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OPTIMAL LOCATION OF MULTI-TYPES OF FACTS DEVICES USING GENETIC ALGORITHM

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***Abstract**: The problem of improving the voltage profile and reducing power loss in electrical networks is a task that must be solved in an optimal manner. Therefore, placement of FACTS devices in suitable location can lead to control in-line flow and maintain bus voltages in desired level and reducing losses is required. This paper presents one of the heuristic methods i.e. a Genetic Algorithm to seek the optimal location of FACTS devices in a power system. Proposed algorithm is tested on IEEE 30 bus power system for optimal location of multi-type FACTS devices and results are presented.*

***Keywords:** FACTS Devices; Genetic Algorithm; Optimal location;*

I. INTRODUCTION

In the present day scenario private power producers are increasing rapidly to meet the increase demand of electricity. In this process, the existing transmission lines are overloaded and lead to unstable system. Overloading may also be due to transfer of cheap power from generator bus to load bus. New transmission lines or FACTS devices on the existing transmission system can eliminate transmission overloading, but FACTS devices are preferred in the modern power systems based on its overall performance [1]. The benefits brought about FACTS include improvement of system dynamic behaviour and enhancement of system reliability. FACTS devices provide strategic benefits for improved transmission system management through: better utilization of existing transmission assets; increased transmission system reliability and availability; increased dynamic and transient grid stability and enabling environmental benefits. However their main function is to control the power by controlling the parameters such as transmission line impedances, terminal voltages and voltage angles. Power flow is electronically controlled and it flows as ordered by control center and consequently the cost and losses will be optimized. It has been observed that installation of FACTS devices increases the network's controllability but the existing conventional OPF algorithms have to be modified such that power system analysis is possible for modern power industry with FACTS devices. For last two decades researchers develop algorithms to solve OPF incorporating FACTS devices. Still research is in progress to meet the present congestion management problem with help of FACTS devices efficiently. Taranto et al.[6] have proposed decomposition method to solve OPF dispatch problem incorporating FACTS devices. This method deals with the representation of series compensators and phase shifters but this method did not consider the specified line flow constraints. Linear Programming (LP) based security constrained. OPF method has been successfully used to determine the FACTS parameters to control the power flow in the specific lines [7]. Ambriz-Perez et al.[8] have solved OPF problem incorporating FACTS devices using Newton's method, leading to highly robust iterative solutions. Chung and Li [9] have presented GA to determine the parameters of FACTS devices. Ongsakul and Bhasaputra [10] have proposed hybrid Tabu Search and Simulated Annealing *(TS/SA)* technique to solve OPF problems with FACTS devices. For Optimal location of different types of FACTS devices in the power system has been attempted using different techniques such as GA, hybrid tabu approach and Simulated Annealing (SA). The best location for a set of phase shifters was found by GA to reduce the flows in heavily loaded lines resulting in an increased loadability of the network and reduced cost of production. The best optimal location of FACTS devices in order to reduce the production cost along with the device's cost using real power flow performance index was reported [11]. In this paper, an approach to find the optimal location of thyristor-controlled series compensator (TCSC), static var compensator (SVC) and unified power flow controller (UPFC) in the power system to improve the loadability of the lines and minimize the total loss using GA is presented. Examination of the proposed approach is carried out on IEEE 30-bus system. The Genetic Algorithm tool (ga-tool) of MATLAB is implied to solve the problem.

II. FACTS DEVICES MODEL

A. FACTS Devices

In this paper, three different FACTS devices have been selected to place in suitable location to improve security margins in power system. These are: TCSC (Thyristor Controlled Series Compensators), SVC (Static VAR Compensator) and UPFC (Unified Power Flow Controller). These are shown in Fig. 1.Power flow through the transmission line i-j namely P_{ij} is depended on line reactance X_{ij}, bus voltage magnitudes V_i, V_j, and phase angle between sending and receiving buses δ_i-δ_j. This is expressed by Eq.1.

$$Pij = \frac{Vi * Vj \sin(\delta\iota - \delta j)}{Xij} \qquad \text{(Eq.1)}$$

TCSC can change line reactance and SVC can be used to control reactive power in network. UPFC is the most versatile member of FACTS devices family and can be applied in order to control all power flow parameters. Power flow can be controlled and optimized by changing power system parameter using FACTS devices. So, optimal choice and allocation of FACTS devices can result in suitable utilization in power system.

