International Journal of Electrical Engineering.
ISSN 0974-2158 Volume 5, Number 5 (2012), pp. 611-628

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Application of Stochastic Algorithms for Optimal Location of SVC to avoid Voltage Instability

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Abstract

Voltage instability and voltage collapse are very important issues to be considered when load increase and major faults occur in the system. Flexible AC Transmission System (FACTS) can be used to prevent voltage instability, increase power transfer capability and reduce the power loss of the system. Identification of optimal location of FACTS device in the power system is very important task. Stochastic algorithms such as Particle Swarm Optimization (PSO), Genetic Algorithm (GA) and hybrid Particle Swarm Optimization Genetic Algorithm (PSOGA) can be used to solve multi-objective optimization problem. This paper investigates application of PSO, GA and PSOGA to solve multi-objective optimization problem to find optimal location and rating of SVC device to improve voltage stability in the power system. The problem is formulated as multi-objective optimization problem with five objectives such as minimize voltage stability index, total power loss, load voltage deviation, cost of generation and cost of FACTS device. The proposed algorithm is verified with IEEE 14 bus, IEEE 30 bus, IEEE 57 bus and IEEE 118 bus.

Keywords*:* Voltage stability analysis, Voltage collapse, SVC, PSO, GA, PSOGA.

Introduction

Modern power system networks are being operated under highly stressed conditions due to continuous increase in power demand. This has been imposed the threat of maintaining the required bus voltage, and thus the systems have been facing voltage instability problem. Voltage stability is defined as the ability of a power system to maintain steady voltages at all the buses in the system after being subjected to a disturbance from a given initial operating condition. A system enters a state of voltage instability when a disturbance, increase in load demand, or change in system condition causes a progressive and uncontrollable decline in voltage. The main factor causing voltage instability is the inability of the power system to meet the demand for reactive power as in [1]. Different techniques for voltage stability analysis are P-V Analysis, Q-V Analysis, Modal Analysis and Time-Domain Analysis as in [2].

FACTS have made the power systems operation more flexible and secure. They have the ability to control, in a fast and effective manner, it is also possible to control the phase angle, the voltage magnitude at chosen buses and/or line impedances of transmission system as in [3] and [4]. FACTS controllers enhance the voltage profile and the load ability margin of power systems as in [5] and [6]. FACTS devices include Thyristor controlled series compensator (TCSC), Static VAR Compensator (SVC), Thyristor controlled phase angle regulator (TCPST), Static compensator (STATCOM), Unified power flow controller (UPFC) etc. SVC is used for voltage control applications. SVC helps to maintain a bus voltage at a desired value during load variations. The SVC can be made to generate or absorb reactive power by adjusting firing angle. FACTS devices can be modeled and used for power flow analysis as in [7] and [8]

There are several stochastic algorithms such as Genetic Algorithms, Differential Evolution, Tabu Search, Simulated Annealing, Ant Colony Optimization and Particle Swarm Optimization. Each of these algorithms has its own advantageous. Particle Swarm Optimization (PSO) and Genetic Algorithms (GA) are efficient and well known stochastic algorithms.

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr. Eberhart and Dr. Kennedy in 1995, inspired by social behavior of bird flocking or fish schooling. The main idea is based on the food-searching behavior of birds as in [9]. It is observed that they take into consideration of the global level of information to determine their direction. The global and local best positions are computed at each iteration and the output is the new direction of search. Once this direction is detected, it is followed by the cluster of birds.

The optimal location of SVC can be found using PSO in order to improve the voltage stability margin, minimize load voltage deviation and reduce power loss as in [10]. Simultaneous application of particle swarm optimization (PSO) and continuation power flow (CPF) to improve voltage profile, minimize power system total losses, and maximize system load ability with respect to the size of STATCOM can be made as in [11].

Genetic Algorithm is initially developed by John Holland, University of Michigan during 1970's, it is an iterative procedure, which maintains a constant size population of candidate solutions. During each iteration step, three genetic operators such as reproduction, crossover, and mutation are performed to generate new populations and the chromosomes of the new populations are evaluated via the value of the fitness. Based on these genetic operators and the evaluations, the better new populations of candidate solution are formed. If the search goal has not been achieved, again GA creates offspring strings through three operators and the process is continued until the search goal is achieved.

Genetic algorithm is used to optimize the various process parameters involved of FACTS devices in a power system. The various parameters taken into consideration are the location of the device, their type, and their rated value of the devices as in [12]. Multi-type FACTS devices can be placed in optimal location to improve security margins and reduce losses in the network as in [13]. GA can be applied to find optimal location of SVC to increase the power transfer capability and to reduce the generation costs as in [14].

PSO shares many similarities with evolutionary computation techniques such as Genetic Algorithms (GA). The system is initialized with a population of random solutions and searches for optima by updating generations. In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles. Compared to GA, the advantages of PSO are that PSO is easy to implement and there are few parameters to adjust. GA and PSO algorithms are implemented for optimal location of SVC using MATLAB software as in [15].

This paper deals with the applications of PSO, GA and hybrid PSOGA to find optimal location and rating of SVC to minimize the voltage stability index, total power loss, load voltage deviation, cost of generation and cost of FACTS device to improve voltage stability in the power system.

