THOMSON REUTERS ENDNOTE

[Kashyap*, 5(2): February, 2016] ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

DETERMINATION OF OPTIMAL LOCATION OF SVC CONTROLLER DEVICES IN ELECTRIC TRANSMISSION SYSTEM BY USING PSO METHOD

Vibha Kashyap*, Mr. Rahul Rahangdale, Mr. M. K. Pradhan
M.tech Scholar (Power Electronics) Dept of electronics & Communication MATS University Arang(C.G.).
Asst. Professor Dept of electronics & Communication MATS University Arang (C.G.).
Head of department Dept of electronics & Communication MATS University Arang (C.G.).

ABSTRACT

This paper aims to identify the optimal location for the installation of SVC controller using Particle Swarm Optimization (PSO) method to mitigate small signal oscillations in a multi machine power system reducing the power losses. The SVC is required to regulate bus voltages and control shunt capacitor banks located at the transmission system other nearby stations. This way proper capacitor switching strategy is established to reduce daily and seasonal voltage fluctuations to within acceptable limits. However, performance of any FACTS devices mainly depends upon its parameters and suitable location in the transmission system .PSO method is an efficient and general solution to solve most non linear optimization problems with nonlinear inequality constraints. In power transmission oscillations require wide area system supervision and effective control scheme for that area. For this application we are providing time delays in the wide area control loop which plays a significant role in the controller design. Based on this methodology, an innovative approach is presented considering this time delay, we can vary the power angle and making wide area damping control feasible. Only with such a control scheme, UPFC controller or SSSC and STATCOM can be applied beneficially in the future.

KEYWORDS: Particle Swarm Optimization (PSO), UPFC, FACTS, STATCOM.

INTRODUCTION

The main objective to introduce FACTS Technology is to increase the power transfer capability of a transmission network in a power system, giving the direct control of power flow over designated transmission routes and to provide secure loading of a transmission line near the thermal limits. For improve the damping of oscillations as this can threaten the security or limit the usage line capacity. FACTS devices can control the parameters depending on electric transmission systems and thereby improving the characteristics of electric transmission systems. Power flow control is the main role of series FACTS devices.

In this paper this fact has been taken into consideration as well as PSO based technique has been proposed to place FACTS controller in a multi machine system in order to reduce load uncertainty damp small signal oscillations. Under various system conditions and thereby improve the power system transmission and distribution stability a effectively operating Static Var Compensator (SVC) are provided continuously the reactive power required to control dynamic voltage oscillations .By Installation for increasing transfer capability and reduce losses while maintaining a smooth voltage profile under different network conditions SVC is placed at one or more suitable points in the network. Also SVC can mitigate active power oscillations through voltage amplitude modulation. In this paper we are using PSO method for obtaining the best location of SVC controller in transmission system where we get effective power flow control.

PSO OVERVIEW

Inspired from the nature social behavior and dynamic movements with communications of insects, birds and fish. PSO is a meta heuristic optimisation algorithm which uses a number of agents (**particles**) that constitute a swarm moving around in the search space looking for the best solution. Each particle in search space adjusts its “flying” according to its own flying experience as well as the flying experience of other particles.

Collection of flying particles (swarm) - Changing solutions
Search area - Possible solutions
Movement towards a promising area to get the global optimum
Each particle keeps track:

- its best solution, personal best, *pbest*
- the best value of any particle, global best, *gbest*

In the basic particle swarm optimization algorithm, particle swarm consists of "n" particles, and the position of each particle stands for the potential solution in D-dimensional space. The particles change its condition according to the following three principles:

(1) to keep its inertia (2) to change the condition according to its most optimist position (3) to change the condition according to the swarm's most optimist position.

The position of each particle in the swarm is affected both by the most optimist position during its movement (individual experience) and the position of the most optimist particle in its surrounding (near experience). When the whole particle swarm is surrounding the particle, the most optimist position of the surrounding is equal to the one of the whole most optimist particle; this algorithm is called the whole PSO. If the narrow surrounding is used in the algorithm, this algorithm is called the partial PSO. Each particle can be shown by its current speed and position, the most optimist position of each individual and the most optimist position of the surrounding. Algorithm parameters used in PSO method:

A : Population of agents
$\mathbf{p_i}$: Position of agent $\mathbf{a_i}$ in the solution space
f : Objective function
$\mathbf{v_i}$: Velocity of agent's $\mathbf{a_i}$
$\mathbf{V(a_i)}$: Neighborhood of agent a_i (fixed)
The neighborhood concept in PSO is not the same as the one used in other meta-heuristics search, since in PSO each particle's neighborhood never changes (is fixed).