B. Mathematical Model of FACTS Devices

In this paper steady state model of FACTS devices are developed for power flow studies. So TCSC is modelled simply to just modify the reactance of transmission line. SVC and UPFC are modelled using the power injection models. Models integrated into transmission line for TCSC and UPFC and SVC is modelled and incorporated into the bus as shunt element of transmission line. Mathematical models for FACTS devices are implemented by MATLAB programming

language.

TCSC: TCSC acts as the capacitive or inductive compensator by modifying reactance of transmission line. This changes line flow due to change in series reactance. In this paper TCSC is modelled by changing transmission line reactance as below:

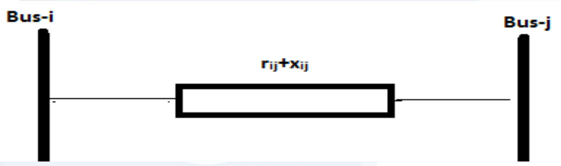

Fig.1 TCSC structure.

$$X_{ij} = X_{line} + X_{t\,csc} \qquad \text{(Eq.2)}$$

$$X_{t\,csc} = r_{t\,csc} * X_{line} \qquad \text{(Eq.3)}$$

where X_{line}= reactance of transmission line, r_{TCSC}=compensation factor of TCSC.

TCSC reactance is chosen between -0.7X_{line} to 0.2 X_{line}.

SVC:- SVC can be used for both inductive and capacitive compensation.

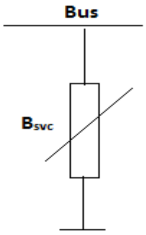

Fig.2 SVC structure

In this paper SVC is modelled as an ideal reactive power injection at bus i:

$$\Delta Q_i = Q_{svc} \qquad \text{(Eq.4)}$$

UPFC:- Two types of UPFC models have been reported . One is coupled model and other is decoupled model. In the first type, UPFC is modelled with series combination of a voltage source and impedance in the transmission line. In decoupled model, UPFC is modelled with two separated buses. First model is more complex compared with the second one because modification of Jacobian matrix in coupled model is inevitable. While decoupled model can be easily implemented in conventional power flow algorithms without modification of Jacobian matrix elements, in this paper, decoupled model has been used for modelling UPFC in power flow study (Fig. 3) UPFC controls power flow of the transmission line where is installed. To obtain UPFC model in load flow study, it is represented by four variables: P_{u1}, Q_{u1}, P_{u2}, Q_{u2}.Assuming UPFC to be lossless, and real power flow from bus *i* to bus *j* can be expressed as[12]:

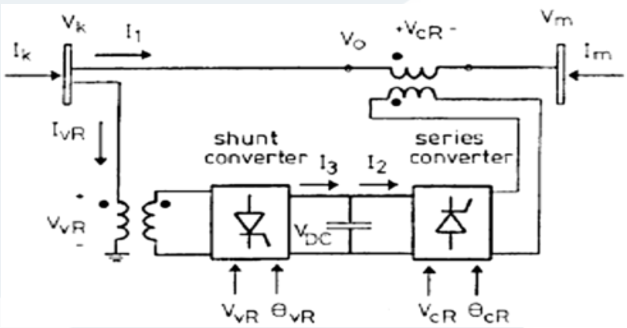

Fig.3 Modelling of UPFC

$$P_{ij} = P_{u1} \qquad \text{(Eq.5)}$$

Although UPFC can control the power flow, but cannot generate the real power. So:

$$P_{u1} + P_{u2} = 0 \qquad \text{(Eq.6)}$$

Each reactive power output of UPFC Q_{u1}, Q_{u2} can be set to an arbitrary value depends on rating of UPFC to maintain bus voltage.

III. GENETIC ALGORITHM

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 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. GAs is 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. 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.

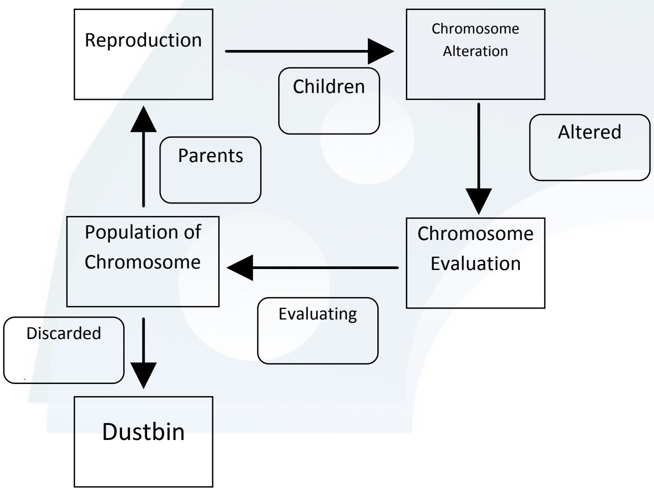

Fig.4 Working of Genetic algorithm.

