Optimal Placement of Facts Device In IEEE 14 Bus System Using Genetic Algorithm

Virendra Singh[1], Mr Ravi Kumar Soni[2]
[2] Asst Prof
[1, 2] SGI SIKAR

Abstract- *With the increasing size of power system, there is a thrust on finding the solution to maximize the utilization of existing system and to provide adequate voltage support. For this the flexibility of power is needed. Flexible AC transmission system (FACTS) if placed optimally can be effective in providing voltage support, controlling power flow and in turn resulting into lower losses.*

The algorithm to find the optimal location of UPFC based on genetic algorithm has been developed. The effect of these devices on line flows and bus voltage profile has been studied by placing at random location and placing them optimally with optimal ratings dictated by genetic algorithm. The effectiveness of developed algorithm has been tested on 14-bus systems. In this work, a comparison of the effects of compensation of a Simplified multi-machine (two-machine system) power system by shunt/series connected FACTS controllers at optimal location using GA. The model procedure of enhance voltage stability and power flows capability of systems is illustrated. The study system is a simple example of multi-machine system, which is simulated in MATLAB/PSAT.

I. INTRODUCTION

The increasing Industrialization, urbanization of life style has lead to rising dependency on the electrical power. This has resulted into quick development of power systems. This quick development has resulted into few uncertainties. Power disruptions and individual power outages are one of the most important harms and affect the financial system of any country. In contrast to the rapid changes in technologies and the power required by these technologies, transmission systems are being pushed to operate closer to their stability limits and at the same time reaching their thermal limits due to the fact that the delivery of power have been increasing. The most important problems faced by power industries in establishing the match between supply and demand are:
Transmission & Distribution; supply the electric demand without exceeding the thermal limit. In large power system, problems causing power disruptions and blackouts leading to huge losses.

These constraints change the value of power delivered. However, these constraints can be suppressed by enhancing the power system control. One of the best methods for reducing these constraints is FACTS devices.

With the rapid increase of power electronics, *Flexible AC Transmission Systems* (FACTS) devices have been planned and implemented in power systems. FACTS devices can be utilized to manage power flow and enhance scheme stability. Mostly with the deregulation of the electricity advertise, there is a rising attention in using FACTS devices in the operation and control of power systems. A superior utilization of the existing power systems to raise their capacities and controllability by installing FACTS devices becomes crucial. FACTS devices are price effective alternatives to fresh transmission line construction [1].

Reactive power compensation is provided to reduce power transmission losses, to keep power transmission capability and to keep the supply voltage. Series compensation is manage of line impedance of a transmission line; with the modify of impedance of a line either inductive or capacitive compensation can be obtained thus facilitating active power transfer or control. Unified Power Flow Controller (UPFC) is a combined series-shunt compensator and is connected in both modes with the transmission line to increase the power transfer capability, recover transient stability, decrease transmission losses and dampen power system oscillations. Shunt compensation is used to increase the steady-state transmittable power and to control the voltage profile along the line. Its combination of SSSC and STATCOM and its one of the most important members of FACTS family that are increasingly being applied to long transmission lines by the value in modern power systems. They can have different applications concerned with operation and manage of power system, such as arrangement power flow; decreasing unsymmetrical components damping the power oscillations and enhancing transient stability.

II. BACKGROUND OF THE RESEARCH

The brief background on the placement of FACTS devices is presented here.

The theory of FACTS and FACTS controllers was first distinct by Hingorani, [1988]. FACTS generally refer to the application of high-power semiconductor devices to manage different parameters and electrical variables such as voltage, impedance, phase angles, currents, reactive and active power.

FACTS can provide flexible benefits to transmission utilities such as manage of power flow, rising capabilities of lines to their thermal limits, reducing loop flows, providing larger flexibility [17-19]. The value of FACTS application lies mainly in the ability of the transmission system to efficiently transmit power or to transfer power under contingency conditions.

Azimoh.,[2009] investigated the effects of two FACTS controllers, STATCOM and UPFC, on voltage stability. Continuation Power Flow (CPF), with correct model of these controllers, is used for this study. Applying saddle node bifurcation theory with the use of Power System Analysis Toolbox (PSAT), the optimal location of these controllers is determined. The study has been carried out on the 6-bus and IEEE 14-Bus Test Systems and results are presented.

