending bus (expressed in MW), Reactive Power Flowing from starting bus to ending bus (expressed in MVAR) and Percentage Underloaded (expressed in %).

First two components Real Power Flowing from starting bus to ending bus and Reactive Power Flowing from starting bus to ending bus are determined in line report. We will now determine how much underloaded the line is with respect to its loading limit.

To make things further clear, we have used a threshold value for making decisions whether our bus is underloaded or not. The threshold value is 70% of the loading limit given on the data sheet.

It is not a warning. It is formal reminder that, the line isn't used 100% rather the efficiency of the line is low with respect to the loading limit.

The algorithm for this part is given below:

$$\text{Apparent Power of the Line} = \sqrt{\text{Real Power}^2 + \text{Reactive Power}^2}$$
$$\text{If apparent power} < \text{loading limit } \times 0.7$$
$$\text{Underloaded} = \frac{\text{loading limit} - \text{apparent power}}{\text{loading limit}} \times 100\%$$

Abnormal Report: Overloaded Lines and Cables

The parameters and the ID's for this section is exactly the same as the previous section, namely underloaded lines and cables.

In this section the last column name is Percentage Overloaded (expressed in %).

Unlike the previous one, this report shows a very important warning. If the lines are overloaded for a large amount of time then the line can get damaged fast. This will harm the line as well as it can cause explosions too. If a line is heavily overloaded, it can burn out immediately. So, we need to pay attention to this kind of report while designing.

In this part, the threshold value for decision making is the loading limit itself. The algorithm for this part is given below:

$$\text{Apparent Power of the Line} = \sqrt{\text{Real Power}^2 + \text{Reactive Power}^2}$$
$$\text{If apparent power} > \text{loading limit}$$
$$\text{Overloaded} = \frac{\text{apparent power} - \text{loading limit}}{\text{loading limit}} \times 100\%$$

Summary Report:

The last report in this project is the summary report. It gives us the summary of the overall network. It mainly gives us the summary of Active Power (MW) and Reactive Power (MVAR) contained in the different part of the system.

We will now see line by line analysis of the summery report.

In the first column it gives us the data of total generation. In bus report, we saw the equations for getting real and reactive power generation. In general, real power for PV bus or generator bus is given. But reactive power is not given in the data list. After solving the network, we can get the reactive power for PV buses. The equation for determining these reactive powers are also given in the bus report part.

We also showed how to get slack bus power.

So, the process of determining total generation power from the known values of different generator and slack bus power is given below:

$$P_{g,total} = \sum P_{gi} + P_{g,Slack}$$
$$Q_{g,total} = \sum Q_{gi} + Q_{g,Slack}$$

In the next row, we get load real and reactive power. We generally know the real and reactive load power of a load bus/load contained PV bus. So total load power will just be their summations. Mathematically showing:

$$P_{d,total} = \sum P_{di}$$
$$Q_{d,total} = \sum Q_{di}$$

In the 3rd row, we see real and reactive power for total losses. In the line report part, we calculated losses for every line. If we add them, we will get the total loss. Mathematical explanation is given in the box below:

$$P_{loss,total} = \sum P_{loss,i}$$
$$Q_{loss,total} = \sum Q_{loss,i}$$

For the first two boxes, the summation is taken over the number of buses with generators and loads respectively. In the third box, we summed over the number of lines.

After getting all these values, we can now calculate mismatches in our overall calculation. The mismatches of real and reactive power are determined by the equations given below:

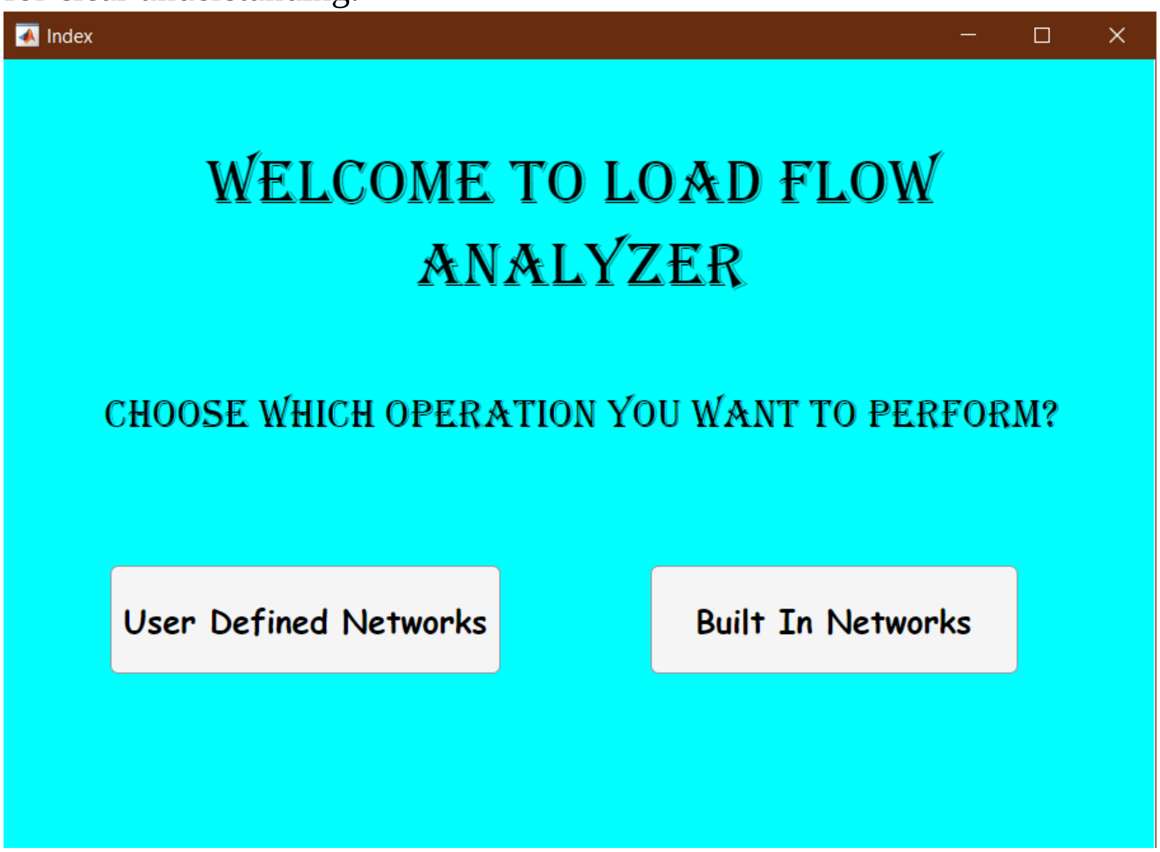
$$P_{mismatches} = P_{g,total} - P_{d,total} - P_{loss,total}$$
$$Q_{mismatches} = Q_{g,total} - Q_{d,total} - Q_{loss,total}$$

So, these are the reports in this experiment.

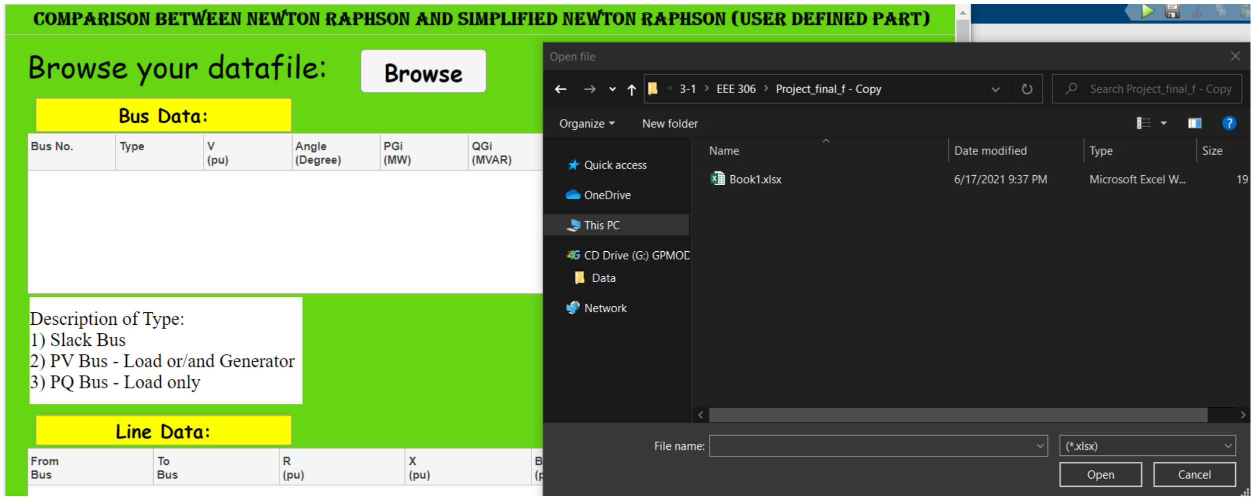
App Interface and Details

User can see two options at the beginning of this project. These are user defined networks and built in networks.

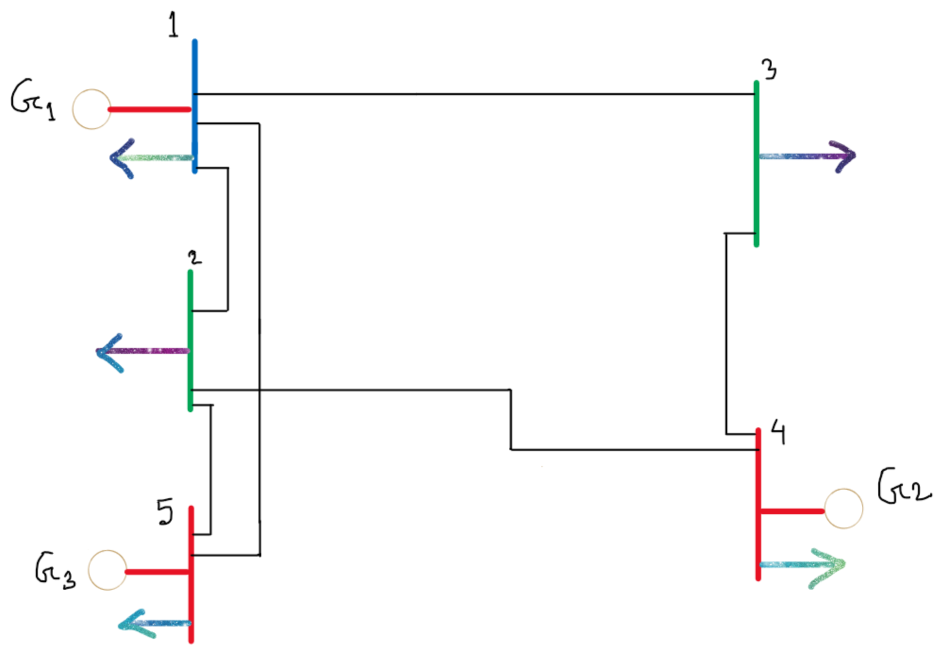
i. <u>User Defined Network:</u>
User can give inputs according to his/her accord in this part. Here he /she inputs bus data, line data. Then MATLAB App Viewer shows results based on our algorithms. It shows results and necessary graphs for newton -raphson and simplified newton-raphson method. MATLAB App Viewer also displays comparison between these two methods mentioned beforehand using bar graph and data table. Screenshots are added below for clear understanding:



