ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

Determination of Location of FACTS Devices using Sensitivity Index

Jyoti Saraswat[1], Ankush Kumar Sharma[2]

Assistant Professor, Dept. of EE, Baddi University of Emerging Sciences &Technology, Baddi, H.P, India[1]

M.Tech Student [PE&D],Dept. of EE, Baddi University of Emerging Sciences &Technology, Baddi, H.P, India[2]

ABSTRACT:Power flow analysis is a necessary tool for power system designing, operation, planning, control and its economic scheduling. It gives information about the voltage, power angle, active and reactive power flow in the transmission lines and losses, using these parameters necessary steps can be taken to mitigate power quality issues. In this load flow is analysed using Newton – Raphson and Gauss – Seidel for IEEE 30 bus system. The voltage and angle find out using load flow is used for locating the optimal location for FACTS device.

With the increase of demand, the transmission lines operates at their stability limits. If the demand is further increased the transmission line gets congested and unable to fulfil that increased demand or system may collapse. For this, we use Flexible AC transmission system devices, since they can increase the usage capability of transmission system by controlling power flow in the network. In this paper location for FACTS device is find out using reduction of total system VAR power losses.

KEYWORDS: Load flow, Newton – Raphson, Gauss – Seidel, Sensitivity analysis, FACTS

I.INTRODUCTION

Load flow study in power system is the steady state solution of the power system network. The power system is modelled by an electric network and solved for the steady-state powers and voltages at various buses. The direct analysis of the circuit is not possible as the load are given in terms of complex power rather than impedances and the generators behave more like power sources than voltage sources[5].

Power flow studies, commonly referred to as load flow, are the backbone of power system analysis and design. They are necessary for planning, operation, economic scheduling and exchange of power between utilities. They are also suitable for analyses such as transient stability and contingency studies [6].

In solving a power flow problem the system is assumed to be operating under balanced condition and a single phase model is used [6]. The load flow analysis gives the information about active, reactive power flow, magnitudes and phase angle of voltages at each bus. The system buses are of following types:-

(i) Slack bus or swing bus: **-** In this, magnitude and phase angle of bus is specified.

(ii) Load bus: **-** In this, active and reactive power are specified. The magnitude and phase angle of bus voltage is unknown. These buses are also called as PQ bus.

(iii)Regulated bus: **-** In this bus, active power and voltage magnitude are specified. These bus are also called as generator bus or PV bus.

The state of power system and the methods of calculating this state are very important in evaluating the operation and control of power system and determination of future expansion for this system. The state of any power system can be determined using load flow analysis that calculates the power flowing through the lines of the system. Developments have been made in finding digital computer solutions for power-system load flows. This involves increasing the reliability and the speed of convergence of the numerical-solution techniques. There are different methods to determine the load flow for a particular system such as Gauss-Seidel, Newton-Raphson and Fast decoupled methods [6].

FACTS devices are used for transmission congestion and better utilization of present transmission system. There are lots of issues associated with the FACTS devices such as cost, controlling, proper locations etc [7]. This paper deals with location for FACTS device using sensitivity analysis. In this first load flow is studied using Newton – Raphson and Gauss – Seidel and then voltage and phase angle are used for location of FACTS device using total system reactive power loss.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

II.POWER FLOW EQUATIONS

Consider a system having n buses as shown in Fig. 1.The transmission lines are represented by their equivalent network where impedances are converted into per unit admittances on a common MVA base. By applying KVL to the system we get equations for bus voltages and equation for power flowing.

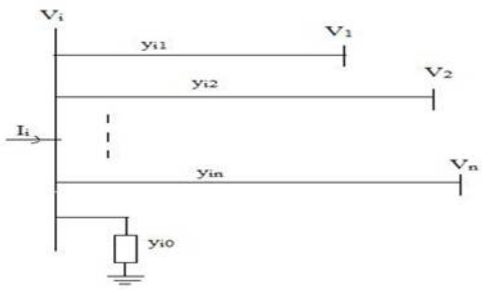

Fig. 1 A n bus system in power system

Applying KVL to this bus system:

$I_i = y_{i0}V_{i0} + y_{i1} (V_i – V_1) + y_{i2} (V_i – V_2) +……… + y_{in} (V_i – V_n)$