Problem Formulation

In the present work, the multi-objective function is formulated to find optimal location and size of SVC device by minimizing certain objective functions subject to satisfying some network constraints. The multi-objective functions can be written as in [18]:

Objective Functions

The five objective functions such as minimization of voltage stability index, total power loss, load voltage deviation, cost of generation and cost of FACTS device are considered.

Voltage stability index

Voltage stability is an important problem to electric power system. An indicator L-index is used to evaluate voltage stability at each bus of the system. The indicator value varies between 0 (no load case) and 1 (voltage collapse) as in [16] and [17]. L index at load bus j can be expressed as:

$$L_j = |L_j| = \left|1 - \frac{\sum_{i \in \alpha_G} C_{ij} V_i}{V_i}\right| j \epsilon \alpha_L \quad (1)$$

where

α_L : set of load buses

α_G : set of generator buses

V_j : complex voltage at load bus j

V_i : complex voltage at generator bus i

C_{ji} : Elements of matrix C determined by

$$[C] = -[Y_{LL}]^{-1}[Y_{LG}] \tag{2}$$

Matrix $[Y_{LL}]$and $[Y_{LG}]$ are sub matrices of Y bus matrix and it can be found from (3)

$$\begin{bmatrix} I_L \\ I_G \end{bmatrix} = \begin{bmatrix} Y_{LL} & Y_{LG} \\ Y_{GL} & Y_{GG} \end{bmatrix} \begin{bmatrix} V_L \\ V_G \end{bmatrix} \tag{3}$$

The objective function considering minimization of voltage stability index can be represented as:

$$F_1 = \text{Voltage Stability Index} = L_{max} \tag{4}$$

where$L_{max} = \max (L_j)\ j \in \alpha_L$

Fuel Cost

The objective function considering minimization of generation cost can be represented by the following quadratic equation.

$$F_2 = F(P_G) = \sum_{i=1}^{n} a_i P_{Gi}^2 + b_i P_{Gi} + c_i \tag{5}$$

where

n is the number of generators

P_{Gi} is generated power of ith generator

a_i is Cost coefficient of ith generator ($/MWh^2)

b_i is Cost coefficient of ith generator ($/MWh)

c_i is Cost coefficient of ith generator

Power loss

The objective of real power loss minimization is done by selecting the best combination of variables, which minimizes the total real power loss of the network simultaneously satisfying all the network constraints. Mathematically it can be expressed as given in (6).

$$F_3 = P_{loss} = \sum_{i=1}^{N_L} g_{i,j}(V_i^2 + V_j^2 - 2V_iV_j\cos(\delta_i - \delta_j)) \tag{6}$$

where$V_i$is the voltage magnitude at bus

$g_{i,j}$is the conductance of line i-j

δ_i is the voltage angle at bus i

$N_L$is the total number of transmission lines

Load Voltage Deviation

To have a good voltage performance, the voltage deviation at each load bus must be made as small as possible. The voltage deviation (VD) to be minimized is given in (7).

$$F_4 = VD = \sum_{i=1}^{nPQ}\left(\left|V_i\text{-}1\right|\right)^2 \quad (7)$$

where V_i is the voltage magnitude at load bus i.

Cost of FACTS device

The objective function considering minimization of cost of SVC device as in [19] can be represented as in (8).

$$F5 = C_{SVC} = 0.0003S2 \text{ -}0.305S+127.38 \quad (8)$$

where

C_{SVC} is cost of SVC in $/var

S is operating range of SVC in MVAR

$$S = |Q_2 - Q_1| \quad (9)$$

Q1 is MVAR flow before placing FACTS device.

Q2 is MVAR flow after placing FACTS device.

Equality and Inequality Constraints

The objective function is subjected to equality and inequality constraints. Power balance constraints are considered as equality constraints.Inequality constraints are considered for the real power output of generating units, generator reactive power, voltages of all PV buses, transformer tap positions, bus voltage magnitudes of all PQ buses and power flow in the transmission line, reactive power rating of SVC.

The total power generated by the units must be equal to the sum of total load demand and total real power loss in the transmission lines. Hence the equality constraint equations (10)-(11) are:

$$P_{Gi} - P_{Di} - \sum_{j=1}^{n}|V_i|\,|V_j||Y_{ji}|\cos(\delta_i\text{-}\delta_j\text{-}\theta_{ij}) = 0 \quad (10)$$

$$Q_{Gi} - Q_{Di} - \sum_{j=1}^{n}|V_i|\,|V_j||Y_{ji}|\sin(\delta_i\text{-}\delta_j\text{-}\theta_{ij}) = 0 \quad (11)$$

where

$P_{Gi}$is the real power generation at bus i

$Q_{Gi}$is the reactive power generation at bus i

$P_{Di}$is the real power demand at bus i

$Q_{Di}$is the reactive power demand at bus i

N is the total number of buses

$\theta_{i,j}$is the angle of bus admittance element i,j

$Y_{i,j}$is the magnitude of bus admittance element i,j

The inequality constraints are given in equations (12)-(18)

$$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max} \quad \text{for } i=1,2\ldots nPV \tag{12}$$