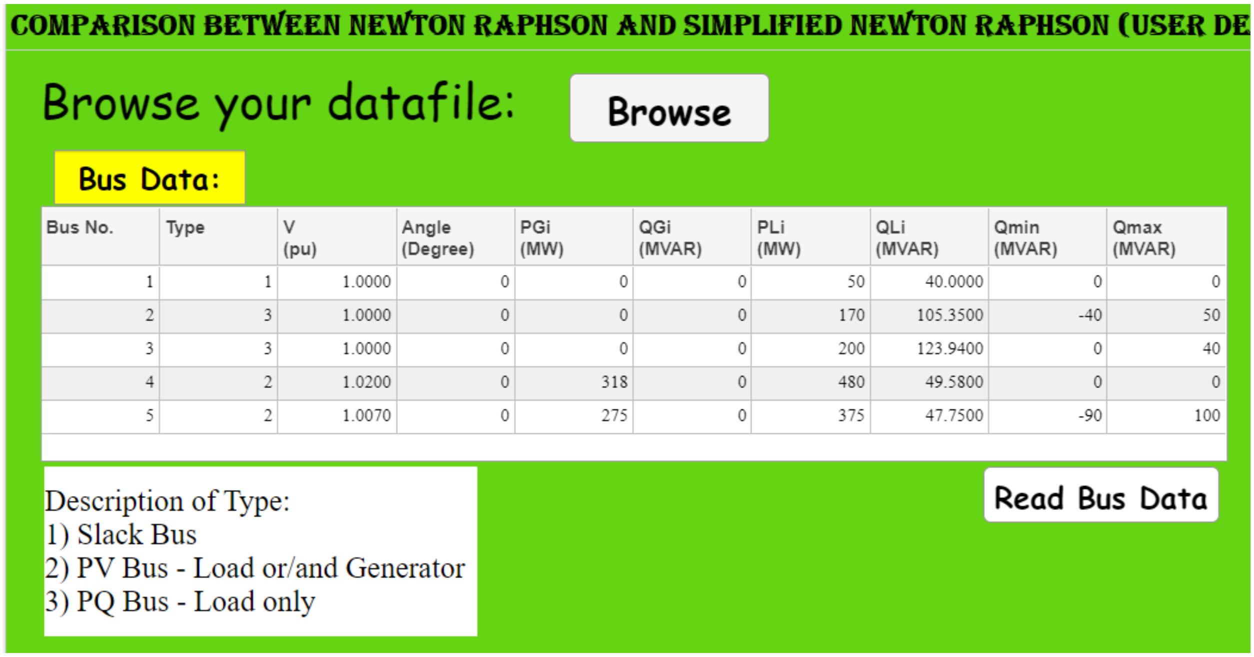
After clicking on user defined network,here comes a window like this where he/she gives inputs for bus and line:



Here, user inputs data in excel file. We used a network, the SLD of which is given below:



In this part, inputs given by user are read after clicking on read bus data.



COMPARISON BETWEEN NEWTON RAPHSON AND SIMPLIFIED NEWTON RAPHSON (USER DE

Browse your datafile: Browse

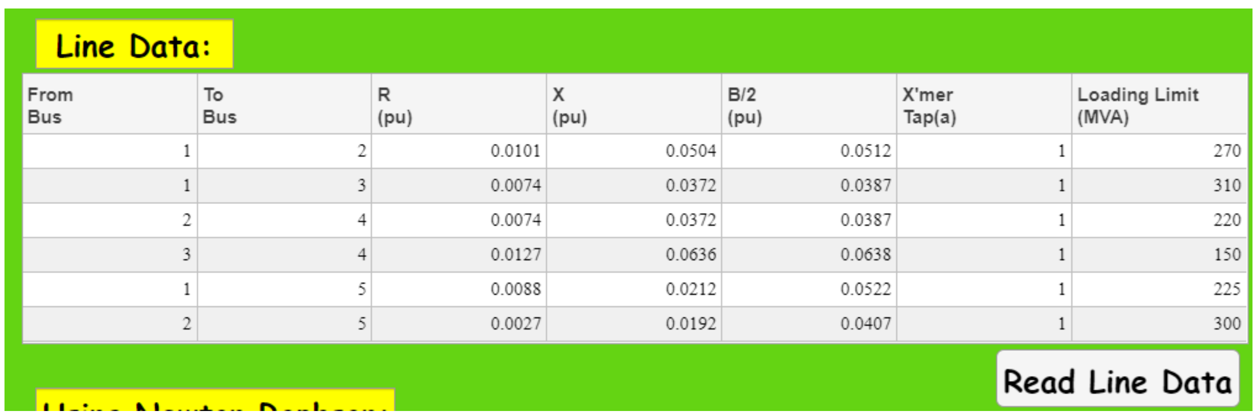
Bus Data:

Bus No.	Type	V (pu)	Angle (Degree)	PGi (MW)	QGi (MVAR)	PLi (MW)	QLi (MVAR)	Qmin (MVAR)	Qmax (MVAR)
1	1	1.0000	0	0	0	50	40.0000	0	0
2	3	1.0000	0	0	0	170	105.3500	-40	50
3	3	1.0000	0	0	0	200	123.9400	0	40
4	2	1.0200	0	318	0	480	49.5800	0	0
5	2	1.0070	0	275	0	375	47.7500	-90	100

Description of Type:
1) Slack Bus
2) PV Bus - Load or/and Generator
3) PQ Bus - Load only

Read Bus Data

For loading line datas given by user, necessary button is added :



Line Data:

From Bus	To Bus	R (pu)	X (pu)	B/2 (pu)	X'mer Tap(a)	Loading Limit (MVA)
1	2	0.0101	0.0504	0.0512	1	270
1	3	0.0074	0.0372	0.0387	1	310
2	4	0.0074	0.0372	0.0387	1	220
3	4	0.0127	0.0636	0.0638	1	150
1	5	0.0088	0.0212	0.0522	1	225
2	5	0.0027	0.0192	0.0407	1	300

Read Line Data

After these steps, our project analyzes given datas using both newton-raphson and simplified newton-raphson method. It also shows comparison between these two methods using both chart and bar graph. Pictures are given below for better understanding:

Read Line Data

Using Newton Raphson:

From Bus	To Bus	P (MW)	Q (MVAR)	From Bus	To Bus	P (MW)	Q (MVAR)	P_loss (MW)	Q_loss (MW)
1	2	162.3907	-17.3530	2	1	-159.7022	30.7956	2.6885	13.4426
1	3	250.8204	50.0520	3	1	-245.9534	-25.7172	4.8670	24.3348
2	4	119.0068	-84.9541	4	2	-117.4030	92.9732	1.6038	8.0190
3	4	45.9534	-88.6405	4	3	-44.5970	95.4226	1.3564	6.7820
1	5	235.9616	-121.7773	5	1	-229.7922	136.7249	6.1694	14.9476
2	5	-129.3046	-38.2326	5	2	129.7922	41.7523	0.4876	3.5197

Perform_Analysis

Using Simplified Newton Raphson:

From Bus	To Bus	P (MW)	Q (MVAR)	From Bus	To Bus	P (MW)	Q (MVAR)	P_loss (MW)	Q_loss (MW)
1	2	162.3907	-17.3530	2	1	-159.7022	30.7956	2.6885	13.4426
1	3	250.8204	50.0520	3	1	-245.9534	-25.7172	4.8670	24.3348
2	4	119.0068	-84.9541	4	2	-117.4029	92.9732	1.6038	8.0190
3	4	45.9534	-88.6405	4	3	-44.5970	95.4226	1.3564	6.7820
1	5	235.9616	-121.7773	5	1	-229.7922	136.7249	6.1694	14.9476
2	5	-129.3046	-38.2326	5	2	129.7922	41.7523	0.4876	3.5197

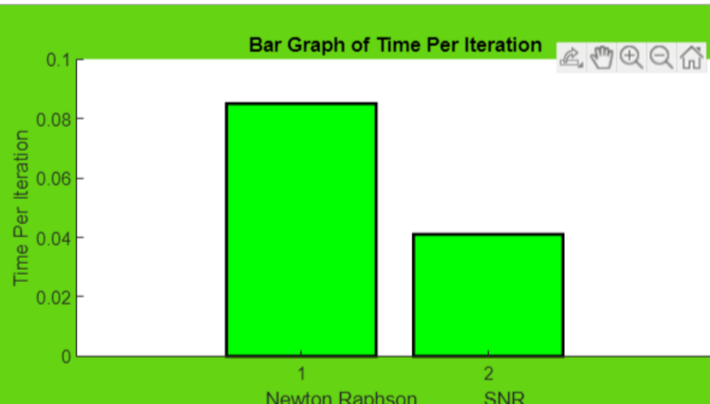
Perform Analysis

Perform Analysis

Comparison:

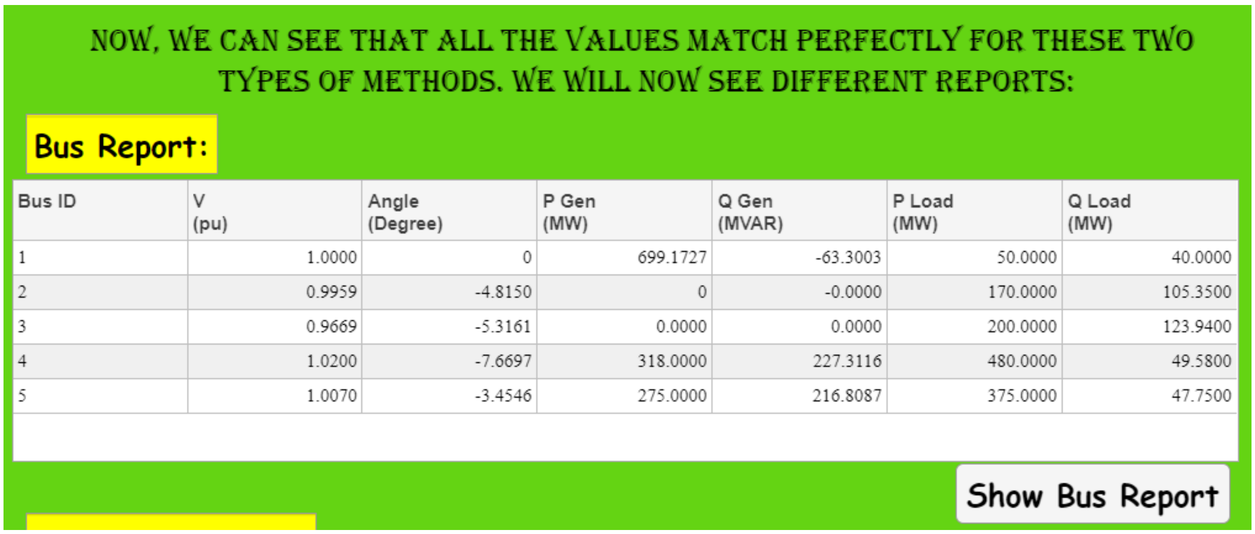
Method	No Of Iteration	Time Elapsed	Time Per Iteration
Newton Raphson	4	0.3401	0.0850
Simplified Newton Raphson	5	0.2052	0.0410

Show Comparison



This bar graph shows differences in time per iteration for these two methods used in this project. This also shows reduction in execution time while using SNR which is an important part of this project.

