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Voltage Stability Enhancement And Power Loss Minimization With Optimal Location And Parameter Setting Of FACTS Device By Particle Swarm Optimization (PSO)

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Abstract: ***Now a day the transmission lines are operated under the heavily stressed condition, hence there is risk of the consequent voltage instability. There is a multi-functional control device which can be effectively control the load flow distribution and the power transfer capability is the flexible alternating current transmission system (FACTS) Device. The FACTS device performance is depends upon its location and parameters setting. In this paper the particle swarm optimization (PSO) technique is used for this problem. The research of this paper is to select the optimal location and parameter setting of thyristor control series capacitor (TCSC) so as to minimize the active power losses in the power network. The simulation is carried out on IEEE-14 bus test system, it gives the encouraging results.***

Keywords:
FACTS (flexible alternating current transmission system), TCSC (thyristor control series capacitor), compensator), PSO (particle swarm optimization)

1. INTRODUCTION:

Due to the ever increasing demand for the electrical power. The power network is more difficult to operate and more insecure.

On the other hand, Flexible AC transmission system (FACTS) device, which can provide direct and flexible control of power transfer and are very helpful in the operation of power network. The power system performance and the power system stability can be enhanced by using FACTS device. [1] Thyristor control series capacitor (TCSC) is one of the most effective measure device for enhancing the power stability and power transfer capability of transmission network, for this the TCSC should be properly installed in the system with appropriate parameter setting. The some factors considering for optimal installation and the optimal parameter of TCSC, Which are the Stability margin improvement, power loss reduction, power blackout prevention and the power transmission capacity enhancement.

In last 20 years, there are algorithm have been developed for optimal power flow incorporating with TCSC device and for the optimal placement of TCSC; such as are Newtons-Raphson load flow algorithm, Genetic algorithm and the Particle swarm optimization technique for optimal location of the FACTS device. [2], [3] & [4]. It is an actual and important subject to appropriately select the suitable location of the FACTS device installation at the viewpoint of the voltage stability enhancement. The world wide researchers in the power system have retained the interest in this problem. The various method and criteria were proposed and used to optimal allocation of FACTS devices in power network. [5]

In this paper the application of particle swarm optimization (PSO) for the optimal location and parameter setting of the TCSC with consideration of active power loss reduction in the power system is highlighted.

2. PROBLEM FORMULATION:

For minimizing the loss of power system the determination of the optimal location and the optimal parameter setting of the TCSC in the power network is the main objective. For this the performance index is selected:

$$\min F = \sum_{k=1}^{ntl} Plk \qquad (1)$$

Subjected to this there is some equality and inequality constraints are as follows:

3.1 Equality constraints:

$$Pgi - Pdi - \sum_{j=1}^{N} ViVjYij(Xtcsc)\cos(\delta ij + \gamma j - \gamma i) = 0 \qquad (2)$$

$$Qgi - Qdi - \sum_{j=1}^{N} ViVjYij(Xtcsc)\sin(\delta ij + \gamma j - \gamma i) = 0 \qquad (3)$$

3.2 Inequality constraints:

$$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max} \qquad (4)$$

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max} \qquad (5)$$

$$V_i^{min} \leq V_i \leq V_i^{max} \qquad (6)$$

$$\delta_{ij}^{min} \leq \delta_{ij} \leq \delta_{ij}^{max} \qquad (7)$$

$$X_{tcsc}^{min} \leq X_{tcsc} \leq X_{tcsc}^{max} \qquad (8)$$

$$\alpha^{min} \leq \alpha \leq \alpha^{max} \qquad (9)$$

where,
F is the objective function.
P_{LK} *is the active power loss in the* K^{th} *line.*
ntl is the number of busses indices.
N is the set of generation bus indices.
NG is the set of generating bus indices.
Y_{ij} *and* Q_{ij} *are the magnitude and phase angle of element in admittance matrix.*
P_{gi} *is the acrive power generation at bus i .*
Q_{gi} *is the active power load at bus i.*
P_{di} *is the active power load at i.*
Q_{di} *is the reactive power load at bus i.*
V_i *is the voltage magnitude at bus i.*
δ_{ij} *is the power angle.*
X_{tcsc} *is the reactance of TCSC as a function of* α *.*
α *is the thyristor firing angle.*

3. METHODOLOGY FOR OPTIMAL LOCATION OF TCSC.

3.1PARTICAL SWARM OPTIMIZATION (PSO):

Mr. Kennedy and Mr. Eberhart first introduced the PSO in the year of 1995.[6] PSO has its roots in artificial life and social psychology as well as in engineering and computer science. It utilizes a population of individuals, called particles, which fly through the problem hyperspace with some given initial velocities. In each iteration the velocities of the particles are stochastically adjusted considering the historical best position of the particles and their neighborhood best position; where these positions are determined according to some predefined fitness function. Then, the movement of each particle naturally evolves to an optimal or at least near-optimal solution. In PSO algorithm, the particles fly in a multidimensional search space. During the flight each particle adjust its position according its own experience , and the experience of the neighboring particles , making use of the best position encountered by itself and its neighbors as shown in fig.1. as follows.

