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OPTIMAL LOCATION OF FACTS DEVICES USING NOBEL METHOD

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Abstract *–This is very complicated task to find out the optimal location of FACTS devices in deregulated power system The optimizations are made on three parameters: the location of the devices, their types and their sizes. The FACTS devices are located in order to enhance the* ***system security.*** *in this paper the Novel method is use ,in which combination of two method are use particle swarm optimization and genetic algorithm .Particle swarm optimization (PSO) has been shown to converge rapidly during the initial stages of a global search, but around global optimum, the search process becomes very slow. On the other hand, the Genetic algorithm is very sensitive to the initial population. In fact, the random nature of the GA operators makes the algorithm sensitive to initial population. This dependence to the initial population is in such a manner that the algorithm may not converge if the initial population is not well selected. In this paper, we have proposed a new algorithm which combines PSO and GA in such a way that the new algorithm is more effective and efficient and can find the optimal solution more accurately and with less computational time. Optimal location of SVC using this hybrid PSO-GA algorithm is found. We have also found the optimal place of SVC using GA and PSO separately and have compared the results. It has been shown that the new algorithm is more effective and efficient. An IEEE 68 bus test system is used for simulation.*

Keywords: FACTS devices, Hybrid PSO-GA, Optimization, Placement

1 INTRODUCTION

The introduction of flexible AC transmission system (FACTS) in a power system improves the stability, reduces the losses, reduces the cost of generation and also improves the loadability and stability of the system recent years, with the deregulation of the electricity market, the traditional concepts and practices of power systems have been changed. Better utilization of the existing power system to increase capacities by installing FACTS devices becomes imperative. The parameter and variables of the transmission line, i.e. line impedance, terminal voltages, and voltage angle can be controlled by FACTS devices in a fast and effective way [10,12]. The benefit brought about FACTS includes improvement of system dynamic behavior and thus enhancement of system reliability. However, their main function is to control power flows. Provided optimal locations, FACTS devices are capable of increasing the system loadability too. These aspects are playing an increasing and major role in the operation and control of competitive power systems. FACTS devices can be connected to a transmission line in various ways, such as in series, shunt, or a combination of series and shunt. The static VAR compensator (SVC) and static synchronous compensator (STATCOM) are connected in shunt, the static synchronous series compensator (SSSC) and thyristor controlled series capacitor (TCSC) are connected in series, and the thyristor controlled phase shifting transformer (TCPST) and unified power flow controller (UPFC) are connected in series and shunt combination. The terms and definitions of various FACTS devices are described in Reference. It has been proved that the steady state power transfer capability of a line can be doubled when a shunt FACTS is placed at midpoint of the transmission. Shunt compensation enhances the real power handling capacity of a line at a much lower cost than building a second transmission line of the same capacity. Shunt FACTS devices are recognized as smooth control of reactive power over a wide range to support the transmission line. There are a lot of factors that can affect the performance of a power system. One of the problems which cause instability to a power system is voltage stability. Voltage stability has been defined by the System Dynamic Performance Subcommittee of the IEEE Power Engineering Committee as being the ability of a system to maintain voltage so that when load admittance is increased, load power will increase and both power and voltage can be controlled. The main cause of voltage instability is insufficient reactive power supply. Properly planned reactive reserve will provide adequate reactive power support at critical buses. 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 means of Thyristor controlled elements. The advent of Flexible AC transmission systems (FACTS) technology has also coincided with the major restructuring of the electrical power industry. The electric supply industry is undergoing a deep change worldwide.

This paper is organized as follows: following the introduction, different FACTS devices mathematical models are described in section II. Then in section III, objective functions are described. In section IV, the genetic algorithms for optimal location of FACTS devices are discussed in detail Finding the optimal location of different types of FACTS devices in the power system has been reported using different techniques such as Genetic Algorithm (GA), hybrid Tabu approach, simulated annealing (SA), and particle swarm optimization (PSO), etc

Population based, cooperative, and competitive stochastic search algorithms have been very popular in recent years in the research arena of computational intelligence. Some well-established search algorithms such as (GA) and Evolutionary Programming (EP) have been successfully implemented to solve simple and complex problems efficiently and effectively. Most of the population based search approaches are motivated by evolution as seen in nature. Particle swarm optimization (PSO), on the other hand, is motivated from the simulation of social behavior. Nevertheless, they all work in the same way, that is, updating the position of individuals by applying some kinds of operators according to the fitness information obtained from the environment, so that the individuals of the population can be expected to move towards better solution areas. The PSO algorithm was first introduced by Eberhart and Kennedy .Instead of using evolutionary operators to manipulate the individuals, like in other evolutionary computational algorithms, each individual in PSO flies in the search space with a velocity which is dynamically adjusted according to its own flying experience and its companions' flying experience. Unlike in genetic algorithms, evolutionary programming, and evolution strategies, in PSO, the selection operation is not performed. All particles in PSO are kept as members of the population through the course of the run (a run is defined as the total number of generations of the evolutionary algorithms prior to termination). It is the velocity of the particle which is updated according to its own previous best position and the previous best position of its companions. The particles fly with the updated velocities. PSO is the only evolutionary algorithm that does not implement survival of the fittest. Although PSO has shown to be very effective and efficient in many optimization problems, it still suffers from some deficiencies. One of the drawbacks of the PSO is its slow convergence in the vicinity of the global optima. In this paper, by applying a combination of PSO technique and genetic algorithm, the optimal location of SVC devices for power system planning is found. We have employed the best features of PSO and GA in a single algorithm and thus introduced a better algorithm for optimization problems in power system planning. In future research works we intend to focus on how to apply this novel approach for other practical optimization problems.