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 [14].

Fitness calculation:- In this work, the fitness function is bus overloading consider.

$$Fitness = Bus\ loading * 100000000;$$

Where,

$$Bus\ loading = OVL(k) + pcost\_f + pcost\_v + pcost\_qg + pcost\_s;$$

$$OVL(k) = \exp(lamda * abs(1 - abs(spq(k))'\,)/spqmax(k))));$$

pcost_f=calculating penalty for violation of line flow limits;

pcost_v= calculating penalty for violation of load bus voltage limits;

pcost_qg= calculating penalty for violation of generator reactive power limits;

pcost_s= calculating penalty for violation of slack bus active power limits;

Selection Operator:--

Key idea: give preference to better individuals, allowing them to pass on their genes to the next generation. The goodness of each individual depends on its fitness. Fitness may be determined by an objective function or by a subjective judgement.

Crossover Operator:-

Prime distinguished factor of GA from other optimization techniques. Two individuals are chosen from the population using the selection operator .A crossover site along the bit strings is randomly chosen. The values of the two strings are exchanged up to this point. If S1=000000 and S2=111111 and the crossover point is 2 then S1'=110000 and S2'=001111. The two new offspring created from this mating are put into the next generation of the population .By recombining portions of good individuals, this process is likely to create even better individuals.

Mutation Operator:-

With some low probability, a portion of the new individuals will have some of their bits flipped. Its purpose is to maintain diversity within the population and inhibit premature convergence. Mutation alone induces a random walk through the search space;

IV. CASE STUDY AND RESULT

In order to verify the effectiveness of the proposed method, IEEE 30 bus system is used. Different operating conditions are considered for finding the optimal choice and location of FACTS controllers.

Maximum Generation=200;
Maximum no. of iteration=100;
Population size=60;
Elitism probability=0.150000;
Mutation probability=0.001000;
Crossover probability=0.950000.

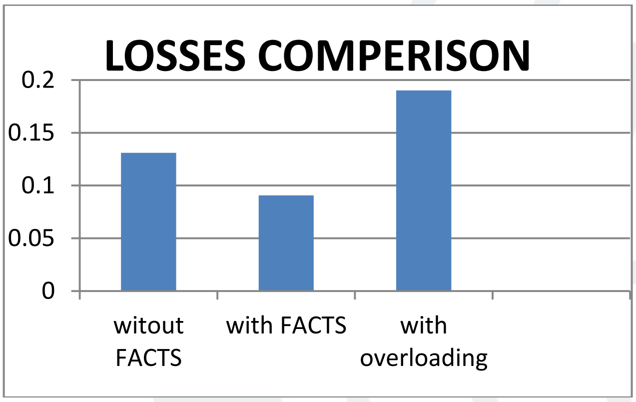

Fig.5 Total losses of the IEEE 30 bus system before and after FACTS insertion.