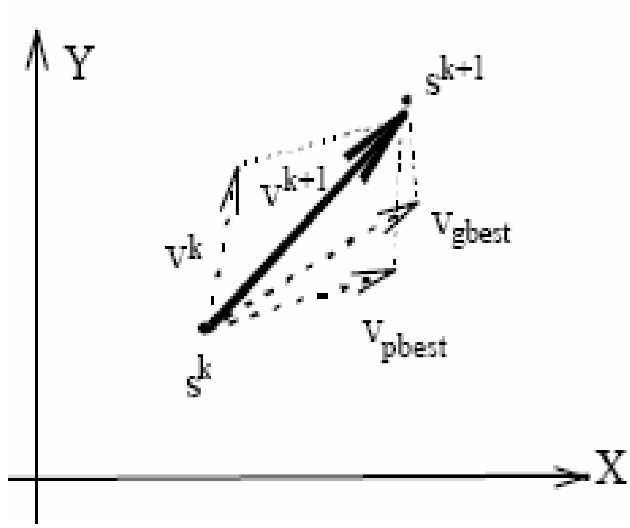

Fig.1: The swarm direction of a particle is defined by the set of particle neighboring the particle and its history experience.

S^k : current searching point,
$S^{k+}1$: modified searching point,
V^k : current velocity,
V^{k+1} : modified velocity,
V_{pbest}: velocity based on Pbest,
V_{gbest}: velocity based on Gbest.

Each particle keeps track of its coordinates in the problem space which are associated with the best solution (fitness) it has achieved so far. The fitness value is also stored. This value is called *Pbest*. When a particle takes all the population as its topological neighbors, the best value is a global best and is called *Gbest*. After finding the two best values, the particle updates its velocity and positions with following equations.

$$v_{id}^{(t+1)} = w.v_{id}^{(t)} + c_1 * rand0 * (p_{id}^{best} - x_{id}^{(t)} + c_2 * rand1 * \left(g_d^{best} - x_{id}^{(t)}\right) \quad (10)$$

$$x_{id}^{(t+1)} = x_{id}^{(t)} + v_{id}^{(t+1)} \quad (11)$$

i=1,2,……..,n, d=1,2,……m.

Where,
p_{id}^{best} is the particle best of agent i.
g_d^{best} is the globle best.
n is the number of particles in a group.
m is the number of members in a particle.
t is the pointer of iterations(generations)
w is the inertia weight factor .
c_1 and c_2 are two acceleration constants .
rand0 and rand1 are two uniform random values in the range [0,1].
$v_i^{(t)}$ is the velocity of particle i at iteration t, $v_d^{min} \leq v_{id}^{(t)} \leq v_d^{max}$
$x_i^{(t)}$ is the current position of particle i at iteration i.

1. PSO Parameters:
The performance of the PSO is greatly affected by its parameter values. Therefore, a way to find a suitable set of parameters has to be chosen. In this case, the selection of the PSO parameters follows the strategy of considering different values for each particular parameter and evaluating its effect on the PSO performance.

2. Number of Particles:
There is a trade-off between the number of particles and the number of iterations of the swarm and each particle fitness value has to be evaluated using a power flow solution at each iteration, thus the number of particles should not be large because computational effort could increase dramatically. Swarms of 5 and 25 particles are chosen as an appropriate population sizes.

3. Inertia Weight:
The inertia weight is linearly decreased. The purpose is to improve the speed of convergence of the results by reducing the inertia weight from an initial value of 0.9 to 0.1 in even steps over the maximum number of iterations as shown in equation

$$w_i = w_{max} - \frac{wmax - wmin}{itermax} \text{ x iter} \quad (12)$$

Where,
Wi = The inertia weight at iteration *i*.
iter = the iteration number.
max*iter* = The maximum number of iterations.

4. SIMULATION RESULTS

On the IEEE-14 bus test system (shown in Fig-2) the proposed PSO algorithm technique have been tested. The data for the mentioned system is taken from [7]. A MATBAB code for PSO algorithm was developed for simulation purposes.

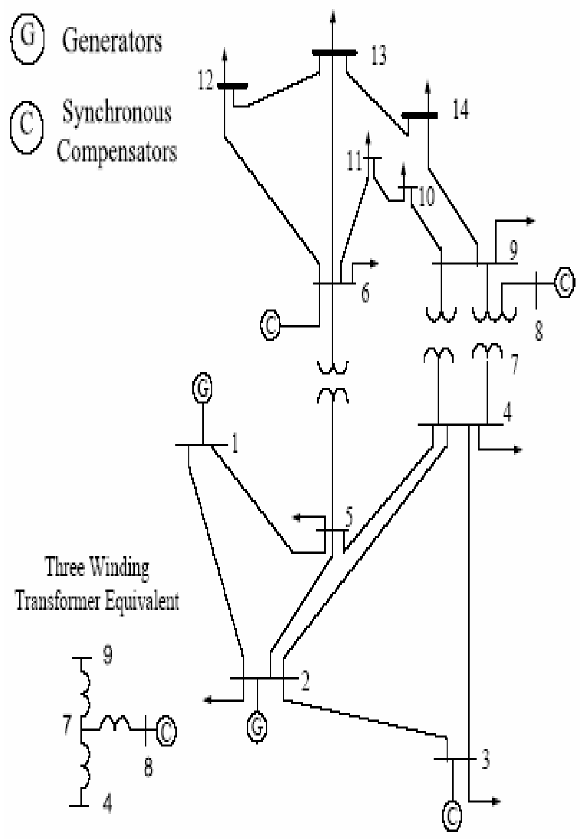

Fig-2: The IEEE-14 Bus system.

