OPEN ACCESS

International Journal Of Modern Engineering Research (IJMER)

Modelling and Simulation Using Matlab for IEEE 14 Bus System to Find out Optimum location of STATCOM

Syed Mohmmad Tanweer[1], Sumbul Zaidi[2]

ABSTRACT: Voltage stability enhancement plays a vital role in power system. Depending upon the type of loading and environmental conditions the voltage stability can be categorized .Now a day's voltage instability problems in a power system have become one of the most concern in power industries. By Showing the voltage stability enhancement which will further lead to improvement in the system performance, reduction of the losses, and making the system more secure. Out of the various means for enhancing stability, in this paper Static Synchronous Controller (STATCOM) devices have been employed which proved to be flexible, reliable and provides desired characteristics. This paper discusses the comparative result before application of STATCOM and after optimal placement of STATCOM in the system network. In the first stage Newton Raphson (NR) method is used to determine voltage magnitude and phase angle at every node of the IEEE 14 bus system with and without STATCOM. In the second stage Genetic Algorithm (GA) finds the optimal location for placing the STATCOM. After placing the STATCOM the losses is reduce. The proposed method is tested on IEEE 14 bus system using MATLAB.
Index Terms Static Synchronous Controller (STATCOM), Flexible AC Transmission System (FACTS), Genetic Algorithm (GA)

I. INTRODUCTION

1.1 AC Load Flow Technique- Two methods of load flow analysis are mostly used in power system operation. They are Gauss-Seidal and Newton-Raphson methods. Both need some input parameters for performing analysis. Network parameters e.g. Y-bus or Z-bus is required to be calculated before proceeding a solution. Buses in a network are divided into three categories: swing bus, generator or PV bus and load or

1.1 (a) PQ bus. Each bus is associated with four parameters: voltage magnitude, phase angle, real and reactive power.

1.1 (b) Swing bus – it is a generator bus whose voltage and angle have been specified for load flow analysis. The real and reactive powers are calculated to match the generation, load and losses.

1.1 (c) Generator bus – Generators are connected in these buses. The bus voltage and real power generation are specified and reactive power and phase angle are determined.

1.1 (d) Load bus – generally loads are connected in these buses. Real and reactive load of these buses are known and bus voltage and phase angle are calculated.

The load flow technique actually solves a set of simultaneous non-linear equations in an iterative process. Gauss-Seidal method is easy to use but takes lot of iterations to give a solution with a specified accuracy. Newton-Raphson method converges faster than Gauss-Seidal method but needs matrix calculations. Due to easy calculation of matrices in computer, Newton-Raphson method is widely used in load flow analysis. Since Newton-Raphson method has been used in this research work, only this method will be explained here. The following simultaneous equations are required for a solution of load flow by Newton-Raphson method.

$$P_k = \sum_{n=1}^{N} |V_k V_n Y_{kn}| \cos(\theta_{kn} + \delta_n - \delta_k) \quad \text{..........(1)}$$

$$Q_k = -\sum_{n=1}^{N} |V_k V_n Y_{kn}| \sin(\theta_{kn} + \delta_n - \delta_k) \quad \text{.........(2)}$$

where,
P_k = real power at Bus k
Q_k = reactive power at Bus k
V_k = voltage magnitude at Bus k
V_n = voltage magnitude at Bus n
Y_{kn} = element of bus admittance matrix between buses k and n
θ_{kn} = angle associated with Y_{kn}
δ_k = phase angle of Bus k
δ_n = phase angle of Bus n