$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max} \quad \text{for } i=1,2\ldots nPV \tag{13}$$

$$|V_i^{min}| \leq |V_i| \leq |V_i^{max}| \quad \text{for } i=1,2\ldots nPV \tag{14}$$

$$|V_i^{min}| \leq |V_i| \leq |V_i^{max}| \quad \text{for } i=1,2\ldots nPQ \tag{15}$$

$$|T_i^{min}| \leq |T_i| \leq |T_i^{max}| \quad \text{for } i=1,2\ldots nT \tag{16}$$

$$S_{Li} < S_{Limax} \text{for } i = 1,2 \ldots NL \tag{17}$$

$$Q_{SVC}^{min} \leq Q_{SVC} \leq Q_{SVC}^{max} \tag{18}$$

where T, S_L, nPV, nPQ, Nt, NL and $Q_{SVC}$are the tap position, power flow in the line, number of PV buses, PQ buses, number of tap changing transformer, number of lines and reactive power (lagging or leading) injected into the bus where SVC is placed respectively..

Fitness function

Considering all the objective functions fromequations (1)-(9) the fitness function is expressed in equation (17).

$$\text{Fitness function} = h_1F_1 + h_2 F_2 + h_3 F_3 + h_4 F_4 + h_5 F_5 \tag{17}$$

where h_1, h_2 h_3, h_4 and h_5 are weighting factor of voltage stability index minimization objective function, weighting factor of fuel cost minimization objective function, weighting factor of loss minimization objective function, weighting factor of voltage deviation minimization objective function and weighting factor of FACTS cost minimization objective function respectively.

$$h_1+h_2+h_3+h_4+h_5=1 \tag{18}$$

The coefficients h_1, h_2, h_3, h_4 and h_5 are optimized to 0.2, 0.2, 0.2, 0.2 and 0.2.by satisfying equation(18).

Facts Devices

Flexible AC Transmission Systems or FACTS introduced by the Electric Power Research Institute (EPRI) in the late 1980. FACTS devices have the ability to control the phase angle, the voltage magnitude at chosen buses and line impedances of transmission system. In order to meet the growing power demand, utilities have an interest in better utilization of available power system capacities, existing generation and existing power transmission network, instead of building new transmission lines and expanding substations.

Power Flow Modelling of SVC

SVC is a shunt-connected static var generator or absorber whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific parameters of the electrical power system (typically bus voltage). It is modeled as an ideal reactive power injection at the load ends as in [8]. Fig.1 shows variable shunt susceptance model. The current injected and reactive power absorption or generation by SVC is given in equations (19) and (20).

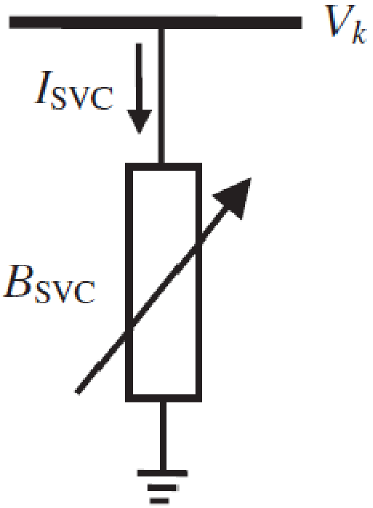

Figure 1: Variable shunt susceptance model

The current drawn by the SVC is

$$I_{SVC} = jB_{SVC}V_k \tag{19}$$

The reactive power drawn by the SVC, which is also the reactive power injected at bus k, is

$$Q_{SVC} = Q_k = -V_K^2\ B_{SVC} \tag{20}$$

Where B_{SVC} is the susceptance of SVC and V_k is the voltage at bus k.

Particle swarm optimization

PSO was proposed by James Kennedy and R. C. Eberhart in 1995, inspired by social behavior of organisms such as bird flocking and fish schooling. PSO as an optimization tool, provides a population based search procedure in which individuals called particles change their position (state) with time. In a PSO system, particles fly around in a multidimensional search space. During flight, each particle adjusts its position according to its own experience, and according to the experience of a neighboring particle, making use of the best position encountered by itself and its neighbor as in [9].

Mathematical Model of PSO

The swarm of particles initialized with a population of random candidate solutions move through the d-dimension problem space to search the new solutions. The fitness, f, can be calculated using equation (17). Each particle has a position and a velocity. After every iteration the best position among the swarm so is stored. Velocity and position of each particle in the swarm are updated after each iteration using equations (21)-(23).