- Particle update rule

$$p = p + v$$

with

$$v = v + c_1 * rand * (pBest - p) + c_2 * rand * (gBest - p)$$

where
p**:** particle's position
v**:** path direction
c_1: weight of local information
c_2: weight of global information
pBest**:** best position of the particle=]]0
gBest**:** best position of the swarm
rand**:** random variable

- Number of particles usually between 10 and 50
- C_1 is the importance of personal best value
- C_2 is the importance of neighborhood best value
- Usually $C_1 + C_2 = 4$ (empirically chosen value)
- If velocity is too low → algorithm too slow
- If velocity is too high → algorithm too unstable

Advantages of the basic particle swarm optimization algorithm:
(1)PSO is based on the intelligence. It can be applied into both scientific research and engineering use.

(2)PSO have no overlapping and mutation calculation. The search can be carried out by the speed of the particle. During the development of several generations, only the most optimist particle can transmit information onto the other particles, and the speed of the researching is very fast.
(3)The calculation in PSO is very simple. Compared with the other developing calculations, it occupies the bigger optimization ability and it can be completed easily.

(4) PSO adopts the real number code, and it is decided directly by the solution. The number of the dimension is equal to the constant of the solution.

Insensitive to scaling of design variables, Simple implementation, easily parallelized for concurrent processing, derivative free, very few algorithm parameters are required, very efficient global search algorithm

Disadvantages of the basic particle swarm optimization algorithm:
(1)The method easily suffers from the partial optimism, which causes the less exact at the regulation of its speed and the direction.

(2)The method cannot work out the problems of scattering and optimization.

(3)The method cannot work out the problems of non-coordinate system, such as the solution to the energy field and the moving rules of the particles in the energy field

DESIGN PROCEDURE

Start
Input PSO parameters and problem parameters
Randomly initialise particles and compute objective values,
Personal bests and swarm best.

While stopping condition is not met
Update velocities and position so fall particles by flight equations
Bound velocities to their limits.
Bound decision variables to their specified ranges. Compute objective values for all particles
Update personal bests
Update swarm best

End While
Display optimal decision vector and optimal objective

End

In most of cases, linearly-decreasing inertia weight PSO is used. This variant focuses more on exploration of search space in initial iterations while at later iterations, the exploitation is mainly conducted, thus, an appropriate trade-off between exploration and exploitation is established. However, in some cases, other PSO variants are adopted for tackling FACTS allocation problem.

In PSO applications on FACTS allocation problem, in most cases, no parameter tuning has been conducted, but the parameters are adopted from PSO literature (normally ωi = 0:9, ωf =0:4, C1 = C2 ¼=2).

Since PSO parameters are problem-dependent, for extract- ing its best computational behaviour, all its parameters should be tuned for the particular FACTS allocation problem to be solved. In PSO literature, there are different methods for tackling constraints. These methods include Penalty approaches (with static/dynamic penalty factors),multi- objective-based approaches, death-penalty approach, flyback approach, co-evolutionary-based approaches, Deb'srules-based approach, stochastic ranking-based approach and ϵ-constrained approach have been demonstrated by numerous installations in the world.