For every bus, there will be two such equations and two unknowns to be solved. The unknowns are real and reactive generations for swing bus; phase angle and reactive generation for PV bus and voltage magnitude and phase angle for load bus. The method starts with some initial values for the specified parameters, P and Q for every bus except the swing bus. Estimated values of V and δ for each bus except the swing bus are used to calculate the same parameters. The mismatch in power calculation originating from specified and calculated values are determined for each bus. For Bus k,

$$\Delta P_k^{(0)} = P_{ks} - P_{kc}^{\ (0)} \quad \text{.......(3)}$$

$$\Delta Q_k^{(0)} = Q_{ks} - Q_{kc}^{\ (0)} \quad \text{........(4)}$$

where the subscript k is bus number, subscripts s and c represent specified and calculated values respectively and the superscript represents the iteration number. From equations of all buses, Jacobian J is determined in following manner;

$$\begin{bmatrix} \Delta P_1^{(0)} \\ \cdots \\ \Delta P_{N-1}^{(0)} \\ \Delta Q_1^{(0)} \\ \cdots \\ \Delta Q_{N-1}^{(0)} \end{bmatrix} = \begin{bmatrix} \frac{\partial P_1}{\partial|\delta_1|} \cdots \frac{\partial P_1}{\partial|\delta_{N-1}|} & \frac{\partial P_1}{\partial|V_1|} \cdots \frac{\partial P_1}{\partial|V_{N-1}|} \\ \vdots \ \ddots \ \vdots & \vdots \ \ddots \ \vdots \\ \frac{\partial P_{N-1}}{\partial|\delta_1|} \cdots \frac{\partial P_{N-1}}{\partial|\delta_{N-1}|} & \frac{\partial P_{N-1}}{\partial|V_1|} \cdots \frac{\partial P_{N-1}}{\partial|V_{N-1}|} \\ \frac{\partial Q_1}{\partial|\delta_1|} \cdots \frac{\partial Q_1}{\partial|\delta_{N-1}|} & \frac{\partial Q_1}{\partial|V_1|} \cdots \frac{\partial Q_1}{\partial|V_{N-1}|} \\ \vdots \ \ddots \ \vdots & \vdots \ \ddots \ \cdots\vdots \\ \frac{\partial Q_{N-1}}{\partial|\delta_1|} \cdots \frac{\partial Q_{N-1}}{\partial|\delta_{N-1}|} & \frac{\partial Q_{N-1}}{\partial|V_1|} \cdots \frac{\partial Q_{N-1}}{\partial|V_{N-1}|} \end{bmatrix} \begin{bmatrix} \Delta\delta_1^{(0)} \\ \cdots \\ \Delta\delta_{N-1}^{(0)} \\ \Delta|V_1^{(0)}| \\ \cdots \\ \Delta|V_{N-1}^{(0)}| \end{bmatrix} \quad \text{..(5)}$$

Equation 5 can be written as

$$\begin{bmatrix} \Delta P^k \\ \Delta Q^k \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta\delta^k \\ \Delta|V^k| \end{bmatrix} \quad \text{......(6)}$$

The diagonal and off-diagonal elements of J_1 are

$$\frac{\partial P_i}{\partial \delta_i} = \sum_{j \neq i} |V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \quad \text{....(7)}$$

$$\frac{\partial P_i}{\partial \delta_j} = -|V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j), \quad j \neq i \quad \text{...(8)}$$

The diagonal & offdiagonal elements of J2

$$\frac{\partial P_i}{\partial|V_i|} = 2|V_i||Y_{ii}|\cos(\theta_{ii}) + \sum_{j \neq i} |V_j||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \quad \text{...(9)}$$

$$\frac{\partial P_i}{\partial|V_j|} = |V_i||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \quad j \neq i \quad \text{...(10)}$$

The diagonal & offdiagonal elements of J3

$$\frac{\partial Q_i}{\partial \delta_i} = \sum_{j \neq i} |V_i||V_j||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \quad \text{.....(11)}$$

$$\frac{\partial Q_i}{\partial \delta_j} = -|V_i||V_j||Y_{ij}|\cos(\theta_{ij} - \delta_i + \delta_j), \quad j \neq i$$ ……(12)