2 CHOICE OF FACTS DEVICES

In an interconnected electrical network, power flows obey Kirchhoff's laws. Usually, the value of the transverse conductance is close to zero and for most transmission lines, the resistance is small compared to the reactance. By neglecting the transverse capacitance, active and reactive power transmitted by a line between two buses 1 and 2 may be approximated by the following relationships:

$$P12 = (V_1 V_2 / X_{12}) \operatorname{Sin} \theta_{12} \quad .... \quad (1)$$

$$Q12 = (1/X_{12}) (V_{12} - V_1 V_2 \operatorname{Cos} \theta_{12}) \quad .... \quad (2)$$

Where V1 and V2 Voltages at buses 1 and 2; X12 is the reactance of the line; θ12 is the angle between V1 and V2. Under normal operating conditions for high voltage lines V1 ≈V2 and θ12 is typically small.

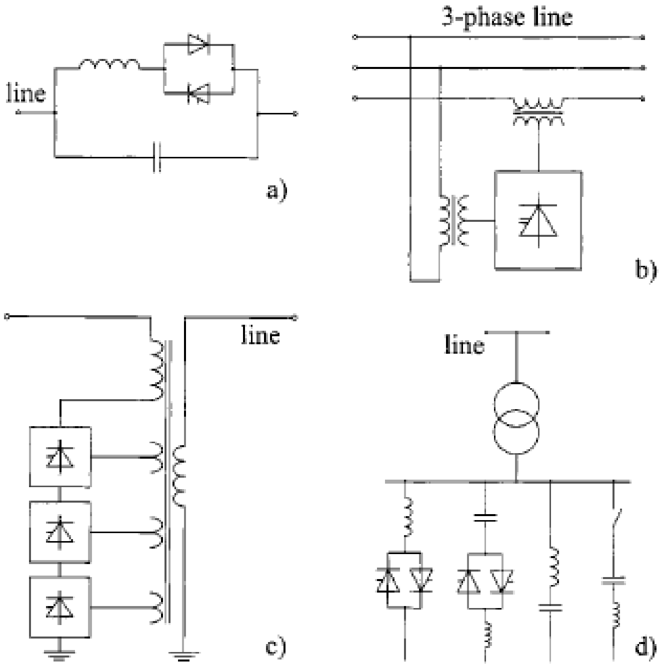


Figure.1 **(a). TCSC, (b). TCPST, (c). TCVR, (d). SVC**

Four different types of devices have been chosen to be optimally located in order to control power flows (Fig.1). Each of them is able to change only one of the above three mentioned parameters. The first one is the **TCSC** (*Thyristor Controlled Series Capacitor*), which permits to decrease or increase the reactance of the line. To control the phase-angle, the **TCPST** (*Thyristor-Controlled Phase Shifting Transformer*) has been selected. The **TCVR** (*Thyristor-Controlled Voltage Regulator*) is picked up to act principally on. Finally, the **SVC** (*Static Var Compensator*) is used to absorb or inject reactive power at the midpoint of the line.

3. MATHEMATICAL MODEL OF FACTS DEVICES

A. FACTS devices:

In an interconnected power system network, power flows obey the Kirchoff's laws. The resistance of the transmission line is small compared to the reactance. Also the transverse conductance is close to zero. The active power transmitted by a line between the buses i and j may be approximated by following relationships

$$P_{ij} = \frac{V_i V_j}{X_{ij}} \sin\delta_{ij} \quad \ldots\ldots\ldots\ldots \quad (1)$$

Where:Vi and Vj are voltages at buses i and j;Xij: reactance of the line; δij: angle between the Vi and Vj. Under the normal operating condition for high voltage line the voltage Vi =Vj and θij is small. The active power flow coupled with θij and reactive power flow is linked with difference between the Vi Vj. The control of Xij acts on both active and reactive power flows. The different types of FACTS devices have been choose and locate optimally in order to control the power flows in the power system network. The reactance of the line can be changed by TCSC.TCPAR varies the phase angle between the two terminal voltages and SVC can be used to control the reactive power. UPFC is most power full and versatile device, which control line reactance, terminal voltage, and the phase angle between the Buses.In this paper, four different typical FACTS devices have been selected: TCSC, TCPAR, SVC and UPFC. Their block diagrams are shown in Figure 2