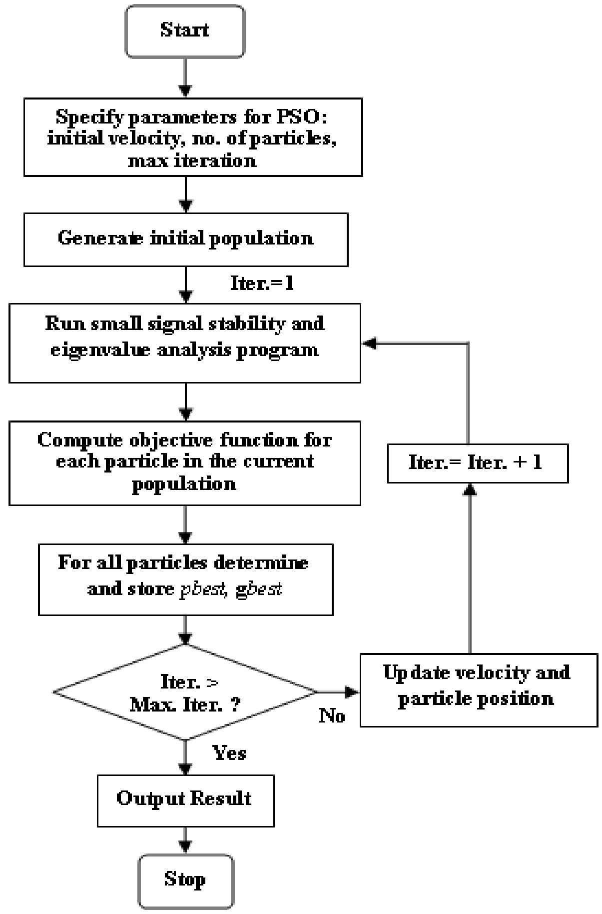

Fig. 1. Flow chart of the implemented PSO

Transmission line segmentation can be expanded for the use of multiple compensators, which are located at equal segments of the transmission line in power system network. Theoretically, we know that the transmittable power would double as the segments are doubles for the same overall line length. As we are increasing the number of segments the variation of voltage along the line would rapidly decrease, and approaching the ideal case of constant voltage profile. Such a distributed compensation depends on the instantaneous response and unlimited var generation and absorption capability of the shunt compensators employed, which would have to stay in synchronism with the prevailing phase of the segment voltages and maintain the predefined amplitude of the transmission voltage, independently of load variation. Such a system, however, would tend to be too complex and probably too expensive, to be practical, particularly if stability and reliability requirements under appropriate contingency conditions are also considered. However, the practicability of limited line segmentation, using thyristor-controlled. The transmission benefits of voltage support by controlled shunt compensation at strategic locations of the transmission system.

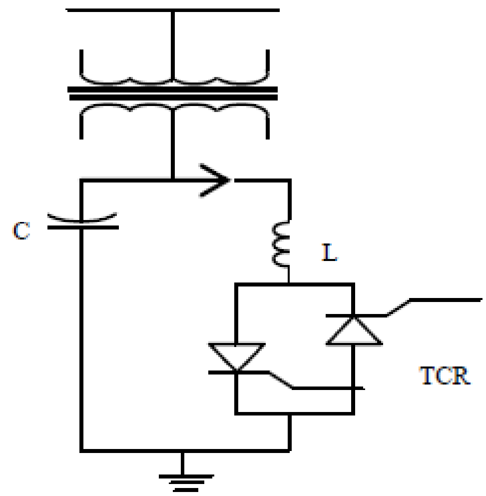

Fig. 2. Configuration of SVC Controller

STATIC MODELLING OF FACTS DEVICES

The equivalent p-representation of a simple transmission line of lumped parameters, connected between bus i and bus j .The complex voltages at bus-i and bus-j are assumed to be Vi\di and Vj\dj respectively. The real and reactive power flows (Pij and Qij) from bus i to bus j are obtained from the following equations.

$$P_{ij} = V_i^2 G_{ij} - V_i V_j [G_{ij} \cos\delta_{ij} + B_{ij} \sin\delta_{ij}] \quad (1)$$

$$Q_{ij} = -V_i^2 (B_{ij} + B_{sh}) - V_i V_j [G_{ij} \sin\delta_{ij} - B_{ij} \cos\delta_{ij}] \quad (2)$$