4.1 Implementation of PSO

To find out the optimal location and parameter setting of the TCSC, the particle swarm optimization technique is implemented in two numbers of flight namely 30 and 50.

The PSO parameters utilized in this simulation are shown in Table-1.

Table I: PARAMETER VALUES FOR PSO

Parameter of PSO	
c_1,c_2	15
W_{max} and w_{min}	0.9 , 0.4
Deviation of initial velocity	10
Number of variable in the problem	2
Number of flight	30,50
Number of swarm beings	30

The optimal placement of the TCSC for this system is in line number three (from bus 2 to bus 3) and TCSC reactance x_{tcsc} = -0.05.

The table II shown the voltage magnitude, phase angle, active and reactive power losses with TCSC for 50 flights. And fig-3 shows the power loss minimization for 50 flight case.

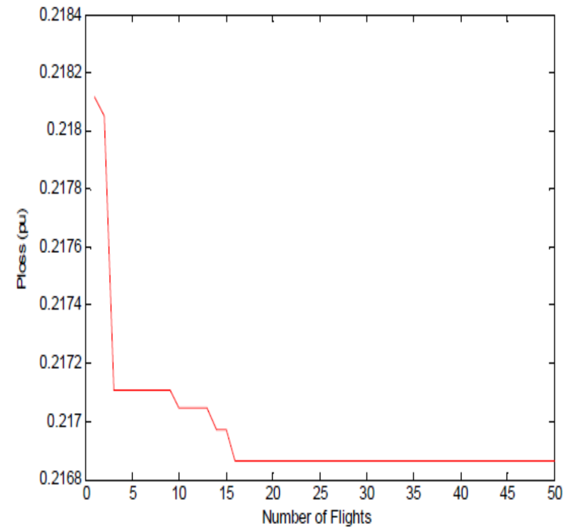

Fig-3: Power losses -50 flights.

TABLE II: Voltage magnitude, phase angle, active and reactive power losses with TCSC

LINE NUMBER	FROM BUS	TO BUS	P^{d}_{loss}(pu)	Q^{d}_{loss}(pu)	BUS NUMBER	VM(pu)	VA(deg)
1	1	2	0.07336	0.0166	1	1.060	0.0
2	1	5	0.0524	0.1644	2	1.0279	-6.42
3	2	3	0.0363	0.110	3	1.0	-14.044
4	2	4	0.025	0.0377	4	0.987	-12.947
5	2	5	0.019	0.0235	5	0.991	-12.063
6	3	4	0.001	0.0316	6	1.0	-18.387
7	4	5	0.0012	0.0074	7	0.979	-16.511
8	4	7	0	0.0182	8	1.0	-16.511
9	4	9	0	0.0167	9	0.964	-18.433
10	5	6	0	0.0482	10	0.961	-18.751
11	6	11	0.0011	0.0023	11	0.977	-18.705
12	6	12	0.001	0.0018	12	0.982	-19.334
13	6	13	0.0026	0.0053	13	0.975	-19.351
14	7	8	0	0.0024	14	0.949	-20.017
15	7	9	0	0.0119	-	-	-
16	9	10	0.002	0.0003	-	-	-
17	9	14	0.0013	0.0027	-	-	-
18	10	11	0.0004	0.0010	-	-	-
19	12	13	0.0001	0.0001	-	-	-
20	13	14	0.0001	0.0019	-	-	-

The average, a worst and best solution for PSO algorithm technique in this system is shown in table III.

Table III: Best,worst and average of objective function for IEEE-14 bus system.

W_{max} and W_{min}		C_1			
		0.5	1.0	1.5	2.0
0.9 0.4	Average	0.221072	0.220226	0.216894	00.21691
	Worst	0.232443	0.232684	0.217032	0.217513
	Best	0.217019	0.217120	0.216860	0.216891

It is observed from the obtained results that the unique advantages of these particle swarm optimization (PSO) technique ,on one hand, there capability of finding the global optimal solution to the optimal location and parameter settings of TCSC problem, on the other hand ,they don't suffer from the extant computational complexity and other limiting mathematical assumptions that the traditional optimization techniques suffer from.

5. CONCLUSION:

In this paper, the optimal location and parameter setting of TCSC device is find out to minimize the active power losses in the power system network using particle swarm optimization (PSO) technique.

With the above proposed algorithm technique, it is possible for utility to place the TCSC device in the transmission grid such that proper power planning can be achieved with minimum system losses. The result obtained from the IEEE-14 bus system test , the power system shows that the PSO algorithm can easily find out the optimal location and the best parameter of the thyristor control series capacitor(TCSC).

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