Sarda Jigar S. ,[2012] presented a novel method for optimal position of FACTS devices in a multi machine power system using Genetic Algorithm (GA).Using the proposed method, the location of FACTS controllers, their type and rated values are optimized simultaneously. Among the different FACTS controllers, Static Var Controller (SVC), Thyristor Controlled Series Compensator (TCSC) and Unified Power Flow Controller (UPFC) are considered.

Kazemi A. (2006) presented the most important causes of voltage instability is the reactive power limit of the system. Improving the system's reactive power handling capacity via Flexible AC transmission System (FACTS) devices is a preparation for prevention of voltage instability and hence voltage collapse. In this paper, the things of two FACTS controllers, STATCOM and UPFC, on voltage stability will be studied .Continuation Power Flow (CPF), with correct model of these controllers, is used for this study. Applying saddle node bifurcation theory with the use of Power System Analysis Toolbox (PSAT), the optimal position of these controllers is determined. The study has been carried out on the 6-bus and IEEE 14-Bus Test Systems and results are presented.[27]

Objective of the Dissertation

The work reported in this thesis has been carried out with the objective of studying the effect of UPFC on swings, voltage and power transfer capability enhancement in power system.

The objectives of the dessertation are:

i. Design and simulate the classical model of the 14-bus system using MATLAB/PSAT tool.
ii. Design and simulate UPFC using MATLAB/PSAT SIMULINK tool .
iii. Deploy UPFC in the 14-bus system using GA.
iv. Study the steady state operating situation of the electrical network. The steady state may be determined by finding out the run of active and reactive power throughout the system, power transmit and the voltage magnitudes at all nodes of network (14-bus system) with and without UPFC.
v. Investigate the result of UPFC for improving voltage and power transmit capability of the multi-machine power structure. The MATLAB/PSAT simulation results of the test system are performed with constant loading effect. To illustrate the performance of the FACTS controller (UPFC), 14-bus Multi-Machine Power System has been considered.

Definitions of the Problem Statement Terms

As FACTS devices are costly so type, number and position of the FACTS devices is major, to decide the optimal position and parameters of FACTS devices the following sspecifications are used in FACTS related researches:

- Transmission pricing issues by maximizing social welfare with or without consideration of FACTS' costs;
- Better utilization of FACTs by maximizing FACTS devices total transferred power.
- Reactive power or voltage control by minimizing transmission losses or voltage fluctuation
- Increase system's security under contingency by minimizing transmission lines loadability.

III. RESULTS

This chapter presents the results obtained on the performance of power system with the placement of UPFC. The installation of UPFC has been studied for their placement at arbitrary location and optimal location decided by GA. The performance has been studied on 14-bus systems the data used for these case studies is given in Appendix-1.

First, Newton-Raphson-Method is run without any FACTS devices with following parameters in PSAT are used:

Base MVA= 100.

And base Kv= 69 kv.

The power flow results of the system are given below.

Results with-out

Power flow report PSAT 2.1.6

Following table 1 shows the system specification for the installation of UPFC.

Table 1
Network statistics

Buses:	14
Lines:	16
Transformers:	4
Generators:	5
Loads:	11

Table 2
Solution statistics

Number of Iterations:	4
Max P mismatch [p.u.]	0
Max Q mismatch [p.u.]	0
Power rate [MVA]	100

Power flow result with -out UPFC

The table 3 shows the values of the per unit voltage, Phase, P generated, Q generated, P load and Q load at different busses in the IEEE 14-bus system with-out UPFC installation.

It is noted that on bus-4 and on bus-14 Voltage per unit value is less than unity.

LINE FLOWS

The table 4 shows the values of the P flow and Q flow forward between different busses or on different lines and P loss and Q loss between different busses with-out installation of the UPFC in the IEEE 14-bus system.

The table 5 shows the values of the P flow and Q flow backward between different busses or on different lines and P loss and Q loss between different busses with-out installation of the UPFC in the IEEE 14-bus system.

GLOBAL SUMMARY REPORT

Without UPFC total generation of Real power and Reactive power ,Total load and taotal losses in the system is given in the following table 5.6.