$$v_i^{k+1} = w_i\, v_i^k + c_1 \times rand_1 \times \left(pbest_i - s_i^k\right) + c_2 \times rand_2 \times \left(gbest_i - s_i^k\right) \tag{21}$$

$$s_i^{k+1} = s_i^k + v_i^{k+1} \tag{22}$$

$$w = w_{max} - \frac{w_{max} - w_{min}}{iterw_{max}} \times iter \tag{23}$$

where

V_i^k	Velocity of i^{th} particle at kth iteration;
V_i^{k+1}	Velocity of i^{th} particle at $(k+1)^{th}$ iteration
S_i^k	Current position of particle i at k^{th} iteration
S_i^{k+1}	Current position of particle i at $(k+1)^{th}$ iteration
$P_{best\ I}$	Best position of i^{th} particle
$G_{best\ I}$	Best position among the particles (group best)
c_1	Coefficient of the self-recognition component,
c_2	Coefficient of the social component
$c_1+c_2 = 4$	$Rand_1$ and $rand_2$ are the random numbers usually chosen between [0, 1]
w	Inertia weight,
w_{max}	Initial value of inertia weight;
w_{min}	Final value of inertia weight;
iter	Current iteration number;
$iterw_{max}$	Maximum iteration number

Proposed Algorithm for PSO

The proposed algorithm for the optimal placement of SVC device using PSO is given below

Step 1: The number of devices to be placed is declared and load flow is performed.
Step 2: The initial population of individuals is created satisfying the SVC device's constraints.
Step 3: For each individual in the population, the fitnessfunction is evaluated after running load flow.
Step 4: The velocity is updated using PSO (21) – (23) and new population is created.
Step 5: If maximum iteration number is reached, then go tonext step else go to step 3
Step 6: Print the results.

Genetic Algorithm (ga)

GA is an evolutionary computing method in the area of artificial intelligence. It is a stochastic global search and optimization method that is based on concepts from natural genetics and the Darwinian survival-of-the-fittest code. Genetics is usually used to reach to a near global optimum solution. In each iteration of GA, a new set of string (.i.e. chromosomes) with improved fitness is produced using genetic operators (i.e. selection crossover and mutation). Main components of GA Algorithm are initialization, selection, crossover, mutation and termination as in [12].

Proposed Algorithm for GA

The proposed algorithm for the optimal placement of SVC device using GA is given below

Step 1: Initialize a population of chromosomes.
Step 2: Evaluate each chromosome in the population.
Step 3: Create new chromosomes by mating current chromosomes.
Step 4: Apply mutation and recombination as the parent chromosomes mate.
Step 5: Delete member of the population to, accommodate room for new chromosomes.
Step 6: Evaluate the fitness value of new chromosomes andinsert them into the population.
Step 7: If time is up, stop and return the best chromosomes if not, go to 3.

Hybrid PSOGA

Hybrid PSOGA algorithm combines the standard velocity and position update rules of PSOs with the ideas of selection and crossover from GAs. The algorithmis designed so that the PSO performs a global search and the GA performs a local search.

Proposed Algorithm for Hybrid PSOGA

The proposed algorithm for the optimal placement of SVC device using GA is given below

Step 1: The number of devices to be placed is declared and the load flow is performed.

Step 2: The initial population of individuals is created satisfying the SVC device's constraints.

Step 3: For each individual in the population, the fitness function is evaluated after running load flow.

Step 4: The velocity is updated using PSO (21) – (23) and new population is created

Step 5: If maximum iteration number is reached, then go to next step else go to step 3.

Step 6: Get the last population obtained from PSO as initial population for GA and update the population using GA.

Step 7: For each individual in the population, the fitness function is evaluated after running load flow.

Step 8: If the stop criterion is met then go to step 9 else go to step 6.

Step 9: Output the results.

Results and Discussion

The solutions for optimal location of SVC device to minimize the objective function for IEEE 14 bus, IEEE 30 bus and IEEE 57 bus systems were obtained and discussed below. The test system data used as in [20]. The location, setting of SVC device, optimal objective function value, voltage profile and total real power losses of power system are obtained using the PSO, GA and PSOGA techniques.The parameters used for GA and PSO techniques are shown in Table 1. The proposed PSO and GA is tested on standard IEEE 14 bus, IEEE 30 bus and IEEE 57 bus systems.

Table 1: GA and PSO parameters

GA		PSO	
Population	20	Population	10
Crossover fraction	0.8	C1	2.5
Migration fraction	0.2	C2	1.5
Elite count	2	Wmax	0.9
		Wmin	0.4

IEEE 14 Bus System

It contains 20 transmission lines. The test system consists of 5 generator buses (bus no.1,2,3,6 and 8), 9 load buses (bus no.4,5,7,9,10,11,12,13 and 14) and 20 transmission lines. The total system demand is 259 MW. Optimal location and rating of SVC using GA, PSO and PSOGA techniques is shown in Table 2.Comparison of voltage profile and Comparison of real power loss of IEEE 14 Bus system for without SVC, with SVC at bus 13 obtained from GA, with SVC at bus 7 obtained from PSO and with SVC at bus 10 obtained from PSOGA for normal loading conditionare shown in Fig. 2and Fig. 3 respectively.

Bus 13 is identified as optimal location of SVC using GA and susceptance rating of SVC is 0.2376 p.u. and real power loss is reduced by 7.3%. Bus 7 is identified as optimal location of SVC using PSO and susceptance rating of SVC is 0.2481 p.u. and real power loss is reduced by 3.9%. Bus 10 is identified as optimal location of SVC using PSOGA and susceptance rating of SVC is 0.1897 p.u. and real power loss is reduced by 15% and voltage profile is increased at all the buses.