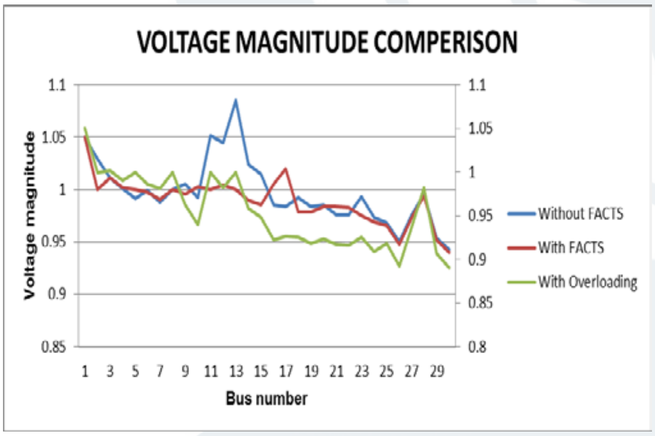

Fig.6 Voltage profile of the IEEE-30 bus at different conditions

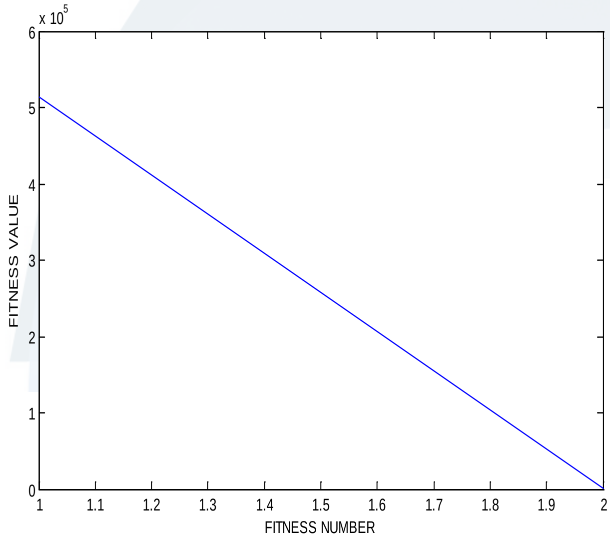

Fig.7 Fitness value plot without overloading condition.

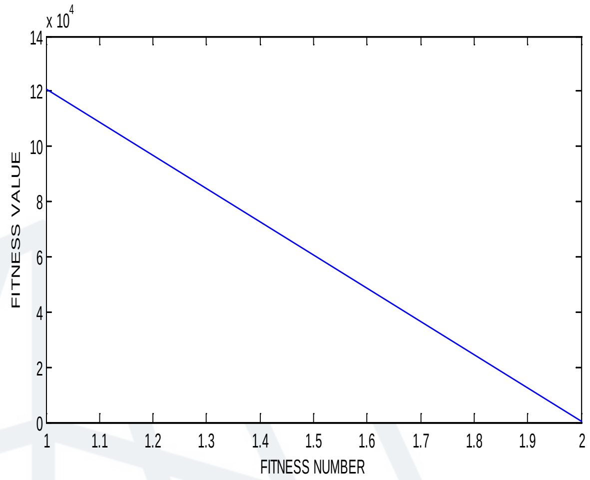

Fig.8 Fitness value plot with overloading condition.

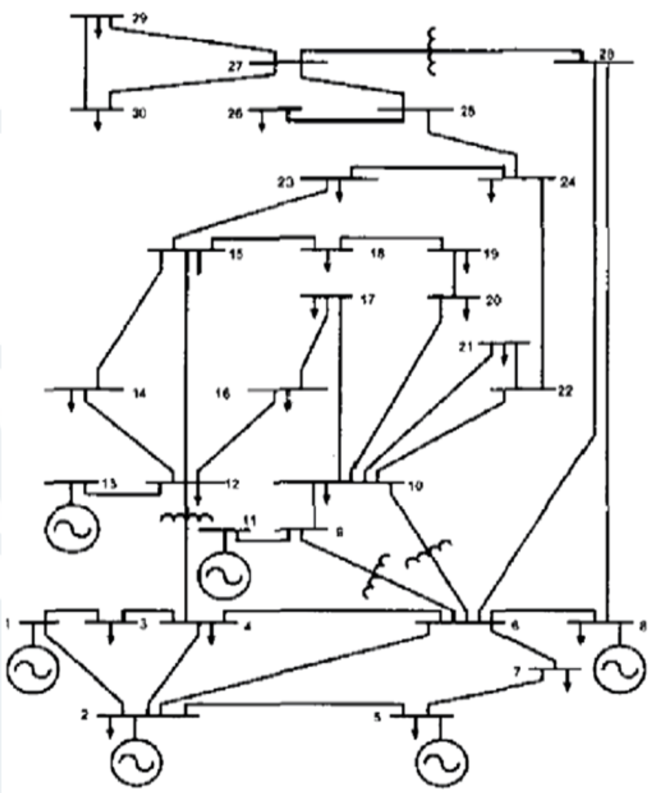

Fig 9. IEEE30 Bus test system

V. CONCLUSION

In this paper a genetic algorithm based approach is proposed to determine the suitable type of FACTS controllers, its optimal location and rating of the parameter of the devices at different loading condition in power system and also minimizes the total losses of the system. The proposed algorithm is an effective and a practical method for the allocation of FACTS controllers.

Table.I Optimal Location, Type, and Parameter value of FACTS Controllers.

Cases	**Location of FACTS devices**	**Device name**	**Para-meter value**	**Fitness value of bus loading**	**Line losses (p.u.)**
Normal loading	LINE-14	UPFC	1.04045	811.093610	0.090742
	LINE-25	SVC	0.019245		
	LINE-32	TCSC	-0.28943		
Increasing 30% load bus loading	LINE-2	TCSC	-0.30755	2537.820205	0.190164
	LINE-5	UPFC	-0.04970		
	LINE-13	TCSC	-0.03952		
	LINE-31	SVC	0.994853		

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