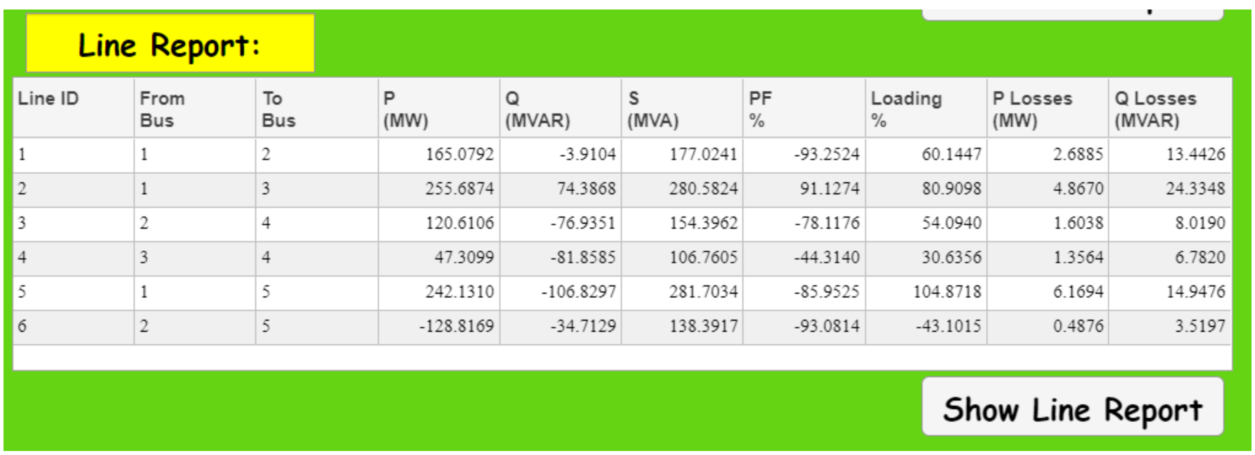
Bus report,load report and generator report options are displayed here too :


NOW, WE CAN SEE THAT ALL THE VALUES MATCH PERFECTLY FOR THESE TWO TYPES OF METHODS. WE WILL NOW SEE DIFFERENT REPORTS:

Bus Report:

Bus ID	V (pu)	Angle (Degree)	P Gen (MW)	Q Gen (MVAR)	P Load (MW)	Q Load (MW)
1	1.0000	0	699.1727	-63.3003	50.0000	40.0000
2	0.9959	-4.8150	0	-0.0000	170.0000	105.3500
3	0.9669	-5.3161	0.0000	0.0000	200.0000	123.9400
4	1.0200	-7.6697	318.0000	227.3116	480.0000	49.5800
5	1.0070	-3.4546	275.0000	216.8087	375.0000	47.7500

Show Bus Report


Line Report:

Line ID	From Bus	To Bus	P (MW)	Q (MVAR)	S (MVA)	PF %	Loading %	P Losses (MW)	Q Losses (MVAR)
1	1	2	165.0792	-3.9104	177.0241	-93.2524	60.1447	2.6885	13.4426
2	1	3	255.6874	74.3868	280.5824	91.1274	80.9098	4.8670	24.3348
3	2	4	120.6106	-76.9351	154.3962	-78.1176	54.0940	1.6038	8.0190
4	3	4	47.3099	-81.8585	106.7605	-44.3140	30.6356	1.3564	6.7820
5	1	5	242.1310	-106.8297	281.7034	-85.9525	104.8718	6.1694	14.9476
6	2	5	-128.8169	-34.7129	138.3917	-93.0814	-43.1015	0.4876	3.5197

Show Line Report

Generator Report:

Generator ID	Bus ID	P (MW)	Q (MVAR)	S (MVA)	PF %	Q max (MVAR)	Q min (MVAR)
1	4	318.0000	227.3116	390.8895	81.3529	0	0
2	5	275.0000	216.8087	350.1871	78.5294	-90.0000	100.0000

Show Generator Report

Load Report:

Load ID	Bus ID	P (MW)	Q (MVAR)	S (MVAR)	PF %
1	1	50.0000	40.0000	64.0312	78.0869
2	2	170.0000	105.3500	199.9966	85.0015
3	3	200.0000	123.9400	235.2894	85.0017
4	4	480.0000	49.5800	482.5538	99.4708
5	5	375.0000	47.7500	378.0279	99.1990

Show Load Report

Lastly, this project shows abnormalities for overloaded and underloaded lines and buses that cross given limit(if there is any):

Overloaded Lines and Cables:

From Bus	To Bus	P (MW)	Q (MVAR)	Percentage Overloaded %
1	5	235.9616	-121.7773	18.0145

Show Abnormal Report

Show Abnormal Report

Underloaded Lines and Cables:

From Bus	To Bus	P (MW)	Q (MVAR)	Percentage Underloaded %
1	2	162.3907	-17.3530	39.5129
2	4	119.0068	-84.9541	33.5371
3	4	45.9534	-88.6405	33.4372
2	5	-129.3046	-38.2326	55.0539

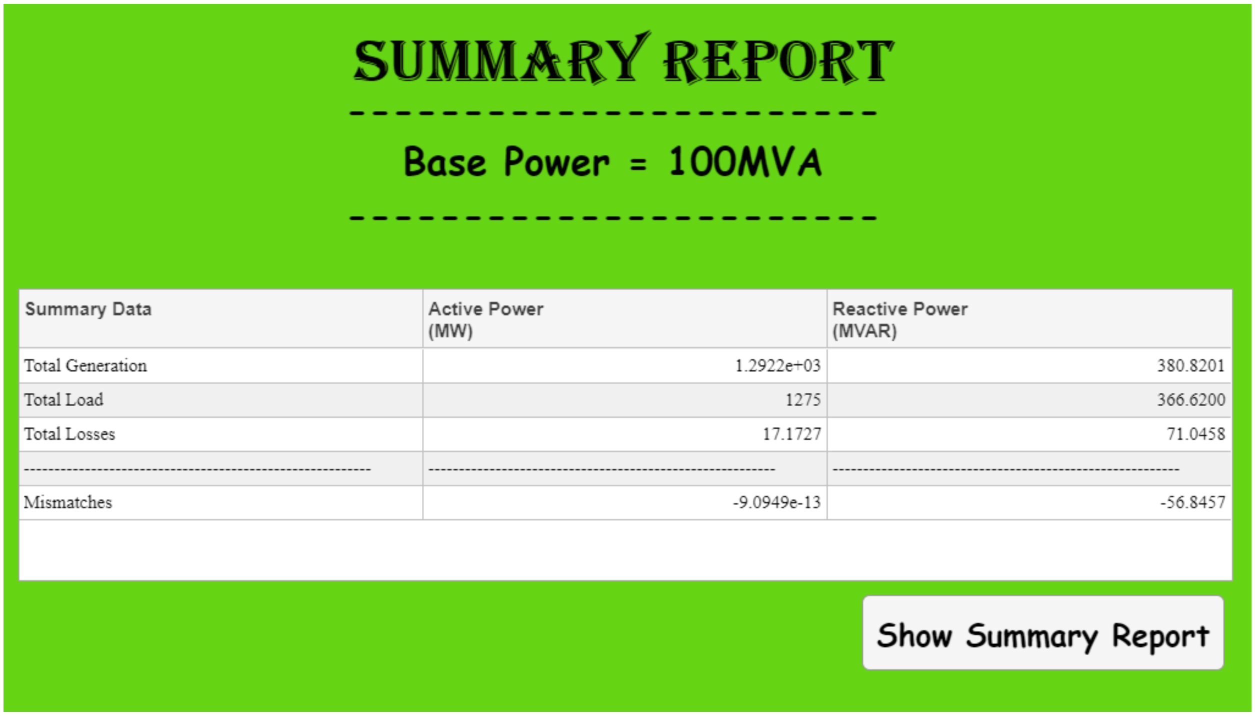
Show Abnormal Report

Buses Outside Voltage Limit:

Bus No. Bus	Loading Condition	Percentage Loaded %

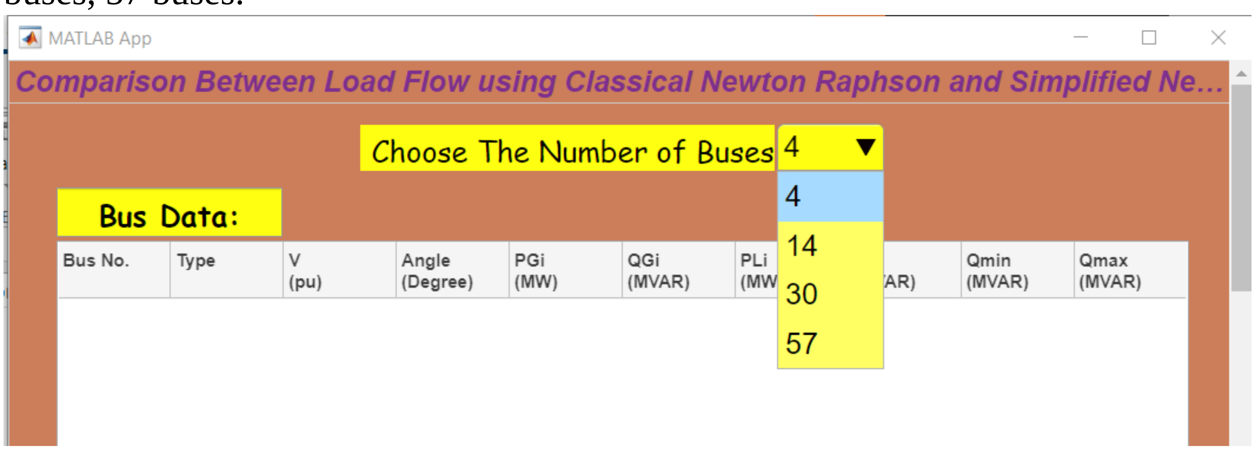
Show Abnormal Report

An overall summary report after completing calculation and analysis is given below:



ii. <u>Choose from Built in Network:</u>

If we click on Built in Network, then this window appears and we can choose from four options of IEEE Standard data- 4 buses, 14 buses, 30 buses, 57 buses.



First, we choose 4 bus. Then the interface is almost similar as user defined network.

Comparison Between Load Flow using Classical Newton Raphson and Simplified Ne...

Choose The Number of Buses 4

Bus Data:

Bus No.	Type	V (pu)	Angle (Degree)	PGi (MW)	QGi (MVAR)	PLi (MW)	QLi (MVAR)	Qmin (MVAR)	Qmax (MVAR)
1	1	1.0000	0	0	0	50	40.0000	0	0
2	3	1.0000	0	0	0	170	105.3500	-40	50
3	3	1.0000	0	0	0	200	123.9400	0	40
4	2	1.0200	0	318	0	480	49.5800	0	0

Description of Type:
1) Slack Bus
2) PV Bus - Load or/and Generator
3) PQ Bus - Load only

Read Bus Data

Line Data:

From Bus	To Bus	R (pu)	X (pu)	B/2 (pu)	X'mer Tap(a)	Loading Limit (MVA)
1	2	0.0101	0.0504	0.0512	1	270
1	3	0.0074	0.0372	0.0387	1	310
2	4	0.0074	0.0372	0.0387	1	220
3	4	0.0127	0.0636	0.0638	1	150

Read Line Data

Analysis and comparison:

Using Newton Raphson:

From Bus	To Bus	P (MW)	Q (MVAR)	From Bus	To Bus	P (MW)	Q (MVAR)	P_loss (MW)	Q_loss (MW)
1	2	259.9730	7.6130	2	1	-253.1545	26.4795	6.8185	34.0925
1	3	289.1671	50.3197	3	1	-282.7576	-18.2720	6.4095	32.0477
2	4	83.1545	-123.2095	4	2	-81.4382	131.7912	1.7163	8.5817
3	4	82.7576	-96.1157	4	3	-80.5618	107.0943	2.1957	10.9786

Perform Analysis

Using Simplified Newton Raphson:

From Bus	To Bus	P (MW)	Q (MVAR)	From Bus	To Bus	P (MW)	Q (MVAR)	P_loss (MW)	Q_loss (MW)
1	2	259.9730	7.6130	2	1	-253.1545	26.4795	6.8185	34.0925
1	3	289.1671	50.3197	3	1	-282.7576	-18.2720	6.4095	32.0477
2	4	83.1545	-123.2095	4	2	-81.4382	131.7912	1.7163	8.5817
3	4	82.7576	-96.1157	4	3	-80.5618	107.0943	2.1957	10.9786

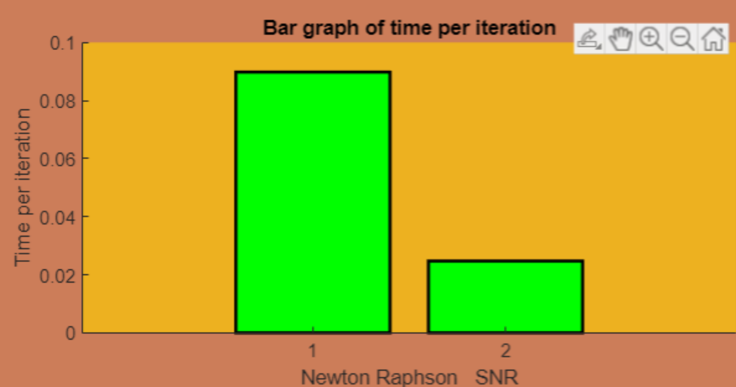
Perform Analysis

Perform Analysis

Comparison:

Method	No Of Iteration	Time Elapsed	Time Per Iteration
Newton Raphson	4	0.3593	0.0898
Simplified Newton Raphson	6	0.1484	0.0247

Show Comparison



However, two graphs are also added here:

Different Reports:

NOW, WE CAN SEE THAT ALL THE VALUES MATCH PERFECTLY FOR THESE TWO TYPES OF METHODS. WE WILL NOW SEE DIFFERENT REPORTS:

Bus Report:

Bus ID	V (pu)	Angle (Degree)	P Gen (MW)	Q Gen (MVAR)	P Load (MW)	Q Load (MW)
1	1.0000	0	599.1401	88.9327	50.0000	40.0000
2	0.9787	-7.6487	0.0000	-0.0000	170.0000	105.3500
3	0.9654	-6.1742	0.0000	0.0000	200.0000	123.9400
4	1.0200	-9.9509	318.0000	277.8014	480.0000	49.5800

Show Bus Report

Load Report:

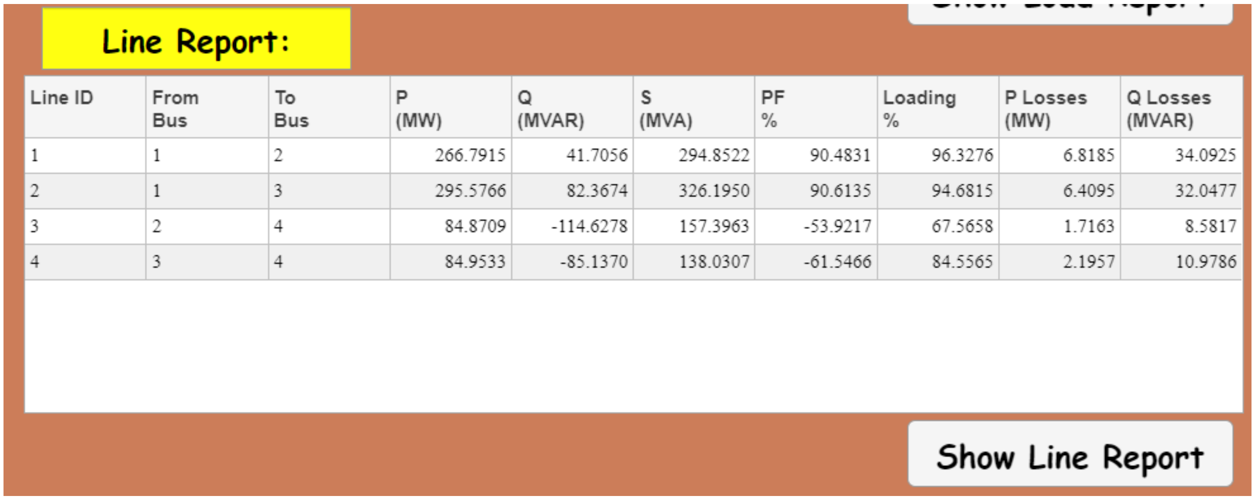
Load ID	Bus ID	P (MW)	Q (MVAR)	S (MVAR)	PF %
1	1	50.0000	40.0000	64.0312	78.0869
2	2	170.0000	105.3500	199.9966	85.0015
3	3	200.0000	123.9400	235.2894	85.0017
4	4	480.0000	49.5800	482.5538	99.4708

Show Load Report

Generator Report:

Generator ID	Bus ID	P (MW)	Q (MVAR)	S (MVA)	PF %	Q max (MVAR)	Q min (MVAR)
1	4	318.0000	277.8014	422.2530	75.3103	0	0

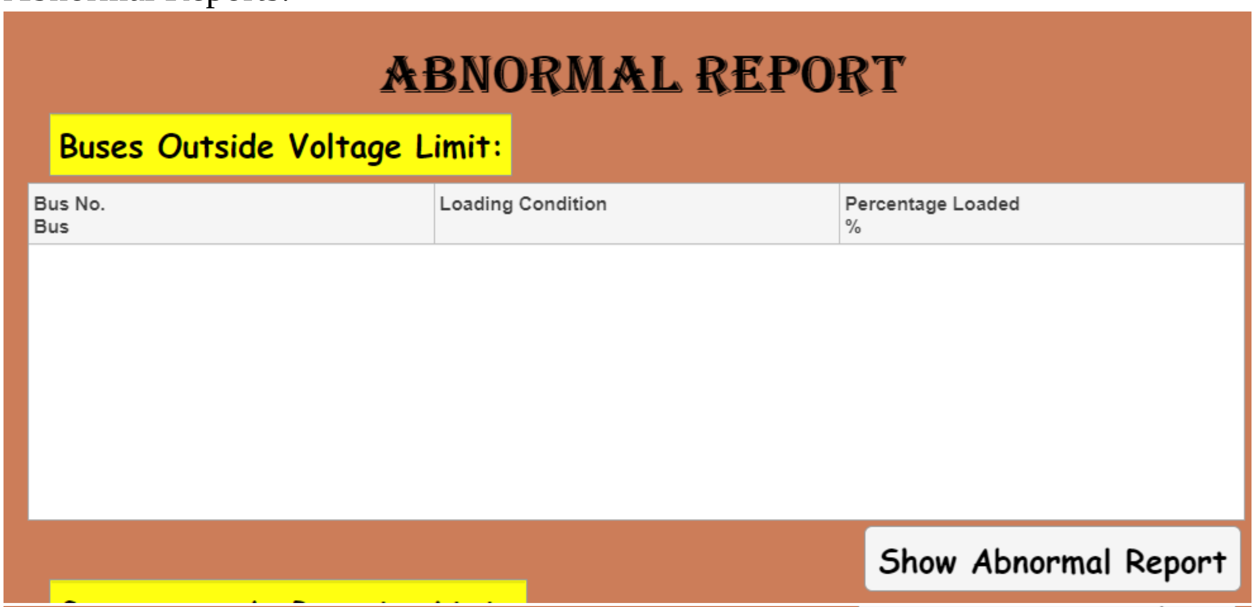
Show Generator Report



Line Report:

Line ID	From Bus	To Bus	P (MW)	Q (MVAR)	S (MVA)	PF %	Loading %	P Losses (MW)	Q Losses (MVAR)
1	1	2	266.7915	41.7056	294.8522	90.4831	96.3276	6.8185	34.0925
2	1	3	295.5766	82.3674	326.1950	90.6135	94.6815	6.4095	32.0477
3	2	4	84.8709	-114.6278	157.3963	-53.9217	67.5658	1.7163	8.5817
4	3	4	84.9533	-85.1370	138.0307	-61.5466	84.5565	2.1957	10.9786

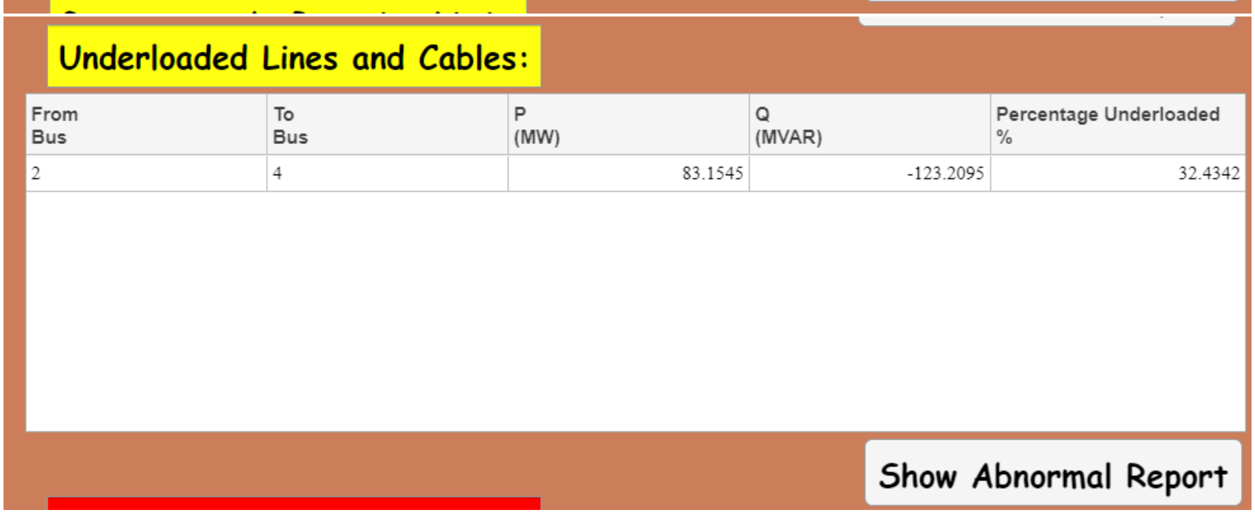
Abnormal Reports:



ABNORMAL REPORT

Buses Outside Voltage Limit:

Bus No. Bus	Loading Condition	Percentage Loaded %



Underloaded Lines and Cables:

From Bus	To Bus	P (MW)	Q (MVAR)	Percentage Underloaded %
2	4	83.1545	-123.2095	32.4342

Overloaded Lines and Cables:

From Bus	To Bus	P (MW)	Q (MVAR)	Percentage Overloaded %

Show Abnormal Report

Generators At Reactive Limit:

Generator ID	From Bus	P-Gen (MW)	Q-Gen (MVAR)	Q-Min (MVAR)	Q-Max (MVAR)	Percentage Outside Limit %
1	4	318.0000	277.8014	0	0	277.8014

Show Abnormal Report

Summary Report:

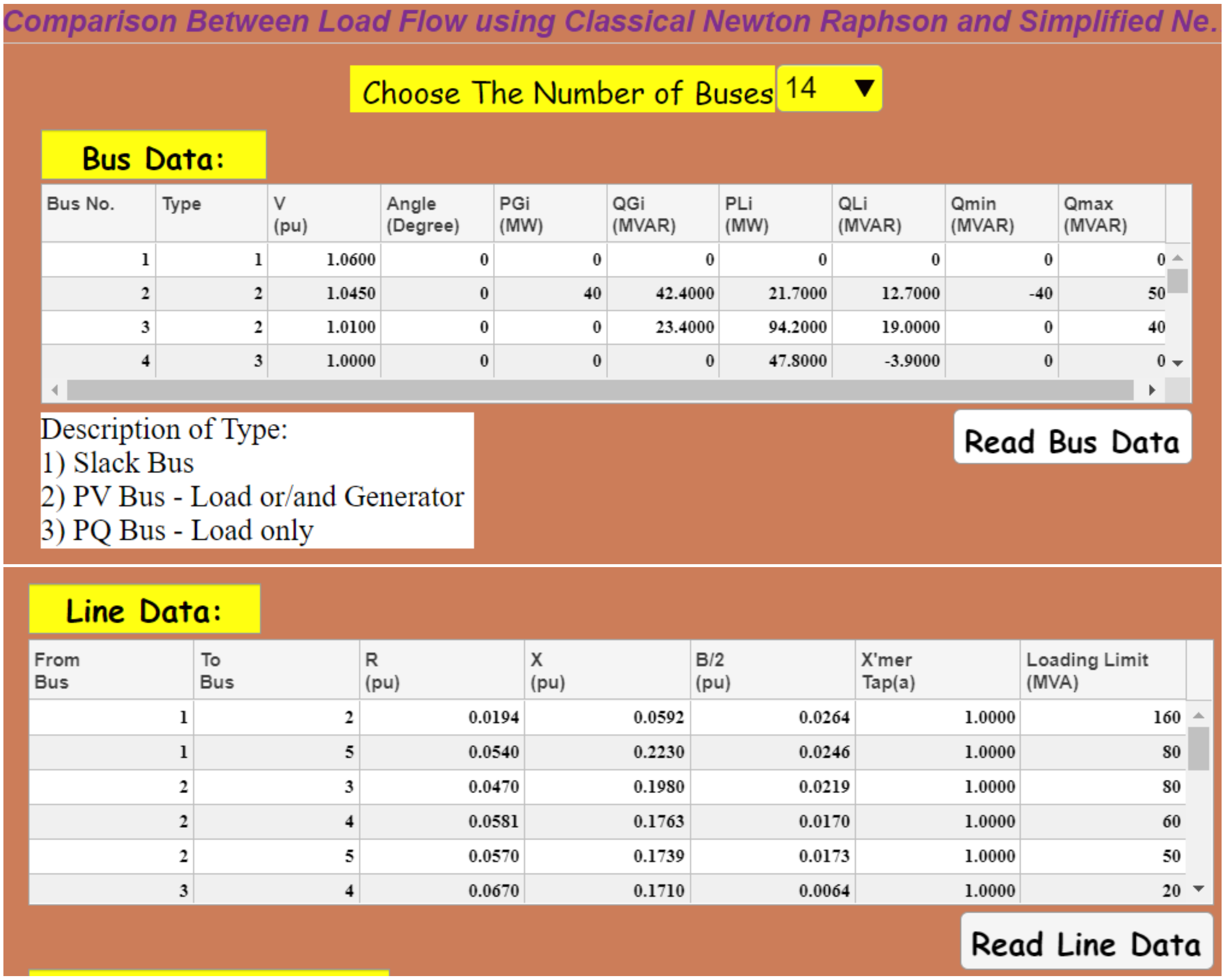
SUMMARY REPORT:

Base Power = 100MVA

Summary Data	Active Power (MW)	Reactive Power (MVAR)
Total Generation	917.1401	366.7341
Total Load	900.0000	318.8700
Total Losses	17.1401	85.7006
---	---	---
Mismatches	-0.0000	-37.8365

Show Summary Report

Then, if we choose 14 bus:



Comparison Between Load Flow using Classical Newton Raphson and Simplified Ne...