Table 2: Optimal location and rating of SVC for IEEE 14Bus using GA, PSO and PSOGA

	GA	**PSO**	**PSOGA**
Location	13	7	10
Rating	0.2376	0.2481	0.1897

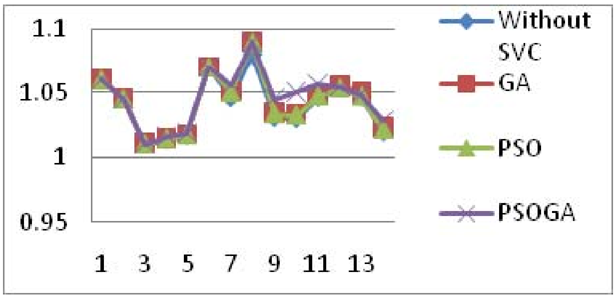

Figure 2: Voltage profile of IEEE 14 Bus system for normal loading condition

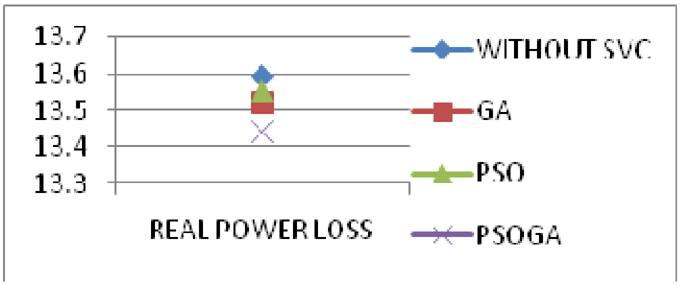

Figure 3: Comparison of real power loss of IEEE 14 Bus system for normal loading condition

IEEE 30 Bus System

The test system consists of 6 generator buses (bus no. 1, 2, 5 ,8, 11,and 13), 24 load buses (bus no. 3, 4, 6, 7, 9, 10, 12, 14 ,15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 and 30) and 41 transmission lines. The total system demand is 283.4 MW.Optimal location and rating of SVCusing GA, PSO and PSOGA is shown in Table 3.Comparison of voltage profile and Comparison of real power loss of IEEE 30 Bus system for without SVC, with SVC at bus 19 obtained from GA, with SVC at bus 17 obtained from PSO and with SVC at bus 10 obtained from PSOGA for normal loading condition are shown in Fig. 4and Fig. 5 respectively.

Table 3: Optimal location and rating of SVC for IEEE 30 Bus using GA, PSO and PSOGA

	GA	PSO	PSOGA
Location	19	17	10
Rating	0.2335	-01189	0.0047

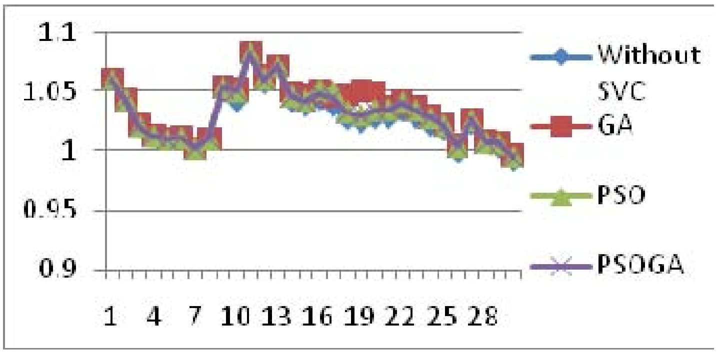

Figure 4: Voltage profile of IEEE 30 Bus system for normal loading condition

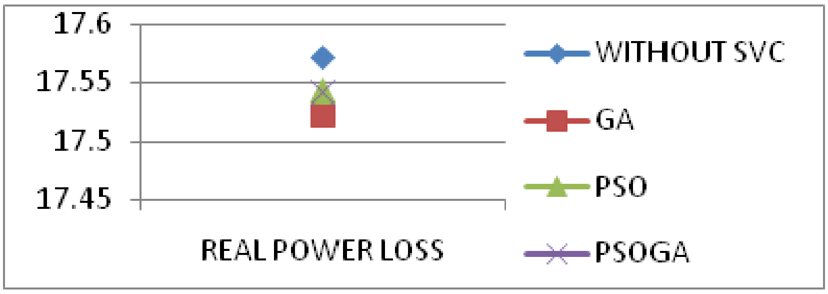

Figure 5: Comparison of real power loss of IEEE 30 Bus system for normal loading condition

Bus 19 is identified as optimal location of SVC using GA and susceptance rating of SVC is 0.2335 p.u. and voltage profile is increased at all the buses and real power loss is reduced by 4.8%. Bus 17 is identified as optimal location of SVC using PSO and susceptance rating of SVC is -0.1189 p.u. and voltage profile is increased at all the buses and real power loss is reduced by 2.8%. Bus 10 is identified as optimal location of SVC using PSOGA and susceptance rating of SVC 0.0047p.u. and voltage profile is increased at all the buses and real power loss is reduced by 3%. When the real power load is increased by 115%, 130% and 150% of normal loading, voltage profile is increased at all the load buses and real power loss is reduced.