$= (y_{i0} + y_{i1} + y_{i2} + …+ y_{in}) V_i - y_{i1} V_1 - y_{i2} V_2 - . . . - y_{in} V_n$ (1)

$I_i = V_i\sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij}V_j \quad i \neq j$ (2)

Where,

I_i = current flowing in bus i

V_i = voltage at bus i

$V_1 , V_2 , . . . V_n$ are the voltages at buses 1 , 2 , . . . n respectively

Now, active and reactive power flowing at bus i is given as:

$P_i + jQ_i = V_i I_i^*$

$I_i = \frac{P_i - Q_i}{V_i^*}$ (3)

Putting the value of I_i from 1.2 in equation 1.3 getting equation as:

$\frac{P_i - Q_i}{V_i^*} = V_i\sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij}V_j$ (4)

So these are the equations involved for active and reactive power flowing from buses 1 to n

Power flow solution using Gauss–Seidel analysis

Gauss–Seidel is the iterative method for calculating the variables involved in load flow flow analysis. It is used because of its simplicity in solving the load flow calculations. In load flow analysis a set of equations are solved for two unknown variables at each node. In GS method the iterative sequence for calculation of V_i for equation 4 is given as:

$$V_i^{K+1} = \frac{\frac{P_i^{sh} - Q_i^{sh}}{V_i^{*k}} + \sum_{j=1}^{n} y_{ij}V_j^k}{\sum_{j=0}^{n} y_{ij}} \quad (5)$$

Where,

y_{ij} = admittance in per unit

P_i^{sh}= active power in per unit flowing through transmission line

Q_i^{sh} = reactive power in per unit flowing through transmission line

For PV buses P_i^{sh} and Q_i^{sh} have positive values because power is flowing in the bus and for PQ buses P_i^{sh} and Q_i^{sh} have negative values because the power is flowing away from the bus. The iterative solution for active and reactive power flow is given as:

$P_i^{k+1} = R \{ V_i^{*k} [V_i^k\sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j^k]\} j \neq i$ (6)

$Q_i^{k+1} = - I \{ V_i^{*k} [V_i^k\sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j^k]\} j \neq i$ (7)

The voltage magnitude and phase angle is known for slack bus. So, there are 2(n-1) equations which are to solve by iterative method. Voltage magnitude at load bus is lower than slack bus whereas voltage magnitude at generator bus may be larger than slack bus. Phase angle of load bus is lower than slack bus whereas phase angle of generator bus is more depending upon active power flow [6].

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

For PQ bus P_i^{sh} and Q_i^{sh} is known, it is used to solve equation 1.8 from that phase angle and voltage magnitude is calculated. For PV bus P_i^{sh} and $| V_i |$ are known and equation 7 is solved for Q_i^{k+1}, this calculated value is used to solve equation 5 , after solving voltage angle is calculated and voltage magnitude remain same.

The iteration process continues until the convergence occurs criteria is not specified. The convergence criteria is given as:

$$|\Delta V_i^{k+1}| = | V_i^{k+1}| - | V_i^{k+1}| \le \varepsilon \quad (8)$$

Power flow solution using Newton- Raphson analysis

Newton Raphson is quadratic in convergence and is less prone to divergence with ill conditioned problems. So it is superior to G-S method. The numbers of iteration required to obtain the solution is independent to the size of network but more functional evaluations are required at each iterations. The newton Raphson is written in polar form. From equation 2 current entering at bus i is given as [6]:

$$I_i = \sum_{j=1}^{n} Y_{ij} Vj \quad (9)$$

By writing this equation in polar form

$$I_i = \sum_{j=1}^{n} |Y_{ij}| \, |V_j| \angle\theta_{ij} + \delta_j \quad (10)$$

The complex power flowing at bus i is given as

$$P_i - jQ_i = V_i^* I_i \quad (11)$$

By putting the value of I_i in equation 11

$$P_i - jQ_i = | V_i | \angle{-\delta_i} \sum_{j=1}^{n} |Y_{ij}| \, |V_j| \angle\theta_{ij} + \delta_j \quad (12)$$