Choose The Number of Buses 14

Bus Data:

Bus No.	Type	V (pu)	Angle (Degree)	PGi (MW)	QGi (MVAR)	PLi (MW)	QLi (MVAR)	Qmin (MVAR)	Qmax (MVAR)
1	1	1.0600	0	0	0	0	0	0	0
2	2	1.0450	0	40	42.4000	21.7000	12.7000	-40	50
3	2	1.0100	0	0	23.4000	94.2000	19.0000	0	40
4	3	1.0000	0	0	0	47.8000	-3.9000	0	0

Description of Type:
1) Slack Bus
2) PV Bus - Load or/and Generator
3) PQ Bus - Load only

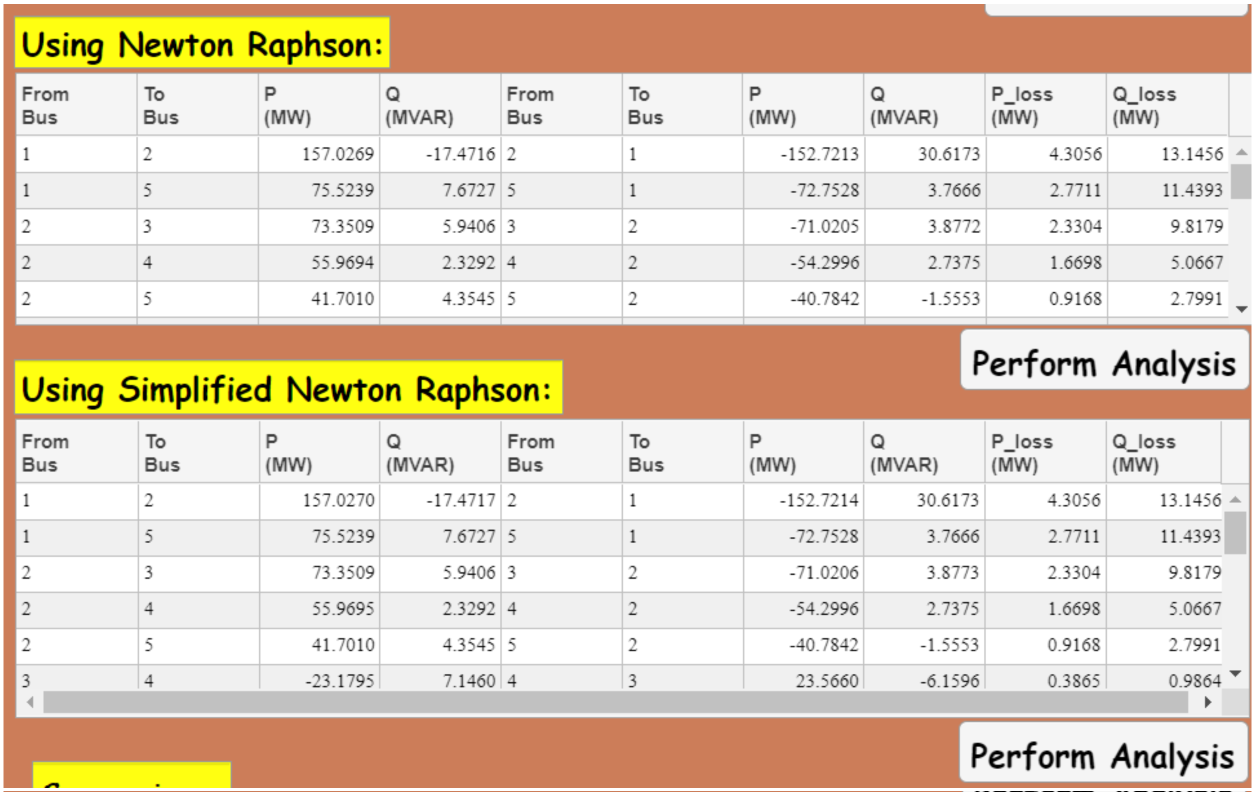
Read Bus Data

Line Data:

From Bus	To Bus	R (pu)	X (pu)	B/2 (pu)	X'mer Tap(a)	Loading Limit (MVA)
1	2	0.0194	0.0592	0.0264	1.0000	160
1	5	0.0540	0.2230	0.0246	1.0000	80
2	3	0.0470	0.1980	0.0219	1.0000	80
2	4	0.0581	0.1763	0.0170	1.0000	60
2	5	0.0570	0.1739	0.0173	1.0000	50
3	4	0.0670	0.1710	0.0064	1.0000	20

Read Line Data

Analysis and Comparison:



Using Newton Raphson:

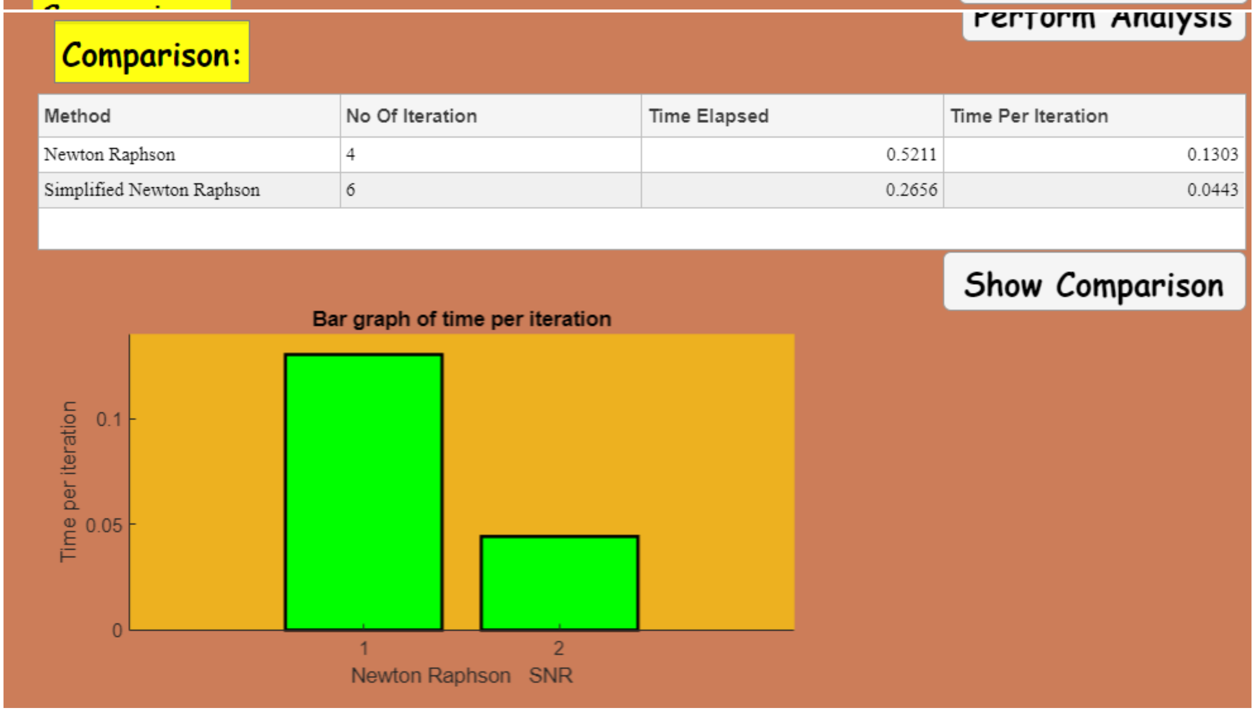
From Bus	To Bus	P (MW)	Q (MVAR)	From Bus	To Bus	P (MW)	Q (MVAR)	P_loss (MW)	Q_loss (MW)
1	2	157.0269	-17.4716	2	1	-152.7213	30.6173	4.3056	13.1456
1	5	75.5239	7.6727	5	1	-72.7528	3.7666	2.7711	11.4393
2	3	73.3509	5.9406	3	2	-71.0205	3.8772	2.3304	9.8179
2	4	55.9694	2.3292	4	2	-54.2996	2.7375	1.6698	5.0667
2	5	41.7010	4.3545	5	2	-40.7842	-1.5553	0.9168	2.7991

Perform Analysis

Using Simplified Newton Raphson:

From Bus	To Bus	P (MW)	Q (MVAR)	From Bus	To Bus	P (MW)	Q (MVAR)	P_loss (MW)	Q_loss (MW)
1	2	157.0270	-17.4717	2	1	-152.7214	30.6173	4.3056	13.1456
1	5	75.5239	7.6727	5	1	-72.7528	3.7666	2.7711	11.4393
2	3	73.3509	5.9406	3	2	-71.0206	3.8773	2.3304	9.8179
2	4	55.9695	2.3292	4	2	-54.2996	2.7375	1.6698	5.0667
2	5	41.7010	4.3545	5	2	-40.7842	-1.5553	0.9168	2.7991
3	4	-23.1795	7.1460	4	3	23.5660	-6.1596	0.3865	0.9864

Perform Analysis



Comparison:

Method	No Of Iteration	Time Elapsed	Time Per Iteration
Newton Raphson	4	0.5211	0.1303
Simplified Newton Raphson	6	0.2656	0.0443

Show Comparison

Different Reports:

NOW, WE CAN SEE THAT ALL THE VALUES MATCH PERFECTLY FOR THESE TWO TYPES OF METHODS. WE WILL NOW SEE DIFFERENT REPORTS:

Bus Report:

Bus ID	V (pu)	Angle (Degree)	P Gen (MW)	Q Gen (MVAR)	P Load (MW)	Q Load (MW)
1	1.0600	0	232.5508	-15.5293	0	0
2	1.0450	-4.9874	40.0000	46.9214	21.7000	12.7000
3	1.0100	-12.7424	-0.0000	27.1364	94.2000	19.0000
4	1.0142	-10.2564	-0.0000	-0.0000	47.8000	-3.9000
5	1.0172	-8.7646	-0.0000	-0.0000	7.6000	1.6000
6	1.0700	-14.4177	0.0000	21.6039	11.2000	7.5000
7	1.0503	-13.2519	0.0000	-0.0000	0	0
8	1.0900	-13.2519	-0.0000	24.5388	0	0

Show Bus Report

Load Report:

Load ID	Bus ID	P (MW)	Q (MVAR)	S (MVAR)	PF %
1	2	21.7000	12.7000	25.1432	86.3057
2	3	94.2000	19.0000	96.0970	98.0259
3	4	47.8000	-3.9000	47.9588	-99.6688
4	5	7.6000	1.6000	7.7666	97.8550
5	6	11.2000	7.5000	13.4792	83.0907
6	9	29.5000	16.6000	33.8498	87.1497
7	10	9.0000	5.8000	10.7070	84.0571
8	11	3.5000	1.8000	3.9357	88.9288

Show Load Report

Show Load Report

Line Report:

Line ID	From Bus	To Bus	P (MW)	Q (MVAR)	S (MVA)	PF %	Loading %	P Losses (MW)	Q Losses (MVAR)
1	1	2	161.3325	-4.3260	171.8287	-93.8915	98.7474	4.3056	13.1456
2	1	5	78.2950	19.1120	87.6828	89.2934	94.8908	2.7711	11.4393
3	2	3	75.6813	15.7585	83.6817	90.4394	91.9888	2.3304	9.8179
4	2	4	57.6393	7.3959	61.3526	93.9475	93.3632	1.6698	5.0667
5	2	5	42.6177	7.1536	44.8731	94.9739	83.8554	0.9168	2.7991
6	3	4	-22.7930	8.1325	25.3154	90.0359	121.2800	0.3865	0.9864
7	4	5	-59.3207	14.0794	62.7117	94.5927	94.0125	0.4846	1.5286
8	4	7	27.2194	-15.1354	34.2574	-79.4555	91.9897	0.0000	2.0610

Show Line Report

Generator Report:

Generator ID	Bus ID	P (MW)	Q (MVAR)	S (MVA)	PF %	Q max (MVAR)	Q min (MVAR)
1	2	40.0000	46.9214	61.6573	64.8747	-40.0000	50.0000
2	3	-0.0000	27.1364	27.1364	0.0000	0	40.0000
3	6	0.0000	21.6039	21.6039	0.0000	-6.0000	24.0000
4	8	-0.0000	24.5388	24.5388	0.0000	-6.0000	24.0000

Show Generator Report

Abnormal Reports:

ABNORMAL REPORT

Buses Outside Voltage Limit:

Bus No. Bus	Loading Condition	Percentage Loaded %
4	Overloaded	1.4232
5	Overloaded	1.7238
7	Overloaded	5.0344
9	Overloaded	3.3711
10	Overloaded	3.2561
11	Overloaded	4.7484
12	Overloaded	5.3501
13	Overloaded	4.7107

Show Abnormal Report

Underloaded Lines and Cables:

From Bus	To Bus	P (MW)	Q (MVAR)	Percentage Underloaded %
5	6	45.6470	-20.5965	33.2285
12	13	1.8488	1.3269	54.4858

Show Abnormal Report

Overloaded Lines and Cables:

From Bus	To Bus	P (MW)	Q (MVAR)	Percentage Overloaded %
3	4	-23.1795	7.1460	21.2800

Show Abnormal Report

Generators At Reactive Limit:

Generator ID	From Bus	P-Gen (MW)	Q-Gen (MVAR)	Q-Min (MVAR)	Q-Max (MVAR)	Percentage Outside Limit %
4	8	-0.0000	24.5388	-6.0000	24.0000	2.2452

Show Abnormal Report

Summary Report:

SUMMARY REPORT:

Base Power = 100MVA

Summary Data	Active Power (MW)	Reactive Power (MVAR)
Total Generation	272.5508	104.6713
Total Load	259.0000	73.5000
Total Losses	13.5508	57.1472
--	--	--
Mismatches	-0.0000	-25.9759

Show Summary Report

Now,30 bus is chosen:

Comparison Between Load Flow using Classical Newton Raphson and Simplified Ne

Choose The Number of Buses 30

Bus Data:

Bus No.	Type	V (pu)	Angle (Degree)	PGi (MW)	QGi (MVAR)	PLi (MW)	QLi (MVAR)	Qmin (MVAR)	Qmax (MVAR)
1	1	1.0600	0	0	0	0	0	0	0
2	2	1.0430	0	40	50.0000	21.7000	12.7000	-40	50
3	3	1.0000	0	0	0	2.4000	1.2000	0	0
4	3	1.0600	0	0	0	7.6000	1.6000	0	0

Read Bus Data

Description of Type:
1) Slack Bus
2) PV Bus - Load or/and Generator
3) PQ Bus - Load only

Line Data:

From Bus	To Bus	R (pu)	X (pu)	B/2 (pu)	X'mer Tap(a)	Loading Limit (MVA)
1	2	0.0192	0.0575	0.0264	1	180
1	3	0.0452	0.1652	0.0204	1	90
2	4	0.0570	0.1737	0.0184	1	50
3	4	0.0132	0.0379	0.0042	1	100
2	5	0.0472	0.1983	0.0209	1	100
2	6	0.0581	0.1763	0.0187	1	100

Read Line Data

Analysis and Comparison:

Read Line Data

Using Newton Raphson:

From Bus	To Bus	P (MW)	Q (MVAR)	From Bus	To Bus	P (MW)	Q (MVAR)	P_loss (MW)	Q_loss (MW)
1	2	173.1430	-18.1076	2	1	-167.9643	33.6169	5.1787	15.5092
1	3	87.7849	6.2478	3	1	-84.6692	5.1398	3.1157	11.3876
2	4	43.6185	5.1943	4	2	-42.6075	-2.1133	1.0110	3.0810
3	4	82.2692	-3.7720	4	3	-81.4115	6.2346	0.8577	2.4626
2	5	82.2929	4.0325	5	2	-79.3475	8.3418	2.9454	12.3743

Perform Analysis

Using Simplified Newton Raphson:

From Bus	To Bus	P (MW)	Q (MVAR)	From Bus	To Bus	P (MW)	Q (MVAR)	P_loss (MW)	Q_loss (MW)
1	2	173.1431	-18.1077	2	1	-167.9643	33.6169	5.1787	15.5092
1	3	87.7850	6.2478	3	1	-84.6692	5.1398	3.1157	11.3876
2	4	43.6185	5.1943	4	2	-42.6075	-2.1133	1.0110	3.0810
3	4	82.2692	-3.7720	4	3	-81.4115	6.2347	0.8577	2.4626
2	5	82.2929	4.0325	5	2	-79.3475	8.3418	2.9454	12.3743
2	6	60.3529	1.4034	6	2	-58.4065	4.5029	1.9464	5.9063

Perform Analysis

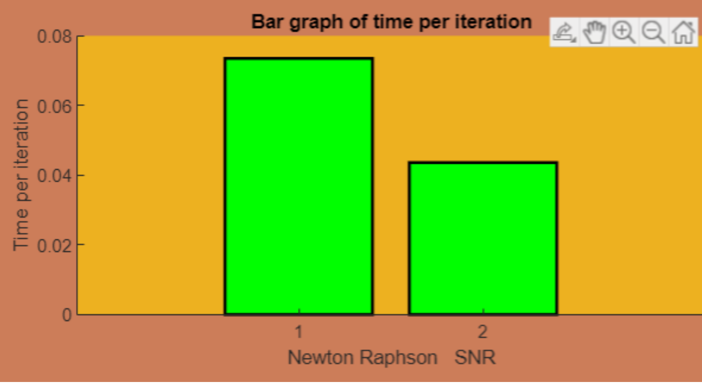
Comparison:

Perform Analysis

Comparison:

Method	No Of Iteration	Time Elapsed	Time Per Iteration
Newton Raphson	4	0.2940	0.0735
Simplified Newton Raphson	7	0.3053	0.0436

Show Comparison



Different Reports:

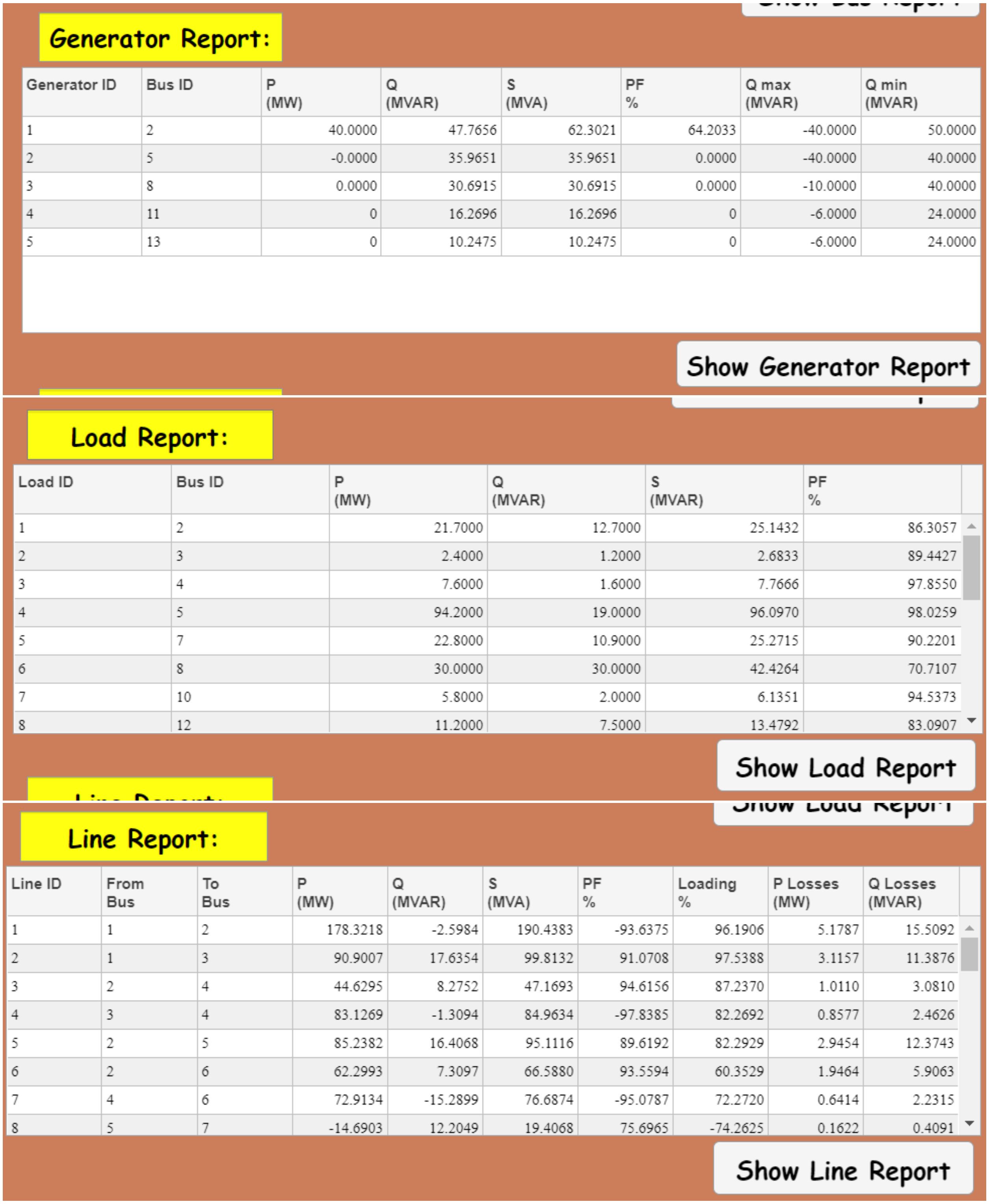
NOW, WE CAN SEE THAT ALL THE VALUES MATCH PERFECTLY FOR THESE TWO TYPES OF METHODS. WE WILL NOW SEE DIFFERENT REPORTS:

Bus Report:

Bus ID	V (pu)	Angle (Degree)	P Gen (MW)	Q Gen (MVAR)	P Load (MW)	Q Load (MW)
1	1.0600	0	260.9280	-17.1183	0	0
2	1.0430	-5.3474	40.0000	47.7656	21.7000	12.7000
3	1.0217	-7.5448	-0.0000	0.0000	2.4000	1.2000
4	1.0129	-9.2989	0.0000	0.0000	7.6000	1.6000
5	1.0100	-14.1542	-0.0000	35.9651	94.2000	19.0000
6	1.0121	-11.0880	0.0000	0.0000	0	0
7	1.0035	-12.8734	-0.0000	-0.0000	22.8000	10.9000
8	1.0100	-11.8039	0.0000	30.6915	30.0000	30.0000