Table 3
Global summary report With-out UPFC

TOTAL GENERATION	
REAL POWER [p.u.]	3.9205
REACTIVE POWER [p.u.]	2.0554
TOTAL LOAD	
REAL POWER [p.u.]	3.626
REACTIVE POWER [p.u.]	1.1396
TOTAL LOSSES	
REAL POWER [p.u.]	0.29452
REACTIVE POWER [p.u.]	0.91576

To analyze the system behavior graphs are plotted for Real Power , Reactive Power available and consumed on different busses, Real and Reactive Power loss in the system.

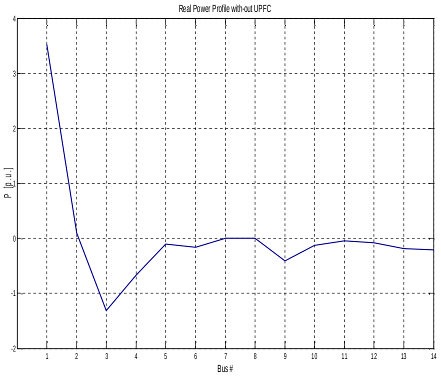

Fig. 1: Available Real power profile with-out UPFC at buses

The Available Real power profile with-out UPFC at buses of the system shown in figure 1. It shows the active power available at each bus of system for with-out UPFC condition.

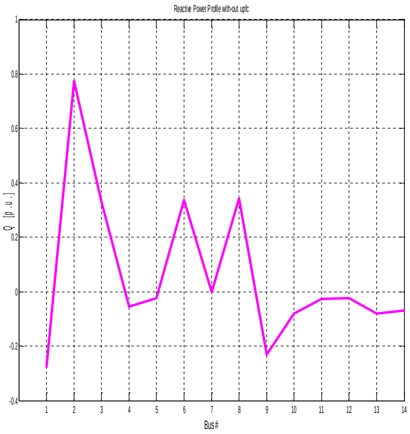

Fig. 2: Available Reactive power profile with-out UPFC at buses

The Available Reactive power profile with-out UPFC at buses of the system shown in figure 2. It shows the reactive power flow at each bus of system for with-out UPFC condition.

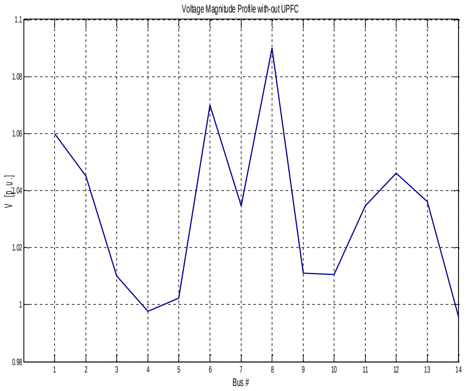

Fig. 3: Voltage profile with-out UPFC at buses

The Voltage profile with-out UPFC at buses of the system shown in figure 3. It shows the Voltages at each bus of system for with-out UPFC condition.

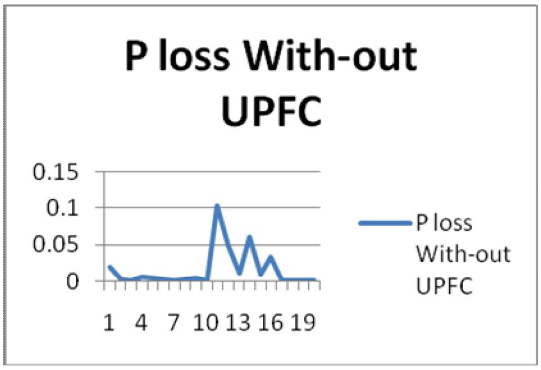

Fig. 4 Active power loss with-outs UPFC of lines

The Active power loss with-out UPFC of lines for the system shown in figure 4. It shows the active power losses for each line of system for with-out UPFC condition.