After separating real and imaginary parts equation 12 becomes

$$P_i = \sum_{j=1}^{n} |Y_{ij}| \, |V_j| \, |V_i| \cos(\theta_{ij} - \delta i + \delta_j) \quad (13)$$

$$Q_i = -\sum_{j=1}^{n} |Y_{ij}| \, |V_j| \, |V_i| \sin(\theta_{ij} - \delta i + \delta_j) \quad (14)$$

By expanding non-linear equations 13 and 14 using Taylor's series about all initial estimates and neglecting all higher order terms results in following sets of linear equations[8],[9].

$$\begin{bmatrix} \Delta P_2^k \\ \vdots \\ \Delta P_n^k \\ \Delta Q_2^k \\ \vdots \\ \Delta Q_n^k \end{bmatrix} = \left[\begin{array}{c|c} \begin{pmatrix} \frac{\partial P_2^k}{\partial \delta_2} & \cdots & \frac{\partial P_2^k}{\partial \delta_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n^k}{\partial \delta_2} & \cdots & \frac{\partial P_n^k}{\partial \delta_n} \end{pmatrix} & \begin{pmatrix} \frac{\partial P_2^k}{\partial | V_2|} & \cdots & \frac{\partial P_2^k}{\partial | V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n^k}{\partial | V_2|} & \cdots & \frac{\partial P_n^k}{\partial | V_n|} \end{pmatrix} \\ \hline \begin{pmatrix} \frac{\partial Q_2^k}{\partial \delta_2} & \cdots & \frac{\partial Q_2^k}{\partial \delta_2} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n^k}{\partial \delta_2} & \cdots & \frac{\partial Q_n^k}{\partial \delta_n} \end{pmatrix} & \begin{pmatrix} \frac{\partial Q_2^k}{\partial | V_2|} & \cdots & \frac{\partial Q_2^k}{\partial | V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n^k}{\partial | V_2|} & \cdots & \frac{\partial Q_n^k}{\partial | V_n|} \end{pmatrix} \end{array}\right] \begin{bmatrix} \Delta\delta_2^k \\ \vdots \\ \Delta\delta_n^k \\ \Delta|V_2^k| \\ \vdots \\ \Delta|V_n^k| \end{bmatrix}$$

The bus is supposed to be a slack bus. The elements of Jacobian matrix are the partial derivative of equations 13 and 14. It gives the relationship between the small change in voltage angles $\Delta\delta_i^k$ and voltage magnitude $\Delta| V_i^k |$ with small change in active and reactive power ΔP_i^k and ΔQ_i^k.In short the Jacobian matrix can written as:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_3 \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} \quad (15)$$

For voltage controlled buses voltage magnitudes are known. If there are m voltage controlled buses then there are m equations which have to solved for ΔQ and ΔV and accordingly the coloumns of jacobian matrix is neglected. If there are n buses then n-1 active power constraints (n – 1– m) reactive power constraints. The jacobian matrix is of the order of (2n – 2 – m) × (2n – 2 – m).

The diagonal and off diagonal elements of J_1 are written as

$$\frac{\partial P_i}{\partial \delta_i} = \sum_{j=1}^{n} |Y_{ij}| \, |V_j| \, |V_i| \sin (\theta_{ij} - \delta i + \delta_j) \qquad j \neq i \quad (16)$$

$$\frac{\partial P_i}{\partial \delta_i} = - | V_i | \, | V_j | \, |Y_{ij} | \sin (\theta_{ij} - \delta i + \delta_j) \qquad j \neq i \quad (17)$$

The diagonal and off diagonal elements of J_2 are written as:

$$\frac{\partial P_i}{\partial | V_i |} = 2 | V_i | \, | Y_{ii} | \cos(\theta_{ii}) + \sum_{j=1}^{n} |Y_{ij}| \, |V_j| \cos(\theta_{ij} - \delta i + \delta_j) \qquad j \neq i \quad (18)$$

$$\frac{\partial P_i}{\partial | V_j |} = | V_i | \, | Y_{ij} | \cos(\theta_{ij} - \delta i + \delta_j) \quad j \neq i \quad (19)$$