IEEE 57 Bus System

The test system consists of 7 generator buses (bus no. 1,2,3,6,8,9,12) 50 load buses (bus no. 4, 5, 7, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57) and 80 transmission lines. The total system demand is 1195.8 MW. Optimal location and rating of SVC using GA, PSO and PSOGA isshown in Table 4.Comparison of voltage profile and Comparison of real power loss of IEEE 57 Bus system for without SVC, with SVC at bus 36 obtained from GA, with SVC at bus 41 obtained from PSO and with SVC at bus 35 obtained from PSOGA for normal loading condition are shown in Fig. 6 and Fig. 7 respectively.

Optimal location of SVC using GA is Bus 36 and susceptance rating of SVC is 0.2335 p.u. and voltage profile is increased at all the buses and real power loss is reduced by 84.9%. Bus 41 is identified as optimal location of SVC using PSO and susceptance rating of SVC is -0.0763 p.u. and voltage profile is increased at all the buses and real power loss is reduced by 56.5%. Bus 35 is identified as optimal location of SVC using PSOGA and susceptance rating of SVC is 0.2137p.u. and voltage profile is increased at all the buses and real power loss is reduced by 64.2%. When the real power load is increased by 115%, 130% and 150% of normal loading, voltage profile is increased at all the load buses and real power loss is reduced.

Table 4: Optimal location and rating of SVC for IEEE 57 Bus using GA, PSO and PSOGA

	GA	**PSO**	**PSOGA**
Location	36	41	35
Rating	0.2335	-0.0763	0.2137

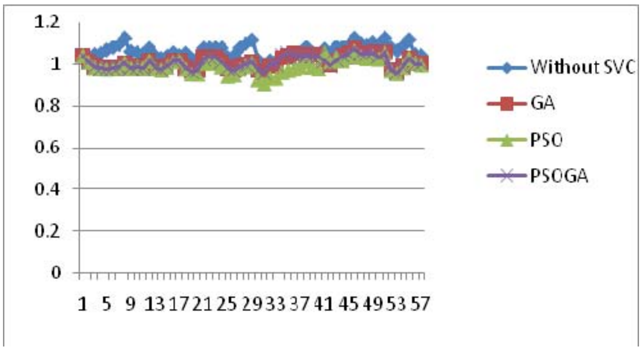

Figure 6: Voltage profile of IEEE 57 Bus system for normal loading condition

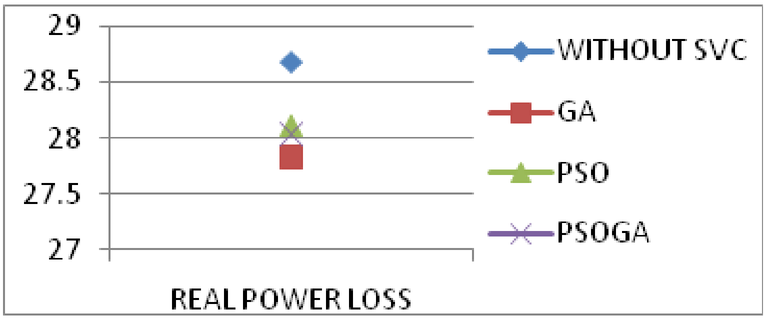

Figure 7: Comparison of real power loss of IEEE 57 Bus system for normal loading condition

IEEE 118 Bus System

The test system consists of 54 generator buses (bus no. 1, 4, 6, 8, 10, 12, 15, 18, 19, 24, 25, 26, 27, 31,32, 34, 36, 40, 42, 46, 49, 54, 55, 56, 59, 61, 62, 65, 66, 69, 70, 72, 73, 74, 76, 77, 80, 85, 87, 89, 90, 91, 92, 99, 100, 103, 104, 105, 107, 110, 111, 112, 113, 116) , 64 load buses (bus no. 2, 3, 5, 7, 9, 11, 13,14, 16, 17, 20, 21, 22, 23, 28, 29, 30, 33, 35, 37, 38, 39, 41, 43, 44, 45, 47, 48, 50, 51, 52, 53, 57, 58, 60, 63, 64, 67, 68, 71, 75, 78, 79, 81, 82, 83, 84, 86, 88, 93, 94, 95, 96, 97, 98, 101,102, 106, 108, 109, 114, 115, 117, 118), 86 transmission lines and bus no. 69 is slack bus.The total system demand is 3668 MW.Optimal location and rating of SVC using GA, PSO and PSOGA is shown in Table 5.Comparison of voltage profile and Comparison of real power loss of IEEE 118 Bus system for without SVC, with SVC at bus 108 obtained from GA, with SVC at bus 33 obtained from PSO and with SVC at bus 95 obtained from PSOGA for normal loading condition are shown in Fig. 8 and Fig. 9 respectively.