The diagonal & offdiagonal elements of J4

$$\frac{\partial Q_i}{\partial |V_i|} = -2|V_i||Y_{ii}|\sin(\theta_{ii}) - \sum_{j \neq i} |V_j||Y_{ij}|\sin(\theta_{ij} - \delta_i + \delta_j)$$ ...(13)

$$\frac{\partial Q_i}{\partial |V_j|} = -|V_i||Y_{ij}|\sin(\theta_{ij} - \delta_i + \delta_j) \quad j \neq i$$ …..(14)

Equation 6 can also be written in the following way

$$\begin{bmatrix} \Delta \delta^k \\ \Delta |V^k| \end{bmatrix} = [J]^{-1} \begin{bmatrix} \Delta P^k \\ \Delta Q^k \end{bmatrix}$$ ………(15)

Equation (15) is solved and errors in voltages and angles are calculated. New values of V and δ are estimated by subtracting these errors from the respective parameters. These new voltage and angles are used to calculate new bus powers using Equations (3) and (4). This process is repeated until mismatch at each bus goes below the tolerance limit.

1.2 Voltage Stability Index:-

Voltage Stability Index is used to calculate the stability indices for all the load buses connected in an IEEE 14 bus network . For a given system operating condition, by using the load flow results obtained from Newton Raphson Technique, the Voltage Stability index (L index) for load buses is to be computed as

$$L_j = \left| 1 - \sum_{i=1}^{g} F_{ji} \frac{V_i}{V_j} \right|$$ ……(16)

Where n is the total number of buses. g is the no of generators connected in the system. And j=g+1….n. The values of Fji can be obtained from Y bus matrix

$$F_{ji} = [Y_{LL}]^{-1}[Y_{LG}]$$ …….(17)

Where YLL and YLG are corresponding partitioned portions of the Y-bus matrix. The L-indices for a given load condition are computed for all load buses. The L index gives a scalar number to each load bus. If the index value (L index) is moving towards zero, then the system is considered as stable and also improves system security. When this index value moves away from zero, the stability of system is relatively decreases then the system is considered as unstable. The L indices are calculated for all the load buses and the maximum of the L indices gives the proximity to the system to voltage collapse

Loss reduction = Before Ploss –After Ploss

1.3 Genetic Algorithm (GA):-In 1960 I. Rechenberg introduced the idea of evolutionary computing in his work Evolutionary strategies. GA's are computerized search and optimization algorithms based on mechanics of natural genetics and natural selection.

Mutation:

It is used to maintain genetic diversity from one generation to next generation. Mutation changes one or more gene values from their initial ones in chromosome and a result obtained in mutation is totally different from the last solutions

Fitness Function:

Due to the Fitness function result is in the form of single figure called figure of merits. After every round of testing, previous worst design solutions are deleted and new ones are raised.

1.4 Algorithm:-

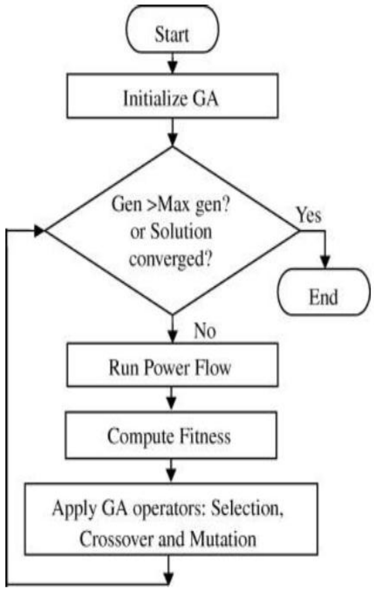

Figure 1(a)

1.5 Advantages of GA:-

- It can vary both the values and structure and the desired result can be obtained.
- Quick response for acceptable solution
- It deals with the large number of solution.