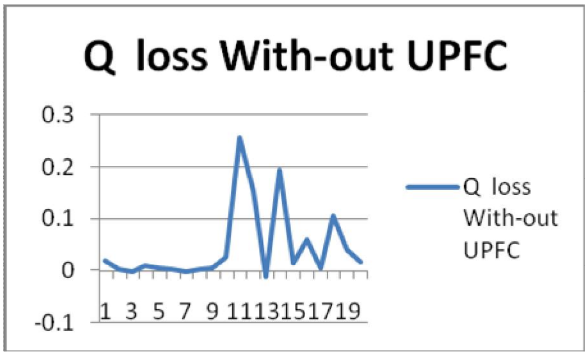

Fig. 5: Reactive power loss with-out UPFC of lines

The reactive power loss with-out UPFC of lines for the system shown in figure 5. It shows the reactive power losses for each line of system for with-out UPFC condition.

RESULTS WITH UPFC

RESULT OF POWER FLOW WITH UPFC

The table 5 shows the values of the per unit voltage, Phase, P generated, Q generated, P load and Q load at different busses in the IEEE 14-bus system with UPFC installation. It is noted that on bus-4 and on bus-14 Voltage per unit value is near to unity.

Global summary report

Table 4

Global summary report With UPFC

TOTAL GENERATION	
REAL POWER [p.u.]	3.8073
REACTIVE POWER [p.u.]	1.8494
TOTAL LOAD	
REAL POWER [p.u.]	3.626
REACTIVE POWER [p.u.]	1.1396
TOTAL LOSSES	
REAL POWER [p.u.]	0.18126
REACTIVE POWER [p.u.]	0.70975

The Available Real power profile with UPFC at buses of the system shown in figure 5.6. It shows the active power available at each bus of system for with UPFC condition.

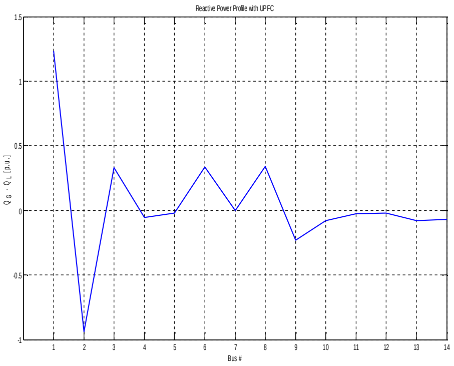

Fig. 6: Available Reactive power profile with UPFC at buses

The Available Reactive power profile with UPFC at buses of the system shown in figure 7. It shows the reactive power flow at each bus of system for with UPFC condition.

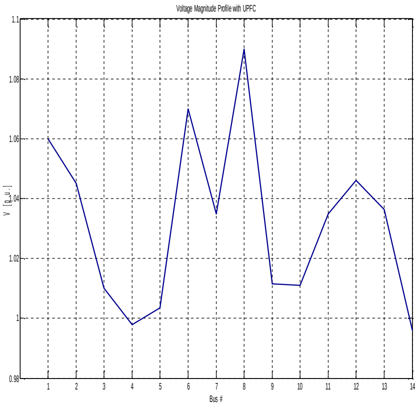

Fig. 7: Result of Voltage profile using UPFC

The Voltage profile with UPFC of the system shown in figure 7. It shows the Voltages at each bus of system for with UPFC condition.

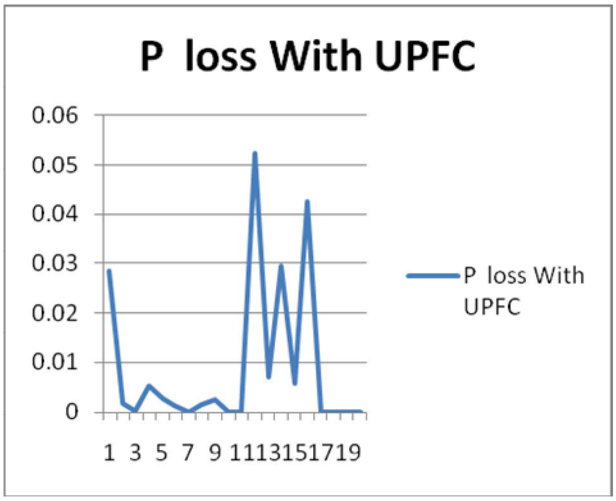

Fig. 8: Active power loss with UPFC of lines

The Active power loss with UPFC of lines for the system shown in figure 8. It shows the active power losses for each line of system for with UPFC condition.