The diagonal and off diagonal elements of J_3 are written as

$$\frac{\partial Q_i}{\partial \delta_i} = \sum_{j=1}^{n} |Y_{ij}| \, |V_j| \, |V_i| \cos(\theta_{ij} - \delta i + \delta_j) \qquad j \neq i \quad (20)$$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

$\frac{\partial Q_i}{\partial \delta_i}$ = - | V_i | | V_j | | Y_{ij} | $\cos(\theta_{ij} - \delta i + \delta_j)$ $j \neq i$ (21)

The diagonal and off diagonal elements of J_4 are written as:

$\frac{\partial Q_i}{\partial |V_i|} = -2|V_i||Y_{ii}|\sin(\theta_{ii}) - \sum_{j=1}^{n}|Y_{ij}||V_j|\sin(\theta_{ij} - \delta i + \delta_j)\ j \neq i$ (22)

$\frac{\partial Q_i}{\partial |V_j|} = -|V_i||Y_{ij}|\sin(\theta_{ij} - \delta i + \delta_j)\ \ j \neq i$ (23)

Also, the mismatch between the scheduled power and calculated power is given as[10]:

$\Delta P_i^k = P_i^{sh} - P_i^k$ (24)

$\Delta Q_i^k = Q_i^{sh} - Q_i^k$ (25)

Where P_i^{sh} , Q_i^{sh} are the scheduled active and reactive power

P_i^k , Q_i^k are the calculated active and reactive power

ΔP_i^k = mismatch in active power

ΔQ_i^k = mismatch in reactive power

So by knowing the values of mismatches in power and Jacobian matrix,the change in voltage magnitude and voltage angle is calculated by the equation as:

$$\begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_3 \end{bmatrix}^{-1} \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} \quad (26)$$

The updated values of voltage magnitude and voltage angle are given as:

$\delta_i^{k+1} = \delta_i^k + \Delta\delta_i^k$ (27)

$|V_i^{k+1}| = |V_i^k| + \Delta|V_i^k|$ (28)

The updating continues until the mismatch were less than some prespecified value.

$|\Delta P_i^k| \leq \varepsilon$ and $|\Delta Q_i^k| \leq \varepsilon$ (29)

III.LOCATION OF FACTS DEVICE

The location of FACTS device is determined using reduction of total system reactive power loss. It is based on the sensitivity of the total system reactive power loss with respect to control variable of the FACTS device. For placement of FACTS device between buses i and j net line series reactance is taken as control variable. Loss sensitivity with respect to control parameter of FACTS placed between i^{th} and j^{th} bus is given as [1],[2]:

$a_{ij} = \frac{\partial Q_l}{\partial x_{ij}}$ (30)

$= [\,V_i^2 + V_j^2 - 2V_iV_j\cos(\delta_{ij})\,] \times \{\frac{r_{ij}^2 - x_{ij}^2}{(r_{ij}^2 - x_{ij}^2)^2}\}$ (31)

IV.RESULTS AND DISCUSSION

To find the location of FACTS device first the voltage and phase is calculated for different buses using load flow analysis and then these are used for finding the location of FACTS device. The analysis is implemented on IEEE 30 bus system[2].The Table I shows the voltage and phase angles of buses 1 to 30 obtained from load flow analysis using Newton – Raphson and Gauss – Seidel .From the load flow analysis the number of iteration is 262 for Gauss – Seidel method whereas for Newton – Raphson took eleven iteration for solution. So it is observed that both the technique produce almost same value of voltage and phase angle but G-S took more numbers of iterations than N-R method.So as the number of buses increased the G-S method takes more iteration and time, and will diverge in some cases .So it is useful to done the load flow analysis using N-R as comparison to G-S. The voltage and phase angle which is calculated from above is used to find out active and power generation in the buses, flows through the lines and also transmission losses in the lines.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