1.6 Simulation & Result :-

Simulation without STATCOM

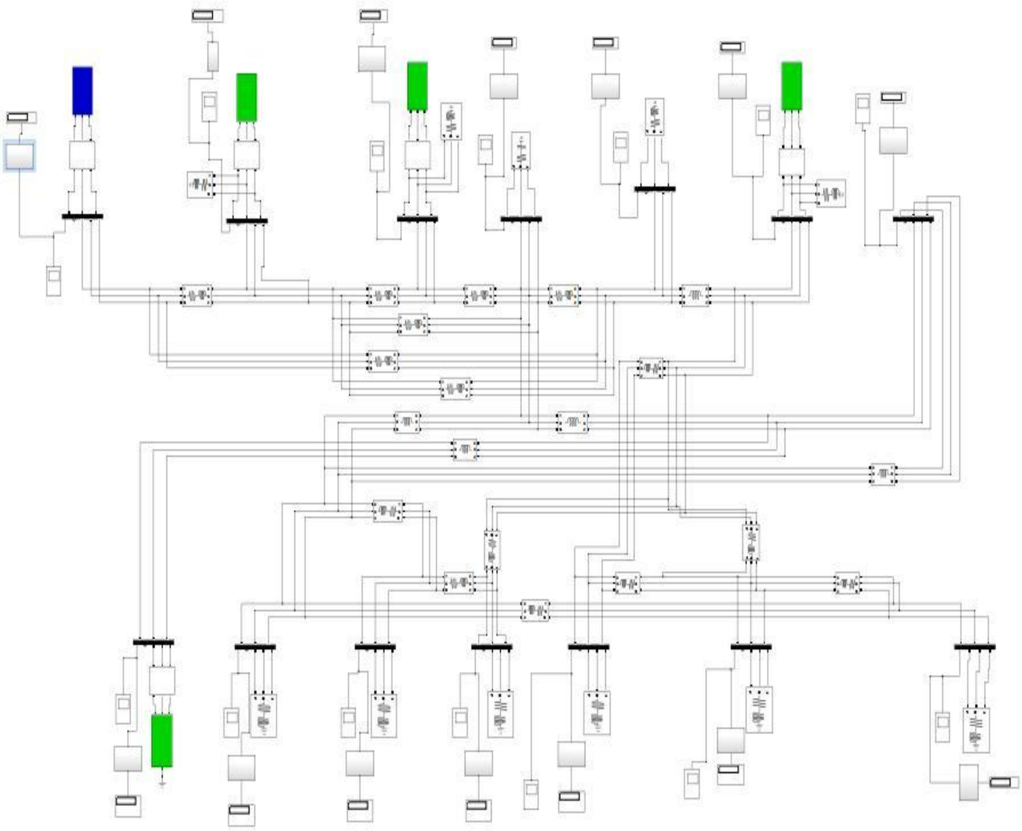

Figure 1(b)