Table 5: Optimal location and rating of SVC for IEEE 118Bus using GA, PSO and PSOGA

	GA	PSO	PSOGA
Location	108	33	95
Rating	0.1737	0.0234	0.1138

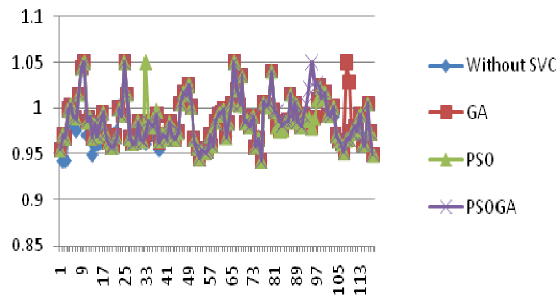

Figure 8: Voltage profile of IEEE 118 Bus system for normal loading condition

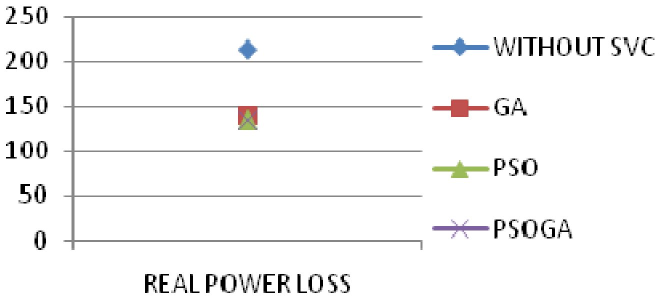

Figure 9: Comparison of real power loss of IEEE 118Bus system for normal loading condition

Conclusion

GA, PSO and PSOGA stochastic algorithms are used to solve five objective functions to find optimal location and rating of SVC. This paper proposed algorithm for GA, PSO and PSOGA to find the optimal location and size of SVC device for decreasing voltage stability index, power loss, voltage deviation, cost of generating unit and cost of SVC device. Simulations were performed on IEEE 14, 30, 57 and 118 bus systems. It is observed from the results thatthe voltages stability margin is improved, voltage profile of the power system is increased, load voltage deviation is reduced and real power losses also reduced by optimally locating SVC device in the power system.

Appendix

Single line diagram of IEEE 14 bus, IEEE 30 bus , IEEE 57 busand IEEE 118 bus systems are given in Fig. A.1, Fig. A.2, Fig. A.3 and Fig. A.4. respectively