Show Bus Report

Generator Report:



Generator Report:

Generator ID	Bus ID	P (MW)	Q (MVAR)	S (MVA)	PF %	Q max (MVAR)	Q min (MVAR)
1	2	40.0000	47.7656	62.3021	64.2033	-40.0000	50.0000
2	5	-0.0000	35.9651	35.9651	0.0000	-40.0000	40.0000
3	8	0.0000	30.6915	30.6915	0.0000	-10.0000	40.0000
4	11	0	16.2696	16.2696	0	-6.0000	24.0000
5	13	0	10.2475	10.2475	0	-6.0000	24.0000

Show Generator Report

Load Report:

Load ID	Bus ID	P (MW)	Q (MVAR)	S (MVAR)	PF %
1	2	21.7000	12.7000	25.1432	86.3057
2	3	2.4000	1.2000	2.6833	89.4427
3	4	7.6000	1.6000	7.7666	97.8550
4	5	94.2000	19.0000	96.0970	98.0259
5	7	22.8000	10.9000	25.2715	90.2201
6	8	30.0000	30.0000	42.4264	70.7107
7	10	5.8000	2.0000	6.1351	94.5373
8	12	11.2000	7.5000	13.4792	83.0907

Show Load Report

Line Report:

Line ID	From Bus	To Bus	P (MW)	Q (MVAR)	S (MVA)	PF %	Loading %	P Losses (MW)	Q Losses (MVAR)
1	1	2	178.3218	-2.5984	190.4383	-93.6375	96.1906	5.1787	15.5092
2	1	3	90.9007	17.6354	99.8132	91.0708	97.5388	3.1157	11.3876
3	2	4	44.6295	8.2752	47.1693	94.6156	87.2370	1.0110	3.0810
4	3	4	83.1269	-1.3094	84.9634	-97.8385	82.2692	0.8577	2.4626
5	2	5	85.2382	16.4068	95.1116	89.6192	82.2929	2.9454	12.3743
6	2	6	62.2993	7.3097	66.5880	93.5594	60.3529	1.9464	5.9063
7	4	6	72.9134	-15.2899	76.6874	-95.0787	72.2720	0.6414	2.2315
8	5	7	-14.6903	12.2049	19.4068	75.6965	-74.2625	0.1622	0.4091

Show Line Report

Abnormal Reports:

ABNORMAL REPORT

Buses Outside Voltage Limit:

Bus No. Bus	Loading Condition	Percentage Loaded %
3	Overloaded	2.1675
6	Overloaded	1.2084
7	Overloaded	0.3468
9	Overloaded	5.0724
10	Overloaded	4.3758
12	Overloaded	5.7605
14	Overloaded	4.2879
15	Overloaded	3.8445

Show Abnormal Report

Generators At Reactive Limit:

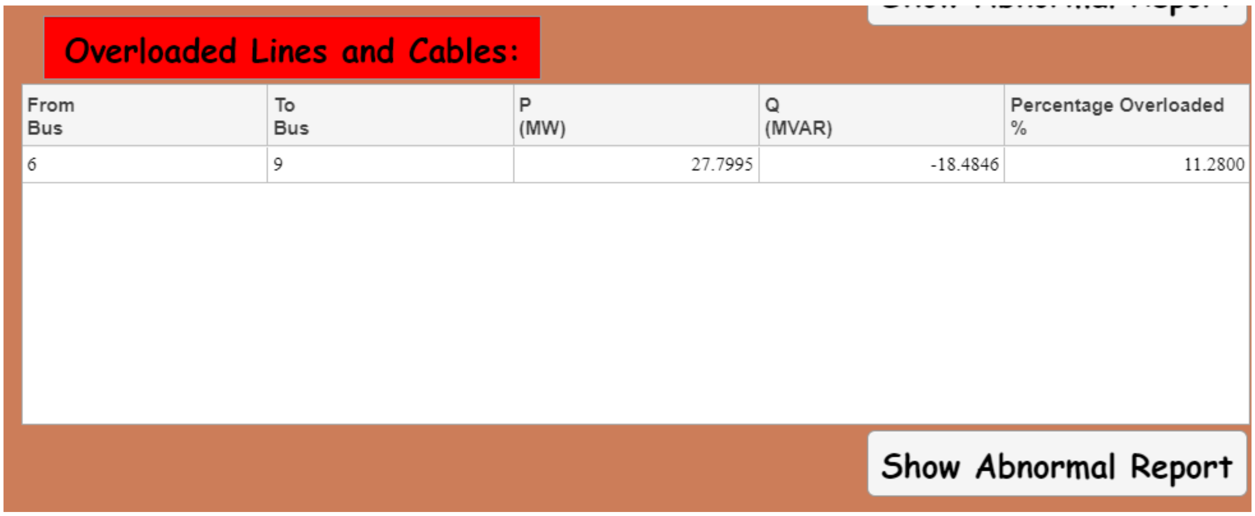
Generator ID	From Bus	P-Gen (MW)	Q-Gen (MVAR)	Q-Min (MVAR)	Q-Max (MVAR)	Percentage Outside Limit %

Show Abnormal Report

Underloaded Lines and Cables:

From Bus	To Bus	P (MW)	Q (MVAR)	Percentage Underloaded %
2	6	60.3529	1.4034	39.6308
24	25	-1.1415	1.7477	30.4182

Show Abnormal Report

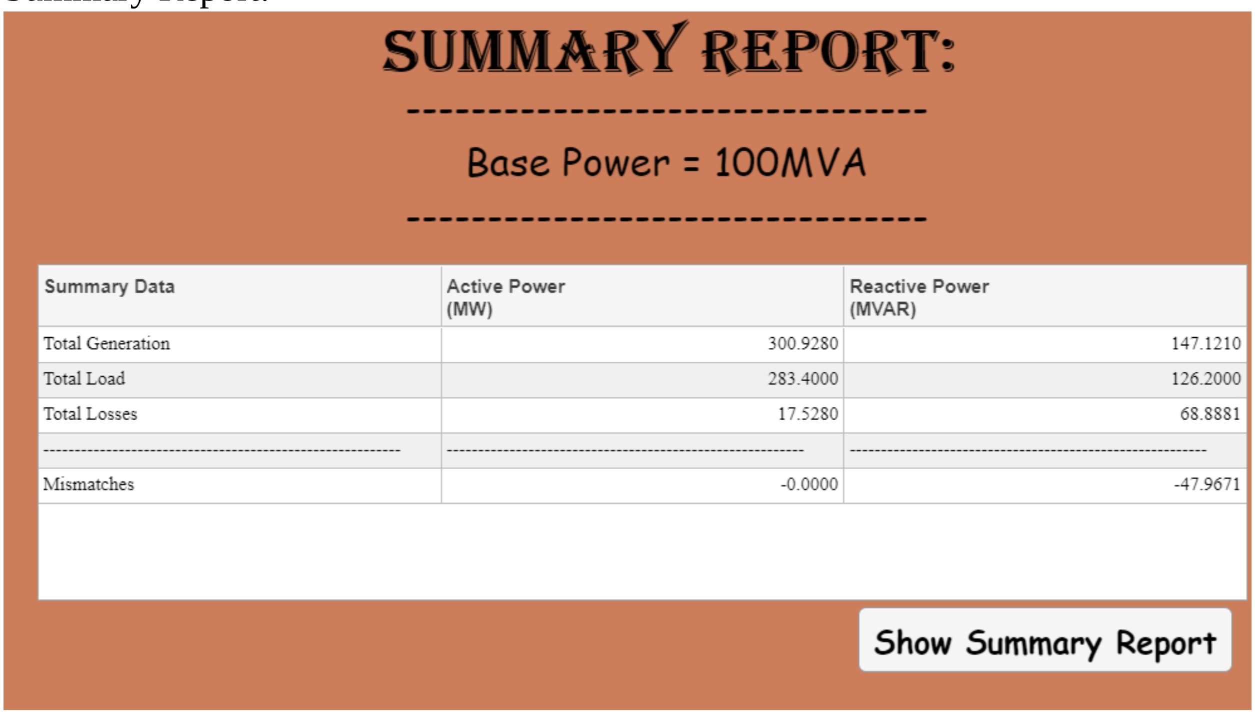


Overloaded Lines and Cables:

From Bus	To Bus	P (MW)	Q (MVAR)	Percentage Overloaded %
6	9	27.7995	-18.4846	11.2800

Show Abnormal Report

Summary Report:



SUMMARY REPORT:

Base Power = 100MVA

Summary Data	Active Power (MW)	Reactive Power (MVAR)
Total Generation	300.9280	147.1210
Total Load	283.4000	126.2000
Total Losses	17.5280	68.8881
--	--	--
Mismatches	-0.0000	-47.9671

Show Summary Report

Finally, if we choose 57 bus:

Comparison Between Load Flow using Classical Newton Raphson and Simplified Ne..

Choose The Number of Buses 57

Bus Data:

Bus No.	Type	V (pu)	Angle (Degree)	PGi (MW)	QGi (MVAR)	PLi (MW)	QLi (MVAR)	Qmin (MVAR)	Qmax (MVAR)
1	1	1.0400	0	0	0	0	0	0	0
2	2	1.0100	0	3	88	0	-0.8000	-17	50
3	2	0.9850	0	41	21	40	-1.0000	-10	60
4	3	1.0000	0	0	0	0	0	0	0

Description of Type:
1) Slack Bus
2) PV Bus - Load or/and Generator
3) PQ Bus - Load only

Read Bus Data

Line Data:

From Bus	To Bus	R (pu)	X (pu)	B/2 (pu)	X'mer Tap(a)	Loading Limit (MVA)
1	2	0.0083	0.0280	0.0645	1	160
2	3	0.0298	0.0850	0.0409	1	120
3	4	0.0112	0.0366	0.0190	1	60
4	5	0.0625	0.1320	0.0129	1	15
4	6	0.0430	0.1480	0.0174	1	15
6	7	0.0200	0.1020	0.0138	1	40

Read Line Data

Analysis and Comparison:

Using Newton Raphson:

From Bus	To Bus	P (MW)	Q (MVAR)	From Bus	To Bus	P (MW)	Q (MVAR)	P_loss (MW)	Q_loss (MW)
1	2	-80.4311	137.2261	2	1	82.3726	-130.6765	1.9415	6.5496
2	3	-79.3726	61.9056	3	2	82.3325	-53.4628	2.9599	8.4428
3	4	-51.5657	2.3181	4	3	51.8733	-1.3130	0.3076	1.0051
4	5	-10.3415	6.2685	5	4	10.4347	-6.0716	0.0932	0.1969
4	6	-10.2138	9.9176	6	4	10.3027	-9.6117	0.0889	0.3059

Perform Analysis

Using Simplified Newton Raphson:

From Bus	To Bus	P (MW)	Q (MVAR)	From Bus	To Bus	P (MW)	Q (MVAR)	P_loss (MW)	Q_loss (MW)
1	2	-80.4311	137.2261	2	1	82.3726	-130.6765	1.9415	6.5496
2	3	-79.3726	61.9056	3	2	82.3325	-53.4628	2.9599	8.4428
3	4	-51.5658	2.3181	4	3	51.8733	-1.3130	0.3076	1.0051
4	5	-10.3415	6.2685	5	4	10.4347	-6.0716	0.0932	0.1969
4	6	-10.2138	9.9176	6	4	10.3027	-9.6117	0.0889	0.3059
6	7	21.5113	-27.9348	7	6	-21.2524	29.2550	0.2589	1.3202