Simulation with STATCOM

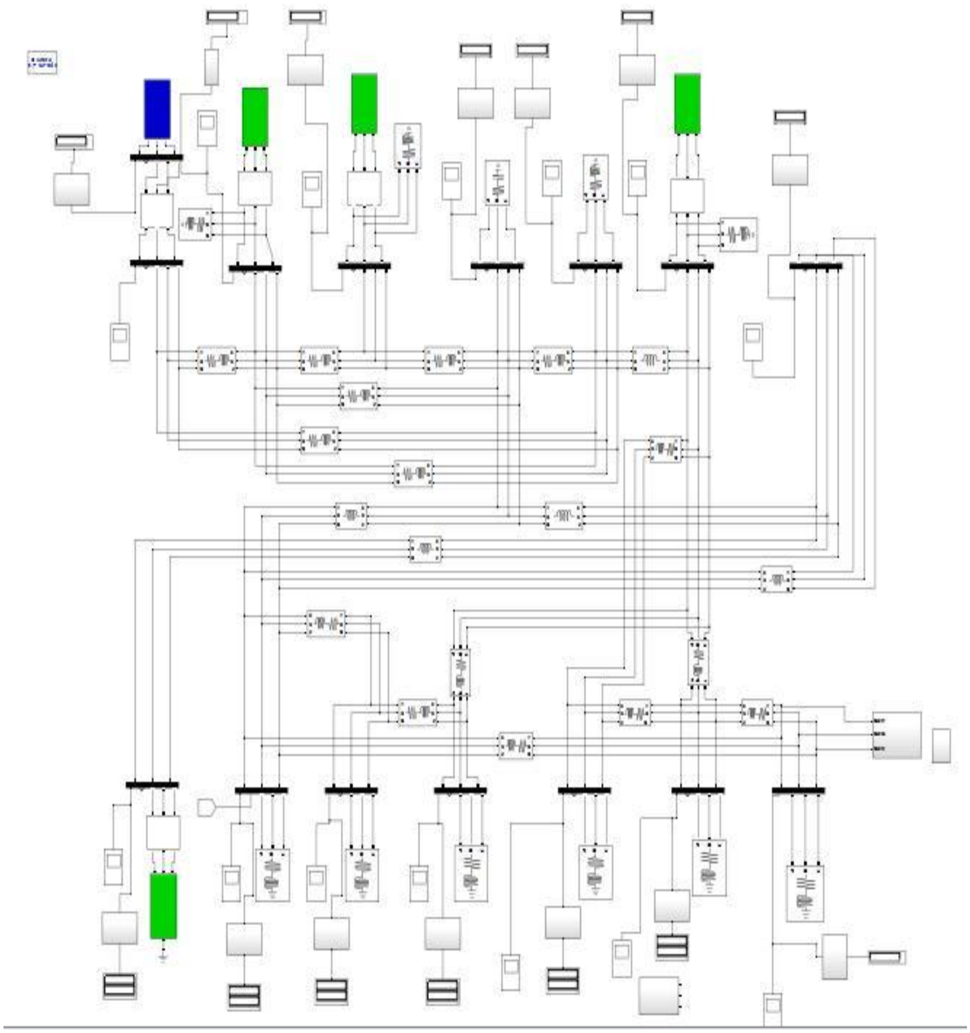

Figure 1(c)

1.7 IEEE 14 Bus Systems:-The IEEE 14 bus system includes 5 Generator buses, 9 load buses and 20 transmission lines as shown in figure 1(d) Line loss Calculations

Lij =

10.4832 +32.0068i
6.3619 +26.2623i
5.1435 +21.6695i
3.6208 +10.9864i
1.9749 + 6.0298i
0.9779 + 2.4959i
1.0497 + 3.3111i
0.0000 + 3.6996i
-0.0000 + 2.7482i
0.0000 +11.5947i
0.2714 + 0.5684i
0.1803 + 0.3753i
0.5646 + 1.1119i
0.0000 + 1.6474i
0.0000 + 2.2230i
0.0132 + 0.0352i
0.2018 + 0.4292i
0.1134 + 0.2654i
0.0237 + 0.0214i
0.2389 + 0.4864i

Table 1.1

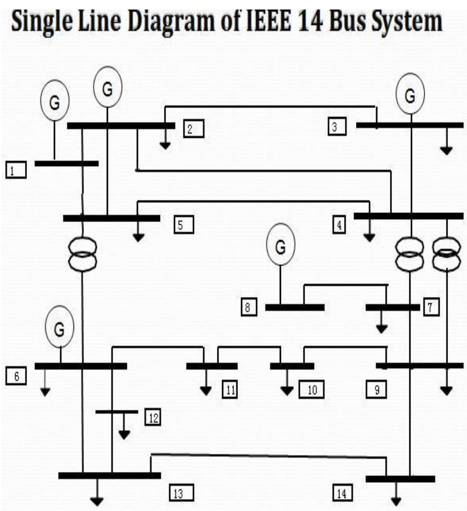

Figure 1(d)