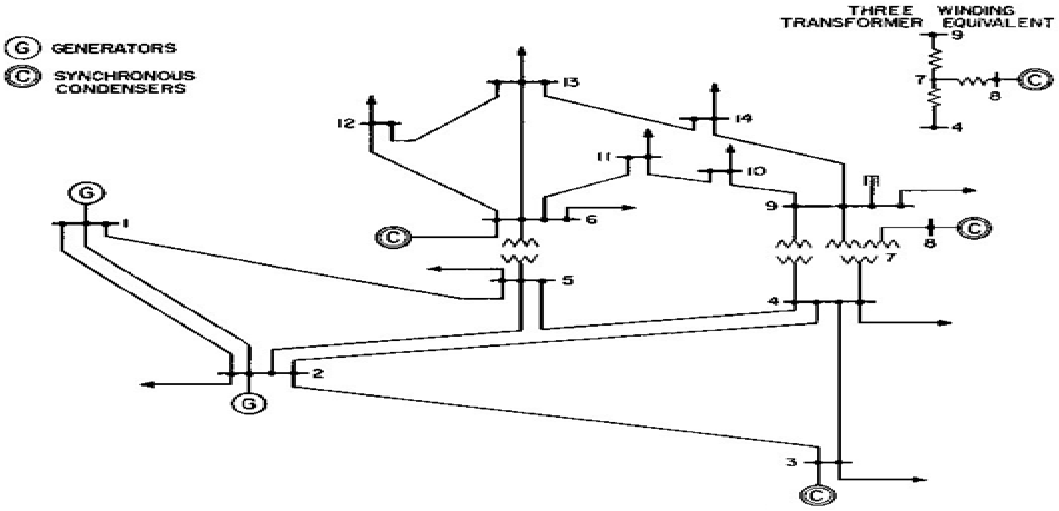

Figure A.1: Single line diagram of IEEE-14 bus system

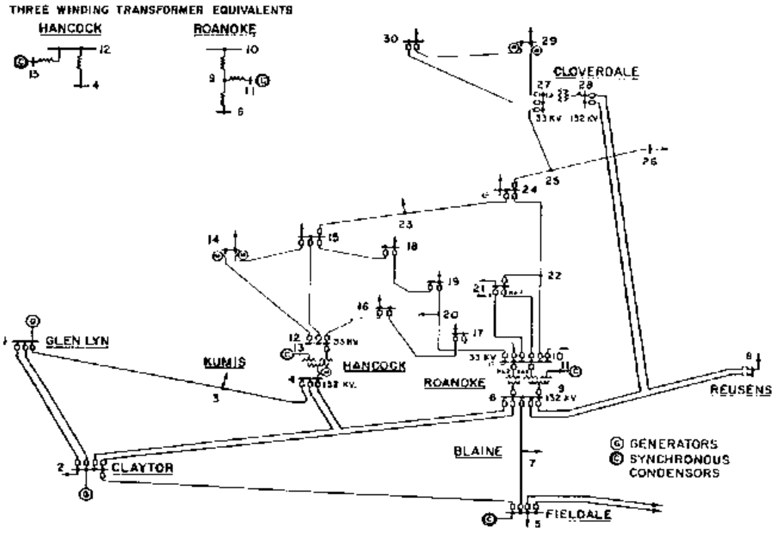

Figure A.2: Single line diagram ofIEEE 30 bus system

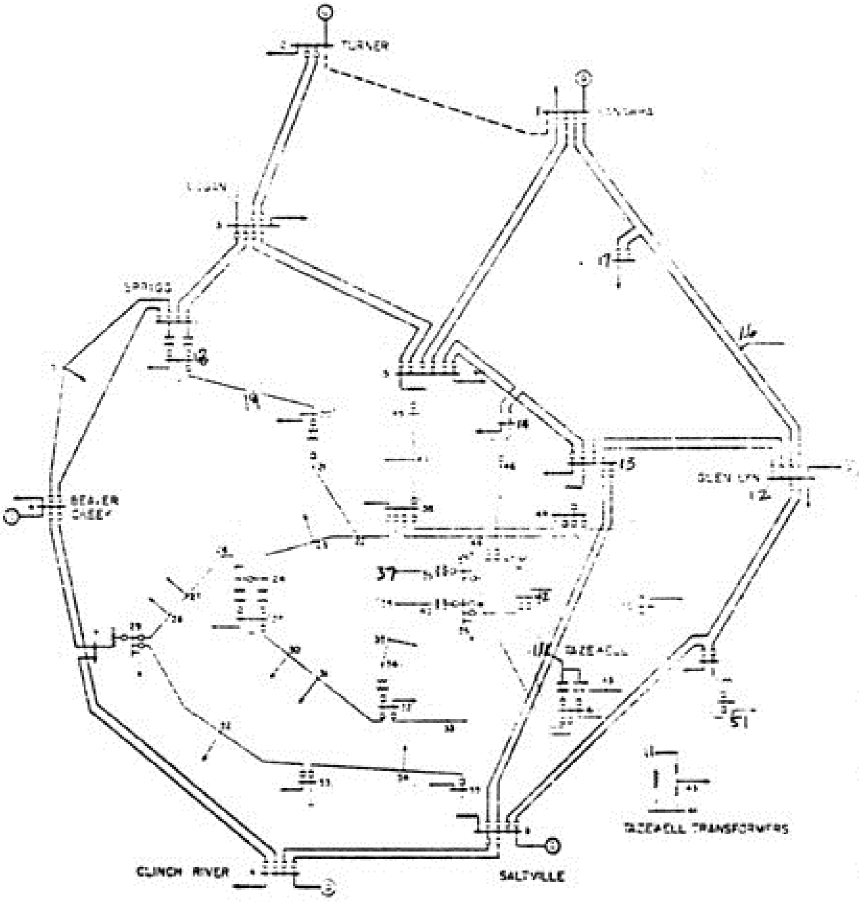

Figure A.3: Single line diagram ofIEEE 57 bus system

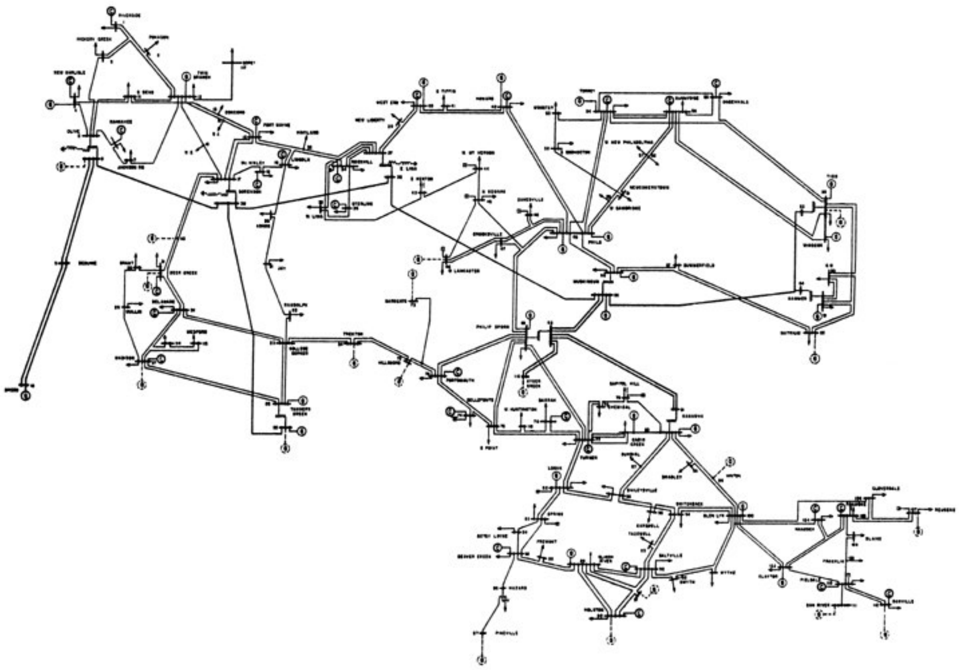

Figure A.4: Single line diagram ofIEEE 118 bus system

Acknowledgment

This work was supported by colleagues and students of Rajalakshmi Engineering College, Chennai, India.

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