Table IVoltage and Phase angle for IEEE 30 bus system

Gauss – Seidel		Newton – Raphson	
Voltage	Phase	Voltage	Phase
V_1= 1.000	0	V_1 = 1.000	0
V_2=0.9973	0.1401	V_2=1.000	0.1840
V_3 = 0.9696	1.8679	V_3 = 1.010	1.1346
V_4 = 0.9696	2.2085	V_4 = 1.010	1.3309
V_5 = 1.0004	0.9480	V_5=1.0079	0.5267
V_6 = 0.9596	2.7507	V_6 = 1.0046	1.7726
V_7 = 0.9807	2.6830	V_7 = 1.010	1.9014
V_8 = 0.9603	4.0566	V_8 = 1.010	2.9519
V_9 = 0.8967	3.3417	V_9= 0.9897	2.2514
V_{10}=0.8638	3.6857	V_{10}=0.9900	2.3494
V_{11}= 0.8967	3.3417	V_{11}= 0.9897	2.1514
V_{12}= 0.8887	1.3679	V_{12}= 0.9700	0.9594
V_{13}= 0.7862	-12.106	V_{13}= 0.8828	-10.004
V_{14}= 0.8988	2.1122	V_{14}= 0.9900	1.3966
V_{15}= 0.8967	1.7644	V_{15}= 0.9900	1.1076
V_{16}= 0.8802	2.3153	V_{16}= 0.9900	1.5978
V_{17}= 0.8715	3.6827	V_{17}= 0.9900	2.4801
V_{18}= 0.8931	3.5862	V_{18}= 0.9900	2.6472
V_{19}= 0.8887	4.3516	V_{19}= 1.0100	2.7054
V_{20}= 0.8830	4.2736	V_{20}= 0.9900	3.0622
V_{21}= 0.8525	4.6544	V_{21}= 0.9700	3.2935
V_{22}= 0.8115	2.9712	V_{22}= 0.9385	1.9588
V_{23}= 0.9065	-0.8194	V_{23}= 1.0000	-0.7643
V_{24}= 0.8305	3.4485	V_{24}= 0.9500	2.4154
V_{25}= 0.8533	2.2902	V_{25}= 0.9900	1.0304
V_{26}= 0.8633	3.3248	V_{26}= 0.9900	2.1374
V_{27}= 0.8626	0.8999	V_{27}= 0.9872	0.4249
V_{28}= 0.9489	3.3258	V_{28}= 0.9900	2.5015
V_{29}= 0.8805	3.2012	V_{29}= 1.0100	1.9779
V_{30}= 0.8897	4.5044	V_{30}= 1.0100	3.2133

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

The table II shows the sensitivity analysis of system, it is done after the load flow is over. The bus voltage and phase angle which are obtained from load flow analysis is used in sensitivity analysis. The sensitivity analysis is done by calculating total system reactive power loss with respect to series reactance of the line. The sensitivity analysis is done through Gauss -Seidel and Newton – Raphson method and optimal location of FACTS device is find out. The FACTS devices are to be placed where the sensitivity is most negative and have positive values because these are the places if a FACTS device is placed there, it will decrease the net series reactance of the transmission line and active power transfer capability of line is increased.

Table IISensitivity using Newton – Raphson and Gauss – Seidel for IEEE 30 bus system

Line	From bus	To bus	Sensitivityusing Newton – Raphson	Sensitivity using Gauss – Seidel
1	1	2	-0.0021	-0.0026
2	1	3	-0.0103	-0.0406
3	2	4	-0.0112	-0.0546
4	2	5	-0.0245	-0.0519
5	2	6	-0.0176	-0.0758
6	3	4	-0.0062	-0.0424
7	4	6	-0.0464	-0.0477
8	4	12	-0.0310	-0.1068
9	5	7	-0.0246	-0.0536
10	6	7	-0.0035	-0.0461
11	6	8	-0.0546	-0.0570
12	6	9	-0.0060	-0.0910
13	6	10	-0.0010	-0.0300
14	6	28	0.0067	0.0037
15	8	28	-0.0088	-0.0053
16	9	11	0	0
17	9	10	-0.0010	-0.0919
18	10	20	-0.00200	-0.0060
19	10	17	-0.00050	-0.0053
20	10	21	-0.682	-0.0349
21	10	22	-0.0633	-0.0666
22	12	13	-0.2006	-0.2530
23	12	14	-0.0036	-0.0019