Where $\delta_{ij} = \delta_i - \delta_j$

Objective function formulated is based on the optimization parameters. It is worth mentioning that the PID damped SVC controller is designed to minimize the power system oscillations after a disturbance so as to improve steady state stability. These oscillations are reflected in the deviations in the generator rotor speed Δw and deviation in terminal voltage Δvt. In the present study the objective function J is formulated as the minimization of

$$J = \int_0^t \left[t(\Delta\omega(t,x))^2 + t(\Delta v_t(t,x))^2 \right] dt$$

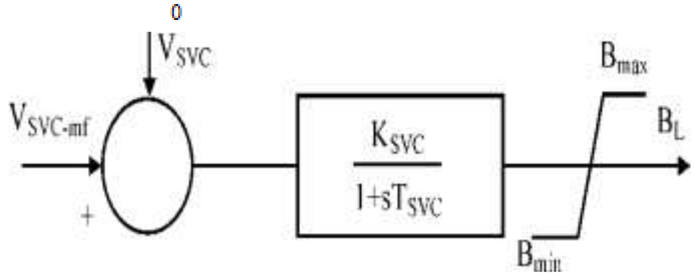

Fig 3. Block representation of svc controller

Particle swarm optimization has become a common heuristic technique in the optimization community, with many researchers exploring the concepts, issues, and applications of the algorithms. The coordinated search for food which lets a swarm of birds land at a certain place where food can be found was modeled with simple rules for information sharing between the individuals of the swarm. A PSO algorithm maintains a population of particles (the swarm), where each particle represents a location in a multidimensional search space (also called problem space). The particles start at random locations and search for the minimum (or maximum) of a given objective function by moving through the search space. The movements of a particle depend only on its velocity and the locations where good solutions have already been found by the particle itself or other (neighbouring) particles in the swarm. PSO algorithm each particle keeps track of the coordinates in the search space which are associated with the best solution it has found so far. The corresponding value of the objective function (fitness value) is also stored. Another "best" value that is tracked by each particle is the best value obtained so far by any particle in its topological neighbourhood. When a particle takes the whole population as its neighbours, the best value is a global best. At each iteration of the PSO algorithm the velocity of each particle is changed towards the Personal and global best (or neighbourhood best) locations. But also some random component is incorporated into the velocity update. Integral time absolute error of the speed deviations is taken as the objective function. The expression of objective function is as follows:

$$J = \int_{t=0}^{t=t_{sim}} |\Delta\omega|.t.dt$$

Where, $\Delta\omega$ is the speed deviation and tsim is the time range of simulation.

Algorithms for Implemented PSO:
The most popular configuration of this type of shunt connected device is a parallel combination of fixed capacitor C with a thyristor controlled reactor (TCR) . The block diagram of a basic SVC incorporating an auxiliary controller has been shown in Fig.2. The voltage input, ΔV_{svc} of the SVC controller is measured from the SVC bus. The machine speed is taken as the control input to the auxiliary controller. The firing angle (α□) of the thyristor determines how much susceptance is included in the network. The SVC equivalent susceptance, *Bsvc* at fundamental frequency is given by :

$$B_{svc} = -\frac{X_L - \frac{X_C}{\pi}(2(\pi-\alpha)+\sin(2\alpha))}{X_C X_L}$$

while its profile as a function of firing angle for
XC □□1.1708 pu and *X L* □□0.4925 pu has been shown in Fig.3

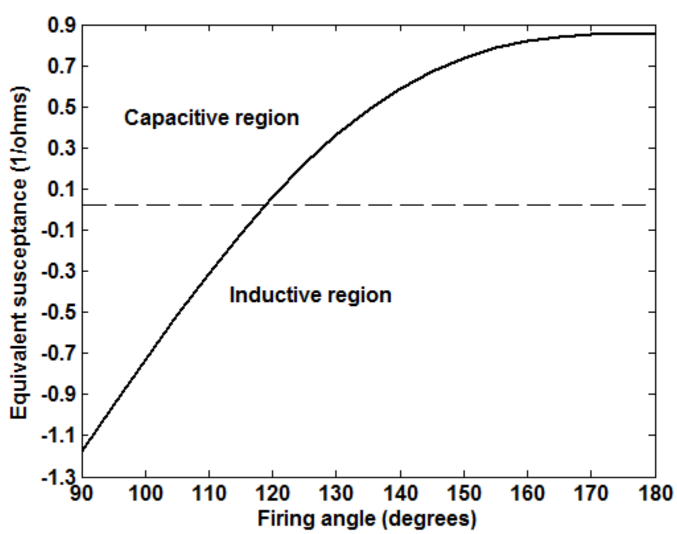

Fig. 4. Bsvc as function of firing angle α

Setting *KP* is zero, the linearized state equations of the SVC controller can be represented as:

$\Delta V_S = -\Delta V_S/T_2 + (K_{SVC}/\omega_S)(\Delta\omega/T_2) + (K_{SVC}/\omega_S)(T_1/T_2)\Delta\omega$ (3)

$\Delta\alpha = -K_1 \Delta V_S + K_1 \Delta V_{SVC} - K_1 \Delta V_{ref}$

$\Delta B_{SVC} = (-\Delta\alpha/T_{SVC}) + (-\Delta B_{SVC}/T_{SVC})$

where*Tsvc* is the time delay of the SVC module and σ □□(π□α) is the conduction angle of the thyristor. *Ksvc* , *T*1 and *T*2 are the gain, lead and lag time constant of the auxiliary controller respectively.

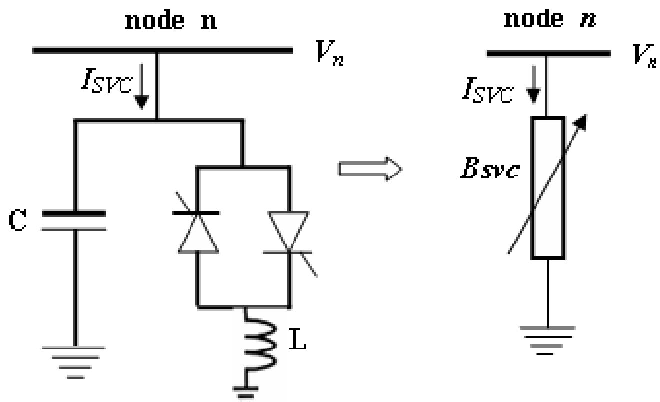

Fig. 5. Advance SVC module

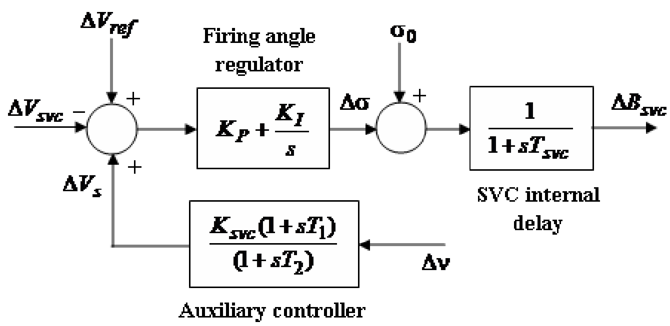

Fig. 6. Block diagram of SVC controller

RESULTS AND PERFORMANCE STUDY

The validity of the proposed PSO based algorithms has been tested here on14 bus system. This system has also been used widely in the literature for small signal stability analysis. In order to study the small signal performance of the system the simulation is carried out for two operating scenarios: (i) real and reactive load increased at a particular bus # 9 (15 % more than nominal case) (ii) outage of a transmission line (# 4-13). The swing modes of the system without SVC are listed in Table I. It has been observed that the mode # 4 is the critical one as the damping ratio of this mode is smallest compared to other modes. Therefore, stabilization of this mode is essential in order to improve small signal performance of the system. Both PSO and the GA algorithms separately generate the best set of parameters as well as the best location (Table II) corresponding to the SVC controller by minimizing the desired objective function *J*. The damping ratio of the critical swing mode # 4 with the application of these PSO and the GA based SVC controllers in their respective optimal locations has been represented in Table III.