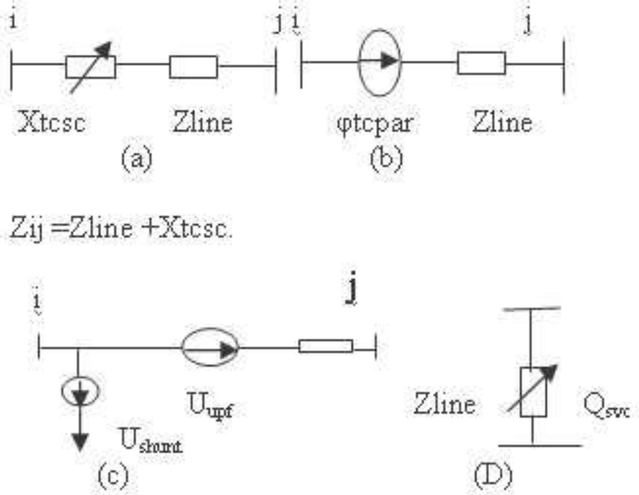


Figure.2 Block diagram of the considered FACTS devices: a) TCSC b) TCPST c) UPFC d) SVC

The above-mentioned FACTS devices can be applied to control the power flow by changing the parameters of power systems, so that the power flow can be optimized.

B Mathematical models

The power-injected model is a good model for FACTS devices because it will handle them well in load flow computation problem. Since, this method will not destroy the existing impedance matrix Z; it would be easy while implementing in load flow programs. In fact, the injected power model is convenient and enough for power system with FACTS devices. The Mathematical models of the FACTS devices are developed mainly to perform the Steady state research. The TCSC, TCPAR, SVC and UPFC are modeled using the power injection method, Furthermore, the TCSC, TCPAR, SVC and UPFC mathematical model are integrated into the model of the Transmission line. Fig: 2 shows a simple transmission line, the parameter are connected between bus i and bus j.the voltages and angles at the buses i and j are Vi, δi and Vj, δj respectively. The real and reactive power flow between the buses i to bus j can be written as

$$P_{ij} = V_i^2 G_{ij} - V_iV_j [G_{ij}\cos(\delta_{ij}) + B_{ij}\sin(\delta_{ij}) \quad \ldots\ldots \; (2)$$

$$Q_{ij} = -V_i^2 (B_{ij}+B_{sh}) - V_iV_j [G_{ij}\sin(\delta_{ij}) - B_{ij}\cos(\delta_{ij})]. \ldots \; (3)$$

Where the $\delta_{ij} = \delta_i - \delta_j$, similarly, the real and reactive power flow between the bus j to bus i is

$$P_{ji} = V_i^2 G_{ij} - V_iV_j [G_{ij}\cos(\delta_{ij}) - B_{ij}\sin(\delta_{ij})] \quad \ldots\ldots \; (4)$$

$$Q_{ji} = -V_i^2 (B_{ij}+B_{sh}) + V_iV_j [G_{ij}\sin(\delta_{ij}) + B_{ij}\cos(\delta_{ij})] \ldots \; (5)$$

TCSC:

The model of a transmission line with a TCSC connected between the buses i and j is shown n figure: 2. The change in the line flows due to series reactance. The real power injection at buses i and bus j (Pi (com)) and Pj(com)can be expressed as

$$P_i (com) = V_i^2 \Delta G_{ij} - V_iV_j [\Delta G_{ij}\cos(\delta_{ij}) + \Delta B_{ij}\sin(\delta_{ij})] \quad (6)$$

$$P_j (com) = V_j^2 \Delta G_{ij} - V_iV_j [\Delta G_{ij}\cos(\delta_{ij}) - \Delta B_{ij}\sin(\delta_{ij})] \quad (7)$$

Similarly, the reactance power injected at bus i and j (Qi (com)) can be expressed as

$$Q_i (com) = -V_i^2 \Delta B_{ij} - V_iV_j [\Delta G_{ij}\sin(\delta_{ij}) - \Delta B_{ij}\cos(\delta_{ij})] (8)$$

$$Q_j (com) = -V_j^2 \Delta B_{ij} + V_iV_j [\Delta G_{ij}\sin(\delta_{ij}) + \Delta B_{ij}\cos(\delta_{ij})] \; (9)$$