Perform Analysis

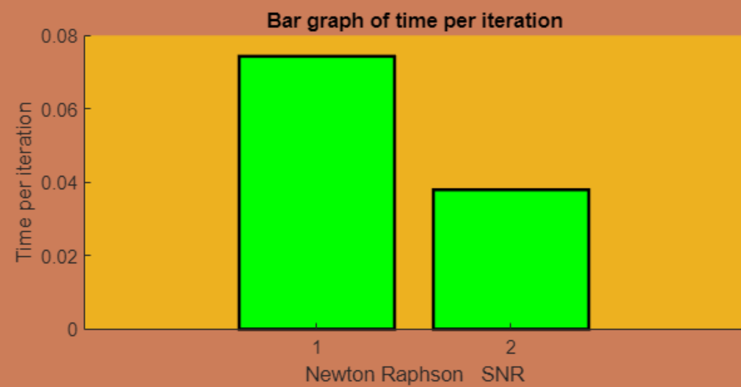
Comparison:

Perform Analysis

Comparison:

Method	No Of Iteration	Time Elapsed	Time Per Iteration
Newton Raphson	5	0.3715	0.0743
Simplified Newton Raphson	6	0.2277	0.0380

Show Comparison



Different Reports:

NOW, WE CAN SEE THAT ALL THE VALUES MATCH PERFECTLY FOR THESE TWO TYPES OF METHODS. WE WILL NOW SEE DIFFERENT REPORTS:

Bus Report:

Bus ID	V (pu)	Angle (Degree)	P Gen (MW)	Q Gen (MVAR)	P Load (MW)	Q Load (MW)
1	1.0400	0	-367.7925	230.8737	0	0
2	1.0100	1.8500	3.0000	-80.3227	0	-0.8000
3	0.9850	6.8042	41.0000	-110.9090	40.0000	-1.0000
4	0.9902	7.9282	-0.0000	-0.0000	0	0
5	0.9885	8.9567	13.0000	4.0000	0	0
6	0.9800	9.0726	75.0000	-75.3705	0	0.8000
7	1.0051	7.4711	-0.0000	-0.0000	0	0
8	1.0050	4.0535	150.0000	193.1156	450.0000	62.1000

Show Bus Report

Generator Report:

Generator ID	Bus ID	P (MW)	Q (MVAR)	S (MVA)	PF %	Q max (MVAR)	Q min (MVAR)
1	2	3.0000	-80.3227	80.3787	-3.7323	-17.0000	50.0000
2	3	41.0000	-110.9090	118.2447	-34.6739	-10.0000	60.0000
3	6	75.0000	-75.3705	106.3284	-70.5362	-8.0000	25.0000
4	8	150.0000	193.1156	244.5274	61.3428	-140.0000	200.0000
5	9	121.0000	-174.7710	212.5697	-56.9225	-3.0000	9.0000
6	12	377.0000	74.7984	384.3485	98.0881	-150.0000	155.0000

Show Generator Report

Load Report:

Load ID	Bus ID	P (MW)	Q (MVAR)	S (MVAR)	PF %
1	3	40.0000	-1.0000	40.0125	-99.9688
2	8	450.0000	62.1000	454.2647	99.0612
3	12	310.0000	128.5000	335.5775	92.3781

Show Load Report

Line Report:

Line ID	From Bus	To Bus	P (MW)	Q (MVAR)	S (MVA)	PF %	Loading %	P Losses (MW)	Q Losses (MVAR)
1	1	2	-78.4896	143.7757	165.8915	47.3138	99.4126	1.9415	6.5496
2	2	3	-76.4127	70.3483	109.6060	69.7158	83.8828	2.9599	8.4428
3	3	4	-51.2582	3.3232	52.6689	97.3215	86.0297	0.3076	1.0051
4	4	5	-10.2483	6.4654	12.3109	83.2460	80.6201	0.0932	0.1969
5	4	6	-10.1250	10.2236	14.5552	69.5624	94.9108	0.0889	0.3059
6	6	7	21.7702	-26.6146	36.6029	-59.4767	88.1437	0.2589	1.3202
7	6	8	46.5972	-16.3826	54.9106	-84.8602	100.5432	0.8921	4.5524
8	8	9	-170.3454	112.9513	217.5493	78.3020	98.8230	3.8289	19.5315

Show Line Report

Abnormal Reports:

ABNORMAL REPORT

Buses Outside Voltage Limit:

Bus No. Bus	Loading Condition	Percentage Loaded %
7	Overloaded	0.5078
10	Overloaded	2.1559
11	Overloaded	0.9661
13	Overloaded	1.7585
14	Overloaded	2.2756
15	Overloaded	1.6997
16	Overloaded	2.8055
17	Overloaded	4.0533

Show Abnormal Report

Generators At Reactive Limit:

Generator ID	From Bus	P-Gen (MW)	Q-Gen (MVAR)	Q-Min (MVAR)	Q-Max (MVAR)	Percentage Outside Limit %
1	2	3.0000	-80.3227	-17	50	372.4867
2	3	41.0000	-110.9090	-10	60	1.0091e+03
3	6	75.0000	-75.3705	-8	25	842.1318
5	9	121.0000	-174.7710	-3	9	5.7257e+03

Show Abnormal Report

Underloaded Lines and Cables:

From Bus	To Bus	P (MW)	Q (MVAR)	Percentage Underloaded %
9	12	-3.1463	-10.9352	43.1060
1	16	-69.3306	26.7920	32.4298

Show Abnormal Report

Overloaded Lines and Cables:

From Bus	To Bus	P (MW)	Q (MVAR)	Percentage Overloaded %
6	8	45.7052	-20.9350	0.5432
41	43	12.3209	9.3506	3.1159

Show Abnormal Report

Summary Report:

SUMMARY REPORT:

Base Power = 100MVA

Summary Data	Active Power (MW)	Reactive Power (MVAR)
Total Generation	828.0075	193.8144
Total Load	800.0000	191.8000
Total Losses	28.0075	187.2187
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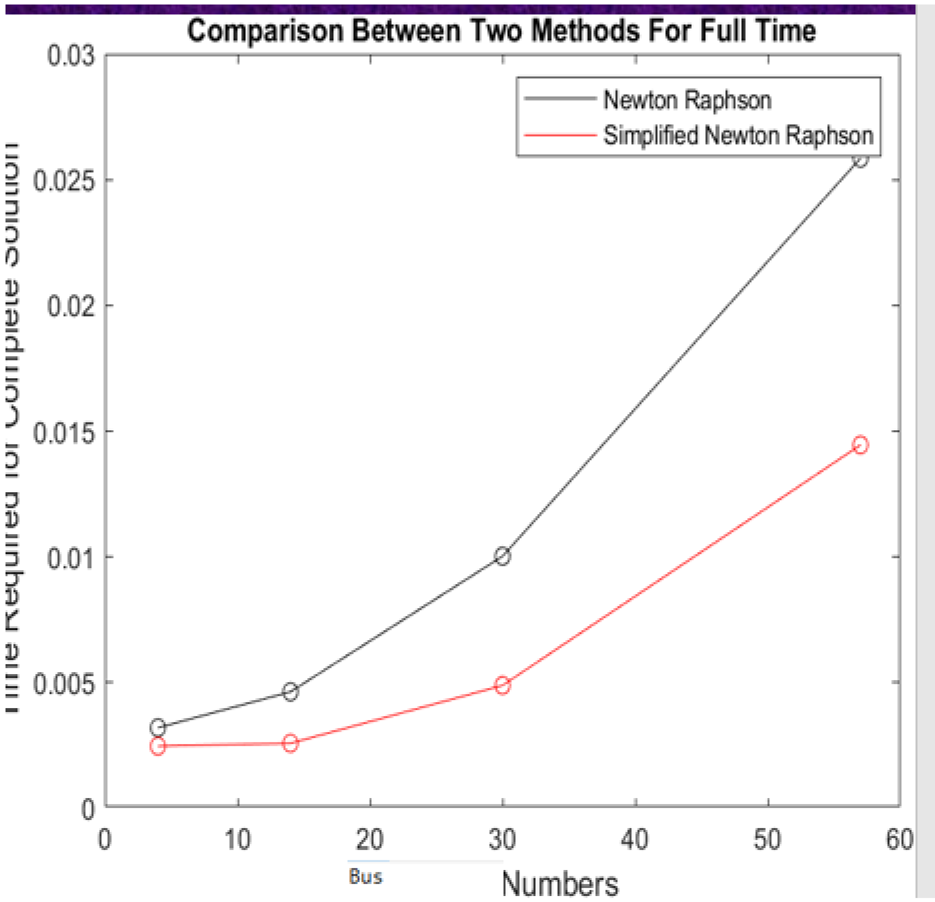
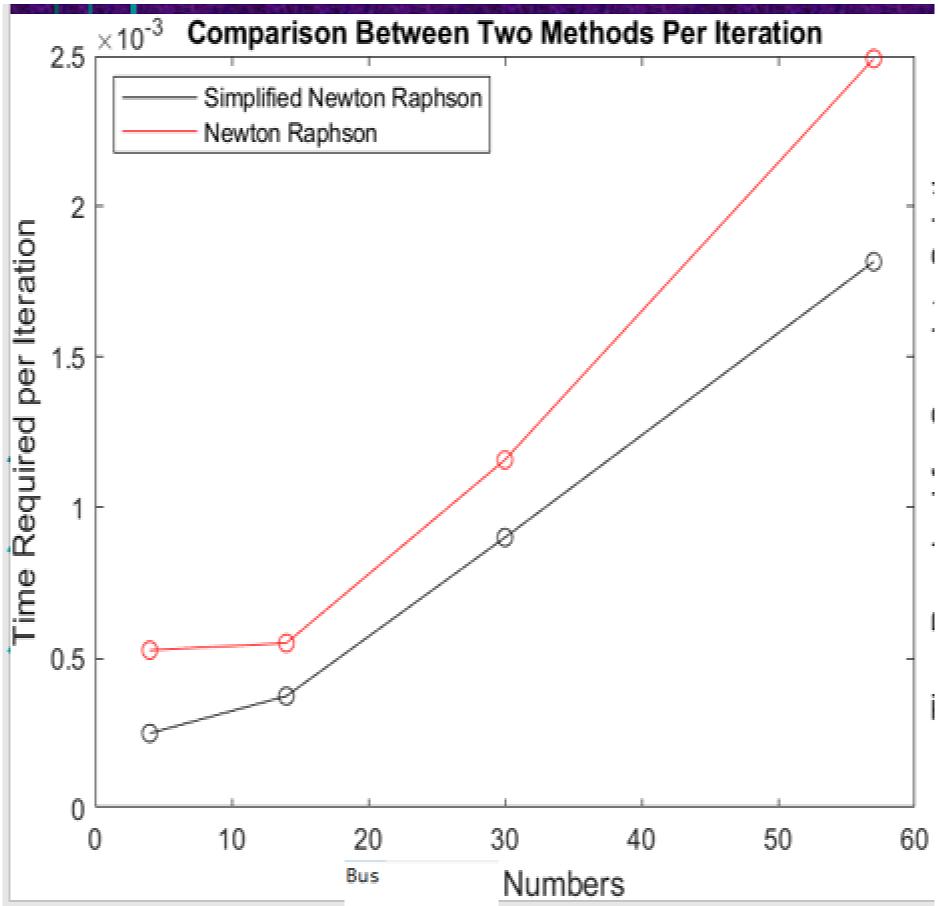
Mismatches	0.0000	-185.2043

Show Summary Report

Finally, we have compiled the results for these four options and plotted two graphs. One graph is for the total time elapsed:



We can see that, for SNR method, with the number of buses increasing, the time does not increase as rapidly as Newton-raphson Method i.e. the slope is less sharp. The other graph will show the time per iteration varying for different bus numbers:



Discussion:

The main advantage of this project is an improved algorithm of Simplified Newton-raphson method. We can see clearly from the graphs that this method is performing significantly better than Newton-raphson method. However, we also tried to give the user an improved experience. So, in this app, the user can perform the operations separately, so the user does not have to press all the buttons sequentially to get the desired result. He/she can just press the 'perform analysis' or 'show comparison' button and see the results. Though there is no option for loading limit of transformers and the resistances and reactances of transformers cannot be input separately in our project.

We could work on this project in future by implementing LU factorization. Currently, we are using inverse matrix systems, which is time-consuming for big network.