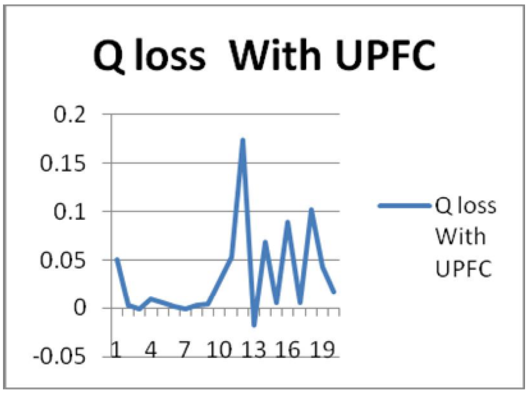

Fig. 9: Reactive power loss with UPFC of lines

The reactive power loss with UPFC of lines for the system shown in figure 9. It shows the reactive power losses for each line of system for with UPFC condition.

Comparative result analysis for the power system with and with-out UPFC

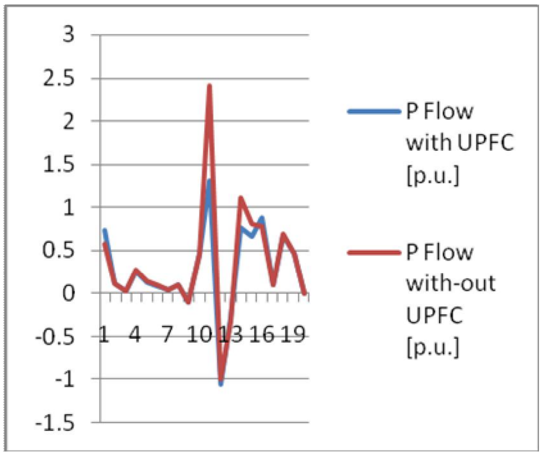

Fig. 10 Active Power flow (transfer) Comparison With and With-out UPFC

The figure 10 Shows Active Power flow (transfer) Comparison With and With-out UPFC of lines. It shows the comparative analysis of Active Power flow Transfer for with and with-out UPFC condition. So the analysis denotes the Active Power flow Transfer with UPFC of lines is reduced at high power flow lines so the Active Power Transfer capability of system is increased.

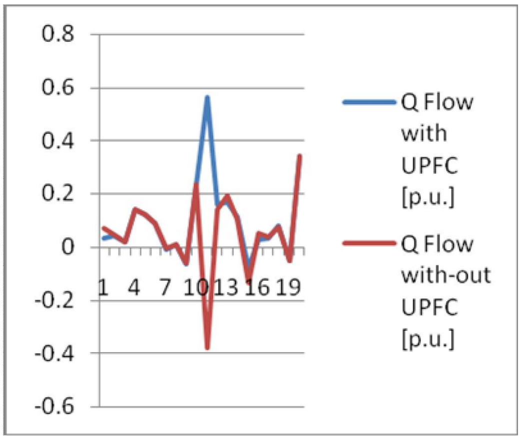

Fig. 11 Reactive Power flow (transfer) Comparison With and With-out UPFC

The figure 11 Shows Reactive Power flow (transfer) Comparison With and With-out UPFC of lines. It shows the comparative analysis of Reactive Power flow Transfer for with and with-out UPFC condition. So the analysis denotes the Reactive Power flow Transfer with UPFC of lines is reduced at high power flow lines so the Reactive Power Transfer capability of system is increased and the Reactive power consumption is reduces hence availability increased.