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

24	12	15	-0.0103	-0.0026
25	12	16	-0.0353	-0.0194
26	14	15	0.0002	0.00030
27	15	18	-0.0070	-0.0082
28	15	23	-0.0135	-0.0204
29	16	17	-0.0038	-0.0082
30	18	19	-0.0127	-0.0051
31	19	20	-0.0522	-0.0040
32	21	22	-0.0306	-0.0467
33	22	24	-0.0019	-0.0042
34	23	24	-0.0377	-0.0691
35	24	25	-0.0074	-0.0028
36	25	26	-0.0007	-0.0007
37	25	27	-0.0012	-0.0053
38	27	29	-0.0032	-0.0040
39	27	30	-0.0035	-0.0045
40	28	27	-0.0081	-0.0557
41	29	30	-0.0012	-0.0013

The table III shows the location of FACSTS devices after analysis from table II. The optimal location are the values where sensitivity have positive or most negative value or close to zero.

Table III Optimal location for FACTS device for IEEE 30 bus system

Line	From bus	To bus
14	6	28
19	10	17
26	14	15
36	25	26
41	29	30

So, the location for FACTS device for IEEE 30 bus system is find out using Gauss – Seidel and Newton – Raphson.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

V. CONCLUSION

From the present work it can be inferred that Newton – Raphson method is better than Gauss –Seidel method in finding the load flow solution. The N – R takes lesser numbers of iterations as comparison to Gauss – Seidel. As the numbers of buses increases the numbers of iterations for G – S increases and if we further increases the number of buses the Gauss – Seidel may diverge in some cases. The calculation used in Gauss – Seidel are simple whereas in Newton – Raphson method the calculation is difficult for Jacobian matrix, it is most time consuming in N – R. The Newton – Raphson method may diverge in some cases if Jacobian matrix becomes singular, so its singularity has to be removed. Also, the optimal location findings using N – R are better than Gauss – Seidel method because G – S may diverge if system requires higher accuracy and high bus number. The numbers of optimal locations increases as the bus number increases. So the optimal location for FACTS device is points where sensitivity are positive and close to origin.

VI. FUTURE SCOPE

The proposed work is done to find out the load flow and then optimal location for FACTS device. In future the work can be extended to design the control scheme of FACTS devices and find its operating characteristics, so that it can be placed in the transmission line, finding its effect on the active power flowing through the line, its effect on the transient behaviour on the line and other other effects. In future other FACTS devices such as UPFC, TCSR can be studied for their optimal location and control characteristics.

REFERENCES

[1] L.Rajalakshmi,M.V. Suganyadevi, S. Parameswari, "CongestionManagement in Deregulated Power System by Locating Series FACTS Devices," International Journal of Computer Applications, Vol. 13, 2011

[2] Sunil Malival, Y.R. Prajapati, "Optimal Location and Cost Analysis of TCSC for Improving Power System Stablility and Economy," International Journal ofAdvance Engineering andResearch Development, Vol. 1, 2014

[3] J. Teng, "A Modified Gauss SeidelAlgorithm of Three-Phase Power Flow Analysis in Distribution Networks," Electric Power and Energy Systems, Vol. 24, pp. 2–7, 2002.

[4] T. Kulworawanichpong, "Electrical Power and Energy Systems Simplified Newton – Raphson Power-Flow Solution Method," International Journal of Electrical Power and Energy Systems, Vol. 32, No. 6, pp. 551–558, 2010.

[5] D.P.Kothari,I.J Nagrath,"Modern Power System Analysis", Mcgraw-Hill; 2003

[6] Saadat H. "Power System Analysis", Mcgraw-Hill; 2004.

[7] N. G. Hingaroni and L. Gyugyi, "Understanding FACTS Concepts and Technology of Flexible Ac Transmission System," IEEE Press, New York, 2000

[8] H. Le Nguyen, "Newton– Raphson Method in Complex Form," IEEE Transaction on Power Systems, Vol. 12, pp. 1355- 1359, 1997

[9] D. K. Tanti, "Load Flow Analysis on IEEE 30 Bus System," International Journal of Scientific and Research Publication, Vol. 2, No. 11, pp. 1–6, 2012.

[10] W. F. Tinney, C. E. Hart, "Power Flow Solution by Newton's Method," IEEE Transactions on Power Apparatus and System, Vol.-86, pp.1449- 1460, 1967