To optimize routines from PSO toolbox are used. The objective function corresponding to each particle is evaluated by the eigenvalue analysis program of the proposed test system shown . The particle is defined as a vector which contains the SVC controller parameters and the location number: *Ksvc*, *T*1, *T*2 and *Nloc*. The initial population is generated randomly for each particle and is kept within a typical range. The SVC is an effective Shunt FACTS reactive compensation device. It is placed at the mid section of transmission line. SVC modulate the voltage at its terminal by controlling the amount of reactive power injected into or absorbed from the power system. SVC generates the reactive power (capacitive mode), when the system voltage is lower and it absorbs reactive power (inductive mode), when the voltage is higher. reactive shunt compensation can significantly increase the maximum transmittable power. Thus, it is reasonable to expect that, with suitable and fast controls, shunt compensation will be able to change the power flow in the system during and following dynamic disturbances so as to increase the transient stability limit and provide effective power oscillation damping.The potential effectiveness of shunt (as well as other compensation and flow control techniques) on transient stability improvement can be conveniently evaluated by the *equal area criterion.*

TABLE I. SWING MODES WITHOUT SVC

Load increased at bus # 9 (*PL*=0.339 pu, *QL*=0.190 pu)			Transmission line (# 4 - 13) outage	
#BUS NO.	SWING MODE	DAMPING RATIO	SWING MODE	DAMING RATIO
1	-1.5446 ± j7.5274	0.2010	1.5482 ± j7.5222	0.2013
2	-1.4244 ± j6.5313	0.2136	-1.1590 ± j6.1460	0.1853
3	-0.8831 ± j5.8324	0.1497	-0.8845 ± j5.8336	0.1499

TABLE II. APPLICATION OF PSO IN SVC.

applied disturbance	[1] **PSO based SVC controller**	
Load increase (15%)	***Critical swing***	***Damping ratio#4***
	-0.98121 ± j6.0070	0.16121

The convergence rate of the objective function *J* towards best solutions with population size 15 and number of generations 200 has been shown in Figure by graphical point view.

TABLE III. SVC CONTROLLER PARAMETERS AND LOCATION

Obtained controller	SVC gain (*Ksvc*)	Lead time	Lag time	Location (*Nloc*)
PSO based	20	1.00	0.15	BUS#10

The results in minimization of the critical damping index (*CDI*) given by: *CDI* □□*J* □□(1□□*ζ i*)
Here*ζ i* □is the damping ratio of the *i*thcritical swing mode. The objective of the optimization is to maximize the damping ratio as much as possible. There are four tuning parameters of the SVC controller; the controller gain (*Ksvc*), lead time constant (*T*1), lag time constant (*T*2) and the location number (*Nloc*). These parameters are to be optimized by minimizing the objective function *J* given by. With the change of locations and parameters of the TCSC controller the damping ratio (□) as well as *J* varies. The problem constraints are the bounds on the possible locations and parameters of the SVC controller. The optimization problem can then be formulated as:

$$K_{svc}^{min} \le K_{svc} \le K_{svc}^{max}\ ;\ T_1^{min} \le T_1 \le T_1^{max}$$

$$T_2^{min} \le T_2 \le T_2^{max}\ ;\ N_{loc}^{min} \le N_{loc} \le N_{loc}^{max}$$