1.8 Loading Conditions:-

BUS NO		LOAD CONDITIONS
1		SLACK BUS/SWING BUS
2		INDUCTIVE(0.177 VAR)
3		INDUCTIVE(0.191 VAR)
4		CAPACITIVE(0.0139VAR)
5		INDUCTIVE(0.016 VAR)
6		INDUCTIVE(0.075 VAR)
7		NO LOAD
8		CONDENSER(SYN COMP)
9		INDUCTIVE(0.2324 VAR)
10		INDUCTIVE(0.0812 VAR)
11		INDUCTIVE(0.0252 VAR)
12		INDUCTIVE (0.0254 VAR)
13		INDUCTIVE(0.0812 VAR)
14		INDUCTIVE(0.070 VAR)

Table 1.2

1.9 Voltage Profile: After finding the location, by placing the corresponding FACTS devices at suitable location the GA is performed. The corresponding results are shown bellow

S.No	Before placing STATCOM	After placing STATCOM
1	1.045	1.045
2	1.01	1.01
3	0.96	0.96
4	0.9525	0.9729
5	0.9616	0.9883
6	1.02	1.02
7	0.9861	1.04
8	1.04	1.0128
9	**0.9616**	**0.9883**
10	0.9605	0.9872
11	0.9845	1.0112
12	0.9946	1.0213
13	0.9849	1.0116
14	**0.9439**	**0.9706**

Table 1.3

1.10 Graphical Result:-

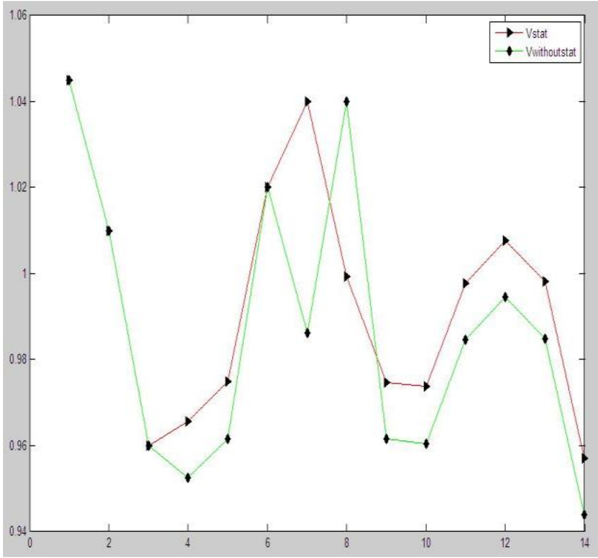

Figure 1(e)

REFERENCES

[1]. Preethi, VA and Muralidharan,S andRajasekar, S "Application of genetic algorithm to power system voltage stability enhancement using facts devices"IEEE, pp.- 333-338,2011

[2]. 1SAKET SAURABH, 2MD IRFAN AHMED" OPTIMAL PLACEMENT OF STATCOM FOR IMPROVING VOLTAGE STABILITY USING GA" ISSN: 2348-4098 VOLUME 2 ISSUE 6 AUGUST 2014 (VER II)" DATE OF PUBLICATION: SEPTEMBER 03, 2014

[3]. G. Naveen Kumar1 , M. Surya Kalavathi2 and R. Harini Krishna" OPTIMAL PLACEMENT OF SVC AND STATCOM FOR VOLTAGE STABILITY ENHANCEMENT UNDER CONTINGENCY USING CAT SWARM OPTIMIZATION" International Journal of Advances in Engineering & Technology, Nov. 2012. ©IJAET ISSN: 2231-1963

[4]. Ali Sadeghizadeh, Mahmoud Zadehbagheri" Optimal Placement of STATCOM in Unbalanced Distribution Networks ConsideringVoltage Stability" International Journal of Scientific & Engineering Research, Volume 5, Issue 2, February-2014 1506 ISSN 2229-5518.