Where,

$$\Delta G_{ij} = \frac{X_c R_{ij} (X_{tcsc} - 2X_{ij})}{(R_{ij}^2 + X_{ij}^2)(R_{ij}^2 + (X_{ij} - X_{tcsc})} \quad (10)$$

$$DB_{ij} = \frac{-X_{tcsc} (R_{ij}^2 - X_{ij}^2 + X_{tcsc}X_{ij})}{(R_{ij}^2 + X_{ij}^2)(R_{ij}^2 + (X_{ij} - X_{tcsc})} \quad (11)$$

TCPAR:

The voltage angle between the buses i and jcan be regulated by TCPAR.The model of a TCPAR with transmission line as shown in fig.1. The injected real and reactive power at buses I and j having the phase shifter are

$$P_i (com) = -V_i^2 S^2 G_{ij} - V_iV_j S [G_{ij}\sin(\delta_{ij}) - B_{ij}\cos(\delta_{ij})] \quad (12)$$

$$P_j (com) = -V_iV_j S [G_{ij}\sin(\delta_{ij}) + B_{ij}\cos(\delta_{ij})] \quad (13)$$

$$Q_i (com) = -V_i^2 S^2 B_{ij} + V_iV_j S [G_{ij}\cos(\delta_{ij}) + B_{ij}\sin(\delta_{ij})] \; (14)$$

$$Q_j (com) = -V_iV_j S [G_{ij}\cos(\delta_{ij}) - B_{ij}\sin(\delta_{ij})] \quad (15)$$

Where, S= (tanφ* tcpar)

UPFC:

A series inserted voltage and phase angel of inserted voltage can model the effect of UPFC on network. The inserted voltage has a maximum magnitude of Vt =0.1Vm, where the Vm is rated voltage of the transmission line, where the UPFC is connected. It is connected to the system through two coupling transformers .The real and reactive power injected at buses i and j can expressed as follows

$P_i\,(com) = -V_t^2 G_{ij} - 2V_iV_jG_{ij}\cos(\varphi_{upfc}-\delta_{ij}) + V_iV_j[G_{ij}\cos\varphi_{upfc}+B_{ij}\sin\varphi_{upfc}]$. (16)

$Q_i(com)=V_iV_j[G_{ij}\sin(\varphi_{upfc}-\delta_{ij})+B_{ij}\sin\varphi_{upfc}]$. (17)

$P_j\,(com) = V_jV_t\,[G_{ij}\cos\varphi_{upfc} - B_{ij}\sin\varphi_{upfc}]$. (18)

$Q_j\,(com) = -V_tV_j\,[G_{ij}\sin\varphi_{upfc}+B_{ij}\cos\varphi_{upfc}]$. (19)

SVC:
The primary purpose of SVC is usually control of voltages at weak points in a network. This may be installed at midpoint of the transmission line. The reactive power output of an SVC can be expressed as follows:

$Q_{svc} = V_i\,(V_i-V_r) / X_{sl}$. (18)

Where, Xsl is the equivalent slope reactance input .equal to the slope of voltage control characteristic, and Vr are reference voltage magnitude. The exact loss formula of a system having N number of buses is [1].

$$P_{ltc}=\sum_{J=1}^{N}\sum_{k=1}^{N}[\alpha_{jk}(P_jP_k+Q_jQ_k)+\beta_{jk}(Q_jP_k-P_jQ_k)]. \quad (19)$$

Where Pj, Pk and Qj, Qk respectively, are real and reactive power injected at bus-j and αjk, βjk are the loss coefficients defined
Where

$$\alpha_{jk} = \frac{R_{jk}}{V_iV_k}\cos(\delta_j-\delta_k) \quad (20)$$

$$\beta_{jk} = \frac{R_{jk}}{V_iV_k}\sin(\delta_j-\delta_k). \quad (21)$$

Where Rjk is the real part of the j-kth element of [Zbus] matrix. The total loss if a FACTS device, one at a time, is used, can be written as follows .

$P_{lk} = (P_{lkc} - [P_i\,(com) + P_j\,(com)]$. (22)

More than one device used at time, can be expressed as

$$P_{lk} = \left(P_{lkc} - \sum_{d=1}^{N_d}[P_i\,(com)+P_j\,(com)]\right) \quad (23)$$

Where, Nd is number of device is to be located at various lines.