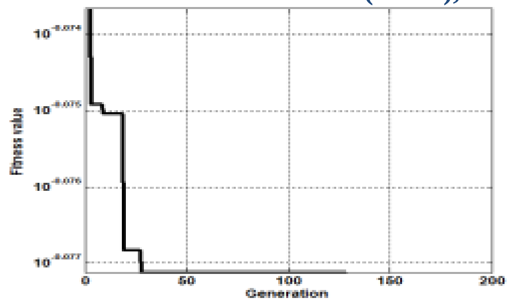

Fig.7 . Convergence of the objective function with PSO

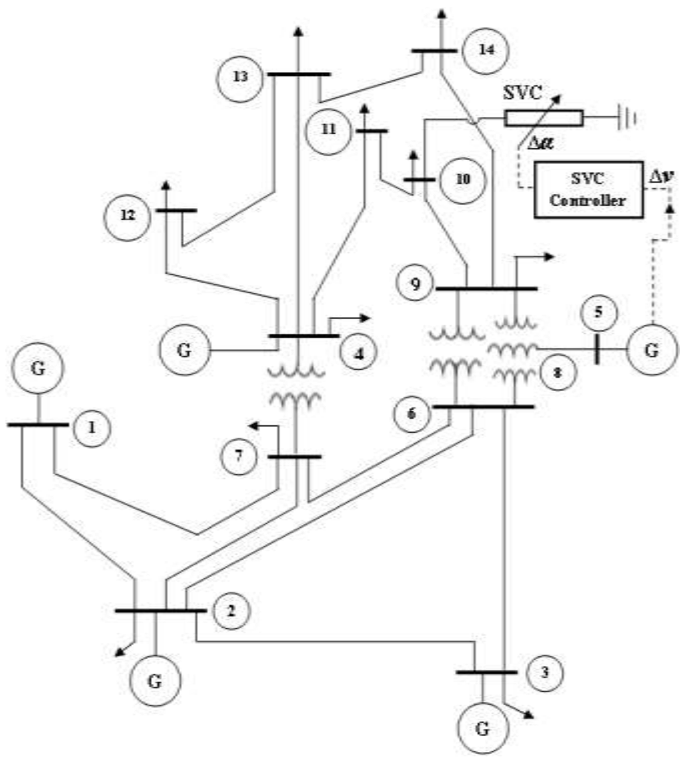

Fig. 8. 14 bus system with the application of SVC

CONCLUSION

In this paper a meta heuristic method PSO has been implemented for determining the optimal parameter and of optimal site of the SVC and multi objective controller in a standard multi-machine power system in order to mitigate the small signal oscillation problem. The present approach of PSO based optimization technique seems to have good accuracy, faster convergence rate. The problem of finding optimal type ,location and size of FACTS devices in electrical power systems is called "FACTS allocation problem" and has widely gained the attention of researchers in electrical power engineering. Problem of finding the best optimal location of SVC controller represents a nonlinear and non-convex optimization problem. Because of the existence of multiple local optimal locating near-global solutions in such an optimization problems PSO is used as a powerful and well-established meta heuristic optimization algorithm. It has been frequently utilized to solve SVC controller allocation problems ,although it suffers from premature convergence problem. In this paper, by the applications of PSO for solving SVC allocation problem to get the best location on transmission line, where reduced power losses and reduced oscillation is achieved.

ACKNOWLEDGEMENT

We would like to show our gratitude to MATS School of Engineering & I.T. for sharing their pearls of wisdom with us during this course. We are immensely grateful to our Principal, Head of Department and M.Tech coordinator for their commands that greatly improved the work in this field. We also thanks to our faculty members for assisting us greatly, Although any errors are our own & should not tarnish the reputation of their esteemed persons.

REFRENCES

[1]. P. Kundur, *Power System Stability and Control*, New York: McGraw-Hill, 1994.

[2]. N. G. Hingorani and L. Gyugyi, *Understanding FACTS: Concepts andTechnology of Flexible AC Transmission System*. IEEE Press. 2000.

[3]. M. Basu, *Multi-objective optimal power flow with FACTS devices, Energy Con-vers. Manage*. 52 (2) (2011)

[4]. S. Ge, T. Chung, *Optimal active power flow incorporating power flow control needs in flexible AC transmission systems*, IEEE Trans. Power Syst. 14 (2) (1999)738–744.

[5]. G. R. Kumar, R. K. Rao and S. S. Tulasi Ram, "Power flow control and transmission loss minimization model with TCSC and SVC for improving system stability and security," *Int. conf. on Industrial and information systems*, India, pp. 1-5, 2008.

[6]. Srinivasa Rao V, Srinivasa Rao.*Comparison of various methods for optimal placement of FACTS devices*. Smart Electric Grid (ISEG), 2014 IEEE International Conference on, pp. 1–7, 19–20 September 2014.

[7]. Kumar A, Chanana S, Parida S. *Combined optimal location of FACTS controllers and loadability enhancement in competitive electricity markets*. In: Proc. Of IEEE PES Summer Meeting. San Francisco; 12–16 June 2005.

[8]. Maliszewski, R. M., and Rahman, M., "Planning and Operating Considerations for the World'sFirst UPFC Installation," *CIGRE Report No.* 37-96 *(US)* 13 *(E)*, Paris, 1996.

[9]. Mehraban, A. S., et aI., "Application of the World's First UPFC on the AEP System," *EPRI Conference-The Future of Power Delivery*, Washington DC, April 9-11,1996.

[10]. Rahman, M., et aI., "UPFC Application on the AEP System: Planning Considerations," *IEEE Trans. on Power Systems*, vol. 12, no. 4, November 1997. *Style Issues*