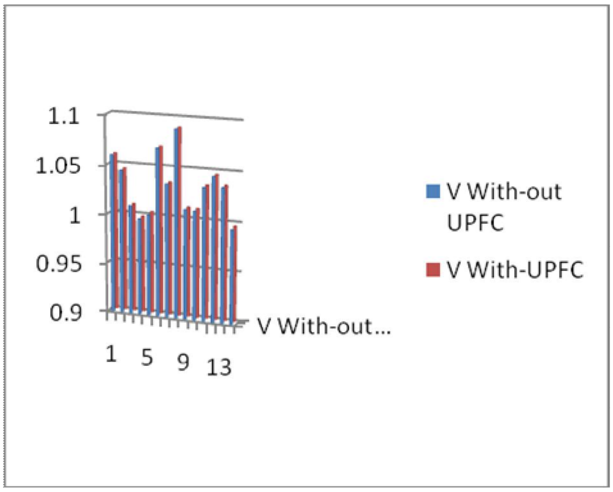

Fig. 12 Voltage magnitude profile Comparison With and With-out UPFC at buses

The figure 12 Shows Voltage magnitude profile Comparison With and With-out UPFC at buses. It shows the comparative analysis of Voltage profile for with and with-out UPFC condition. So the analysis denotes Voltage profile with UPFC of lines is enhanced at buses hence the Voltage profile of system is increased.

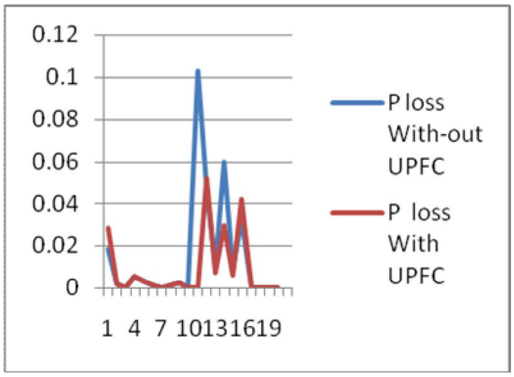

Fig. 13 Active Power (P) loss Comparison With and With-out UPFC of lines

It shows the comparative analysis of Active Power (P) loss for with and with-out UPFC condition. So the analysis denotes the Active Power (P) loss with UPFC of lines is reduced hence the reduction in overall Active Power (Q) losses of system.

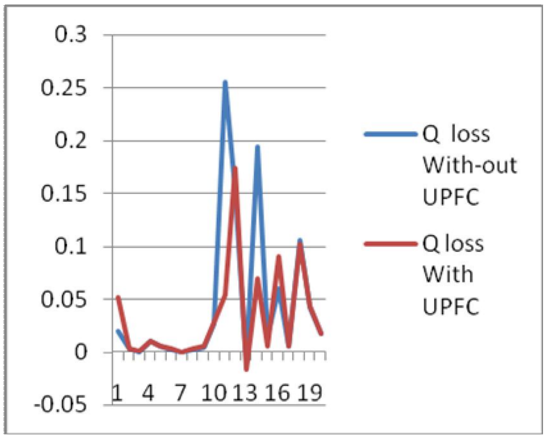

Fig. 14 Reactive Power (Q) loss Comparison With and With-out UPFC of lines

The figure 14 Shows Reactive Power (Q) loss Comparison With and With-out UPFC of lines. It shows the comparative analysis of Reactive Power (Q) loss for with and with-out UPFC condition. So the analysis denotes the Reactive Power (Q) loss with UPFC of lines is reduced hence the reduction in overall Reactive Power (Q) losses of system.

IV. CONCLUSION

The work on ‘Evolutionary Algorithm assisted Optimal Placement of FACTS Controllers in Power System’ has been carried out to find optimal location of UPFC to improve the voltage profile, reduce losses and enhancement in power system transfer capability of the system. The optimal placement of FACTS controllers has been attempted using

Genetic Algorithm. The study has been carried out on 14-bus system. From the study following conclusions are drawn.

- The developed algorithm is effective in deciding the placement of FACTS devices.
- UPFC helps in diverting flow from heavily loaded lines and results in reduction in active power losses.
- UPFC helps in improving voltage profile of the system and results in reduced reactive power losses.
- UPFC enhanced overall power system transfer capability of the system and results in reduced overall power losses.

REFERENCES

[1] Azimoh L.C and Folly K.A ‘Mitigations of Voltage Instability in Power Systems’, Electrical Power and Energy Conference, University of Cape Town, South Africa,IEEE (2009).

[2] Gupta Vibhor, ‘Study and Effects of UPFC and its Control System for Power Flow Control and Voltage Injection in a Power System’ International Journal of Engineering Science and Technology Vol. 2(7), 2010, 2558-2566 (2010).