4. OBJECTIVE FUNCTION

The aim is that to utilize the FACTS device for optimal amount of power in a system is to supply without overloaded line and with an acceptable voltage level. The optimal location of
FACTS device problem is to increases as much as possible capacity of the network. i.e loadability. In this work, the FACTS devices have been considered to Economic saving function, which obtained by energy loss, it requires calculation of total real power losses at the day and light load levels.
Objective function is,
Min F (u) is

$$PL\,(V,d,S) = \sum_{i=1}^{N} PL_t{*}E_{loss}{*}\Delta T - C_{in}] \quad (24)$$

Subject to :

$F\,(b, v) = 0$

$F1(s) < M1$,

$F2\,(v) < M2$

Where, u- set of parameters that indicate the location, devices and rated values (b, v): conventional power flow equations, and ΔT – time duration. Loss is energy loss cost. in is investment cost of FACTS device. F1(s) <M1, and F2 (v) <M2 are inequality constraints for FACTS devices, and conventional power flows. The FACTS devices can be used to change the power system parameters. These parameters derive different results on the objective function (1). Also various FACTS device locations, rated value and types have also influences on the objective function. The abovementioned parameters are very difficult to optimize simultaneously by conventional optimization methods. To solve this type of combinatorial problem, the genetic algorithm is employed. The genetic algorithms are well developed and utilized effectively for this work. The C computer coding are developed and for simulated.

5 COST FUNCTIONS

As mentioned above, the main objective of this paper is to find the optimal locations of FACTS devices to minimize the overall cost function consisting of generation costs and FACTS devices investment costs. For minimizing the generation costs in power systems, algorithms are well developed and being used for unit commitment and operation. In this work, a modified version of power simulation software: Mat power 2.0 is employed . For the intended research, Mat power has been extended by incorporating the mathematical models of FACTS devices. Furthermore, cost functions are incorporated for:
• Generation costs.
• Investment costs of FACTS devices.

A. Generation cost function

The generation cost function is represented by a quadratic polynomial as follows:

$$C_2\,P_G) = \alpha_0 + \alpha_1 P_G + \alpha_2 P_G^{\,2}$$

Where *PG* is the output of the generator (MW), and α_0 , α_1 and α_2 are constant coefficients.

B. FACTS devices cost functions

Based on the Siemens AG Database [8for SVC, TCSC and UPFC are developed:

The cost function for UPFC is

$C_{1UPFC} = 0.0003S^2$-02691S+188.2 (US$ / KVar)

For TCSC

$C_{1TCSC}= 0.0015S^2-.713S+153.75$ (US$ / KVar)

For SVC

$C_{1SVC}= 0.0003S^2-0.3051S+127.38$ (US$ / KVar)

Where C_{1UPFC}, C_{1TCSC} and C_{1SVC} are in *US$/kVar* and *S* is the operating range of the FACTS devices in *MVar*. The cost function for SVC, TCSC and UPFC are shown in Fig. 3.

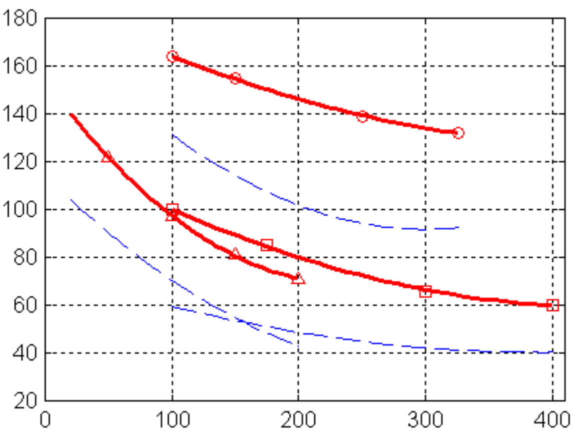


Fig. 3. Cost functions of the FACTS devices: SVC, TCSC and UPFC.

——: Upper limit: Total investment costs

------: Lower limit: Equipment costs

○:-UPFC Δ :- TCSC. □ :- SVC.

The cost of a TCPST is more related to the operating voltage and the current rating of the circuit concerned .Thus, once the TCPST is installed, the cost is fixed and the cost function can be expressed as follows :

$$C_{TCPST}=d*P_{max}+IC$$

where *d* is a positive constant representing the capital cost and *IC* is the installation costs of the TCPST respectively. *Pmax* is the thermal limit of the transmission line where TCPST is installed

6. OPTIMAL FACTS ALLOCATION

The formulation of the optimal allocation of FACTS devices can be expressed as follows :

Min $C_{Total} = C_1(f) + C_2(P_G)$

St $E(f,g) = 0$

$B_1(f)b_1$, $B_2(g) < b_2$

where,

C_{Total} : the overall cost objective function which includes the average investment costs of FACTS devices $C_1(f)$ and the generation cost $C_2(P_G)$. $E(\mathbf{f},\mathbf{g})$: the conventional power flow equations. $B_1(f)b_1$ and $B_2(g) < b_2$ are the inequality constrains for FACTS Devices and the conventional power flow respectively. **f** and **PG** are vectors that represent the variables of FACTS devices and the active power outputs of the generators. **g** represents the operating state of the power system. The unit for generation cost is *US$/Hour* and for the investment costs of FACTS devices are *US$*. They must be unified into *US$/Hour*. Normally, the FACTS devices will be in-service for many years [10,12]. However, only a part of its lifetime is employed to regulate the power flow. In this paper, three years is applied to evaluate the cost function. Therefore the average value of the investment costs are calculated using the following equation:

$$C_1(f) = \frac{C(f)}{8760*3} \quad (\text{US\$/ Hour})$$

where $C(\mathbf{f})$ is the total investment costs of FACTS devices. As mentioned above, power system parameters can be changed using FACTS devices. These different parameters derive different results on the objective function. Also, the variation of FACTS locations and FACTS types has also influences on the objective function. Therefore, using the conventional optimization methods is not easy to find the optimal location of FACTS devices, their types and their rated values simultaneously. To solve this problem, the genetic algorithms method is employed.

7. PARTICLE SWARM OPTIMIZATION (PSO)

Particle swarm optimization (PSO) is a kind of algorithm employed to search for the best solution by simulating the movement and flocking of birds. The algorithm works by initializing a flock of birds randomly over the searching space, where every bird is called a ‘‘particle’’. These ‘‘particles’’ fly with a certain velocity and find the best global position after some iteration. At every iteration, each particle can adjust its velocity vector based on its momentum and the influence of its best position (Pb) as well as the best position of its neighbors (Pg), and then compute a new position that the ‘‘particle’’ is to fly to. Supposing the dimension for a searching space is D, the total number of particles is n and the position of the ith particle is expressed as vector Xi =(xi1,xi2, . . .,xiD); the best position of the ith particle being searched until now is denoted as Pib =(pi1,pi2, . . .,piD), the best position of the total particle swarm being searched until now is denoted as vector Pg =(pg1,pg2, . . .,pgD), and the velocity of the ith particle is represented as vector Vi = (vi1, vi2, . . ., viD). Then the original PSOA is described as :

$$V_{id}(t+1) = V_{id}(t) + C_1{}^* \text{ rand }()^* [P_{id}(t) - X_{id}(t)]+C_2\text{rand }()^* [P_{gd}(t) - X_{id}(t)\}$$

$$X(t+1) = X(t) + V(t+1) \qquad 1 \le i \le X, \quad 1 \le d \le D$$

Where C_1 and C_2 are the acceleration constants with positive values; *rand* () is a random number between 0 and 1; *w* is the inertia weight. In addition to the parameters c_1 , and c_2 , the implementation of the original algorithm also requires placing a limit on the velocity (Vmax). After adjusting the parameters w and Vmax, the PSO can achieve the best search ability. The adaptive particle swarm optimization (APSO) algorithm is based on the original PSO algorithm firstly proposed by Shi and Eberhart in 1998 [15]. The APSO can be described as follows:

$$V_{id}(t+1) = W^{*} V_{id}(t) + C_1^{*} \text{rand}()^{*} [P_{id}(t) - X_{id}(t)]+C_2\text{rand}()^{*} [P_{gd}(t) - X_{id}(t)\}$$

$$X(t+1) = X(t) + V(t+1) \qquad 1 \le i \le X, \quad 1 \le d \le D$$

where *w* is a new inertial weight. By adjusting the parameter w, these algorithms can make w reduce gradually as the generation increases. In the searching process of the PSO algorithm, the searching space will reduce gradually as the generation increases. So the APSO algorithm is more effective, because the searching space reduces step by step nonlinearly, so the searching step length for the parameter w here also reduces correspondingly. Similar to GA, after each generation, the best particle of all the particles in the last generation will replace the worst particle of all the particles in the current generation, thus a better result can be achieved. Generally, in the beginning stages of the algorithm, the inertial weight w should be reduced rapidly, when around optimum, the inertial weight w should be reduced slowly. The step by step algorithm for the proposed optimal placement of SVC devices using PSO is given below:

Step 1. The number of devices to be placed is declared. The load flow is performed.
Step 2. The initial population of individuals is created satisfying the SVC device's constraints given by and also it is verified that only one device is placed in each line.
Step 3. For each individual in the population, the fitness function given by is evaluated after running load flow.
Step 4. The velocity and new population is updated .
Step 5. If maximum iteration number is reached, then go to the next step or else go to step 3.
Step 6. Print the previous best individual's cost of installation and its settings.
Step 7. Stop.

8. GENETIC ALGORITHM (GA)

The GA is a search algorithm based on the mechanism of natural selection and natural genetics. In a simple GA, individuals are simplified to a chromosome that codes for ***180*** *A Novel Algorithm for Optimal Location of FACTS Devices in Power System Planning* the variables of the problem. The strength of an individual is the objective function that must be optimized. The population of candidates evolves by the genetic operators of mutation, crossover, and selection. The characteristics of good candidates have more chances to be inherited, because good candidates live longer. So the average strength of the population rises through the generations. Finally, the population stabilizes, because no better individual can be found. At that stage, the algorithm has converged, and most of the individuals in the population are generally identical, and represent a suboptimal solution to the problem. A GA is governed by three factors: the mutation rate, the crossover rate, and the population size. The implementation of the GA is detailed in . GA are one of the effective methods for optimization problems especially in non-differential objective functions with discrete or continuous decision variables. Figure 4 shows the way that the genetic algorithm works [6]. A brief description of the components of Figure 4 is as below:

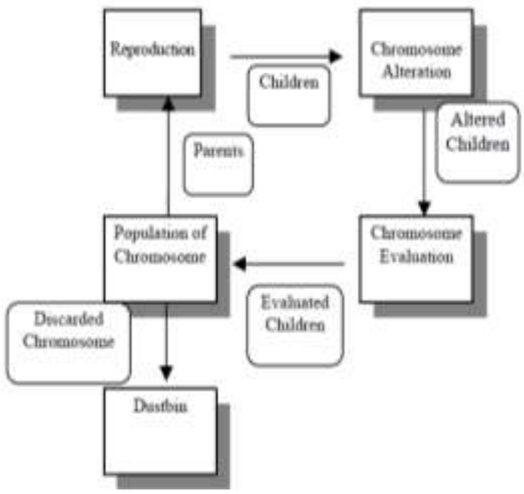
1. Initialize a population of chromosomes.
2. Evaluate each chromosome in the population.
3. Create new chromosomes by mating current chromosomes.
4 Apply mutation and recombination as the parent chromosomes mate.
5. Delete a member of the population to accommodate room for new chromosomes.
6. Evaluate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

As with any search algorithm, the optimum solution is obtained only after much iteration. The speed of the iterations is determined by the length of the chromosome and the size of the populations. There are two main methods for the GA to generate itself, namely generational or steady state. In the case of generational, an entire population is replaced after iteration (generation), whereas in steady state, only a few members of the population are discarded at each generation and the population size remains constant .

One of the drawbacks of the GA is its possibility to converge prematurely to a suboptimal solution . Another drawback of this algorithm is it's high sensitivity to the initial population

There are a few main limitations of a GA when being applied to problems

8. The fitness function must be well-written.
9. It is a blind and undirected search.



10. It is a stochastic search.
11. It is sensitive to initial parameters.
12. It is computationally expensive.

13. What is the stopping criterion?

9 THE PSO-GA ALGORITHM FOR FINDING THE OPTIMAL PALCEMENT OF FACTS

We will use three kinds of algorithm, namely PSO, GA and PSO-GA, for finding the optimal placement of SVC. An IEEE 68 bus test system is used in this simulation. A comparison is made to show the effectiveness of the newly proposed algorithm. The genetic algorithm is very sensitive to the initial population. In fact, the random nature of the GA operators makes the algorithm sensitive to the initial population [19]. This dependence to the initial population is in such a manner that the algorithm may not converge if the initial population is not well selected. However, if the initial population is well selected, the performance of the algorithm may be enhanced. PSO, on the other hand, is not as sensitive as GA to the initial population. One of the characteristics of PSO is its fast convergence towards global optima in the early stage of the search and its slow convergence near the global optima. The idea behind this paper is the combination of the PSO and GA algorithm in such a way that the performance of the newly established algorithm is better than the PSO or GA algorithm. This new algorithm could be used for many optimization problems. In the fist stage of solving the problem of optimization the PSO algorithm will create an initial population near the global optima. After that the algorithm switches to the GA and the GA takes this initial population and continues to solve the optimization problem. The step by step algorithm for the proposed optimal placement of FACTS suppose SVC is considering .using PSO-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 given by (4) and (5) and also it is verified that only one device is placed in each line.
Step 3. For each individual in the population, the fitness function given by (3) is evaluated after running load flow.
Step 4. The velocity and new population is updated by (8).
Step 5. If maximum iteration number is reached, then go to the next step or else go to step 3.
Step 6. Get the last population as the initial population and using the GA update the population.
Step 7. For each individual in the population, the fitness function given by (3) is evaluated after running load flow.
Step 8. If the stop criterion is met, go to step 9 or else go to step 6.
Step 9. Output the results

10 NUMERICAL RESULTS AND DISCUSSION

The goal of optimization is to perform the best utilization of the existing transmission lines. In this respect, the SVC devices are located in order to minimize the power losses and maximize the system loadability while considering voltage constrains and cost of installation. In the following section, optimal placement of SVC in the IEEE 68 bus test system is found using three kinds of algorithms. These algorithms are PSO, GA, and PSO-GA. The results obtained from these algorithms are considered and compared with each other. The simulation studies were carried out on a Pentium IV, 2 GHz system in Matlab environment.