[3] Jahani R. “Optimal Placement of Unified Power Flow Controller in Power System Using Imperialist Competitive Algorithm” Middle-East Journal of Scientific Research 8 (6): 999-1007, 2011, ISSN 1990-9233 © IDOSI Publications, pp. 999-1007, (2011).

[4] Kalaivaniand R., Kamaraj V. ‘Modeling of Shunt FACTS Devices for Voltage Stability Enhancement’ European Journal of Scientific Research ISSN 1450-216X Vol.61 No.1 (2011), pp. 144-154, EuroJournals Publishing, Inc. (2011)

[5] Kazemi A., Vahidinasab V., Mosallanejad A. ‘Study of STATCOM and UPFC Controllers for Voltage Stability Evaluated by Saddle-Node Bifurcation Analysis’ First International Power and Energy Coference PECon, 2006, Putrajaya, Malaysia28-29 November (2006).

[6] Lee K. Y."Dynamic and Static Voltage Stability Enhancement of Power Systems," IEEE Transactions on Power Systems, Vol. 8, No. 1, pp. 231-238, (1993)

[7] Marouani Ismail, Guesmi Tawfik, Hadj Abdallah Hsen, “Optimal Location of Multi Type FACTS Devices for Multiple Contingencies Using Genetic Algorithms”, International Journal of Energy Engineering, Vol. 2(2), pp. 29-35,(2012).

[8] North American Electric Reliability Council (NERC) report ‘Available Transfer Capability Definitions and Determination’ June (1996).

[9] Padiyar K. R. and Devi A. L. “Control and simulation of static condenser,” in Proc. 9thAnnu. Applied Power Electronics Conf. Expo., Feb. 13-17 (1994).

[10] Sarda Jigar S., Parmar Vibha N., Patel Dhaval G., Patel Lalit K. ‘Genetic Algorithm Approach for Optimal location of FACTS devices to improve system loadability and minimization of losses’ International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 1, Issue 3, pp.114-125(2012).

[11] Sreejaya P., RejithaR. ‘Reactive power and Voltage Control in Kerala Grid and Optimization of Control Variables Using Genetic Algorithm’, IEEE, pp. 243-248 (2008).

[12] Stéphane Gerbex, Rachid Cherkaoui, and Alain J. Germond “Optimal Location of Multi-Type FACTS Devices in a Power System by Means of Genetic Algorithms”, IEEE Tra. On popwer system, VOL. 16, NO. 3, pp. 537-544 (2001).

[13] Venkateswarlu K., Saibabu Ch. “A New Evalutionary Algorithms Used For Optimal Location OfUpfc On Power System” Journal of Theoretical and Applied Information Technology, JATIT & LLS, pp. 107-118(2010).

[14] Mishra Pushpendra, h. N. Udupa, piyushghune, “Calculation of Sensitive Node for IEEE – 14 Bus System when Subjected to Various Changes in Load” Proceedings of IRAJ International Conference, Pune, India, pp.89-92 (2013).

[15] HingoraniN.g. “High power Electronics and Flexible AC Transmission System,” IEEE Power Eng. REV(1998).

[16] Proposed terms and definitions for flexible AC transmission system (FACTS), " Power Delivery, IEEE Transactions on , vol.12, no.4, pp.1848,1853, doi: 10.1109/61.634216(1997).

[17] JahaniR. H.A. Shayanfar N. M. Tabatabaei J. Olamaei **“**optimal placement of unified power flow controller in power system by a new advanced heuristic method” International Journal on “Technical and Physical Problems of Engineering” issue 5 volume 2 Number 4 pg(2010).

[18] R Kalaivani, Kamaraj V “Enhancement of Voltage Stability by Optimal Location of Static Var Compensator Using Genetic Algorithm and Particle Swarm Optimization” American J. of Engineering and Applied Sciences 5 (1): 70-77, ISSN 1941-7020(2012).

[19] T.Nireekshana Dr.G.Kesava Rao Dr.S.Siva Naga Raju “Incorporation of Unified Power Flow Controller Model for Optimal Placement using Particle Swam Optimization Technique” 978-1-4244-8679-3/11 IEEE(2011).