10.1 GA:

The parameters of the GA algorithm are set as below:
Population size = 50
Crossover probability = 1
Mutation probability = 0.7
Maximum number of generations = 100
The problem has three variables, namely Bus Number, SVC susceptance, and Voltage. For every generation the GA will return a maximum, minimum, mean, and standard deviation value from the population size. Twenty runs have been performed for this case and the best result obtained is as follows：

Table 1. Output of the GA Algorithm

Bus Number	(per unit) SVC Susceptance	Total Power Loss
34	1.4654	0.3559

As shown in Table 1, in this case total power loss is reduced by 0.3559

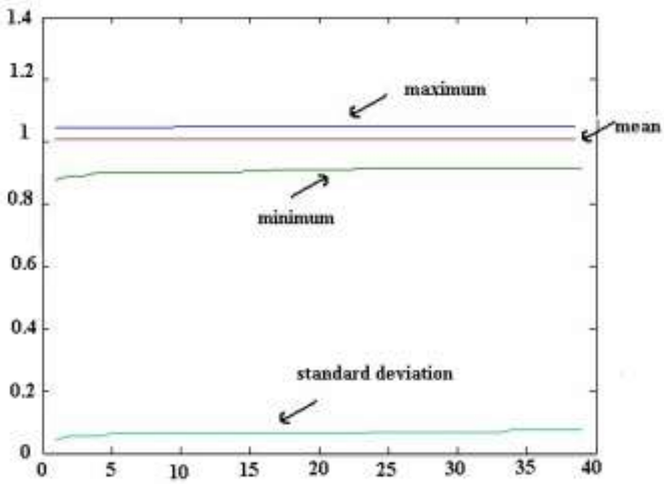


Fig. 4. Results for GA algorithm

As can be seen from Figure 4 the program has converged in 40 iterations. This program took 89.4688 seconds to converge.

10.2 PSO:
The parameters of the PSO algorithm are as follows:
Number of iterations = 100
Inertia = 0.8
Correction factor = 0.2
Swarm size = 50
Only one run has been performed for this case and the result obtained is as follows:

Table 2. Output of the PSO Algorithm

Bus Number	SVC Susceptance (per unit)	Total Power Loss Reduction (pu)
31	1.9754	0.4608

As indicated in Table 2, in this case total power loss is reduced by 0.4608 This program took 150.1671 seconds to converge.

10.3 PSO-GA
The parameters of the PSO-GA algorithm are as follows:
For the PSO
Iteration = 20
Inertia = 0.2
Correction factor = 0.2
Swarm size = 50
For the GA
Population size = 50
Crossover probability = 1
Mutation probability = 0.1
Maximum number of generations = 40
Only one run has been performed for this case and the result obtained is as follows:

Table 3. Output of the PSO-GA algorithm

Bus Number	SVC Susceptance (per unit)	Total Power Loss Reduction (pu)
50	2	0.8823

As shown in Table 3, in this case total power loss is reduced by 0.8823 which is much better than PSO and GA separately.

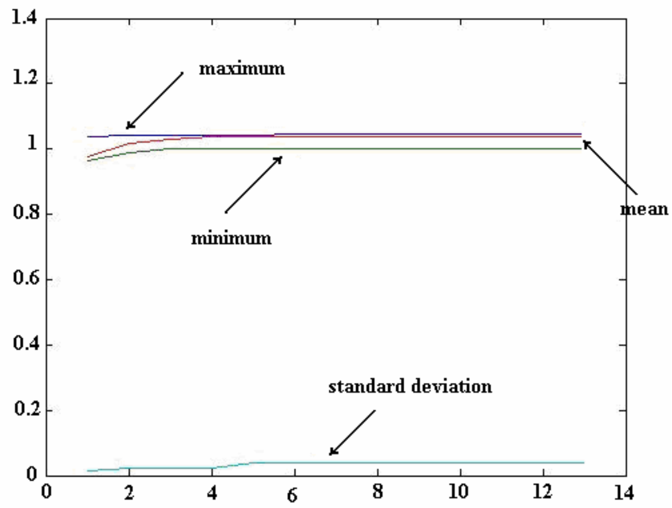


Fig. 5. Results for hybrid PSO-GA Algorithm

As can be seen from Figure 5 the program has converged in 13 iterations. This program took 32.4375 seconds to converge. Figure 5 also shows that the average fitness of the population is very close to the maximum fitness of the population. And thus it is confirmed that the performance of this algorithm is much better than the PSO or GA

11. CONCLUSION

In this paper we have proposed a new algorithm which is a combination of PSO and GA. In this new algorithm we have tried to exploit the best features of both algorithms while obviating the drawbacks of PSO and GA in this new algorithm and thus form a superior algorithm. This algorithm is suitable for solving any optimization problem. With this algorithm we have optimally located the SVC devices in an IEEE 68 bus test system. We have also found the optimal location of SVC using PSO and GA separately and compared the results. By comparing the results we have demonstrated that the new algorithm is more effective and more efficient. In the future research works we intend to focus on how to apply this novel approach for other practical optimization problems.

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