OPTIMAL PLACEMENT AND SIZING OF MULTI TYPE FACTS DEVICES FOR THE REDUCTION OF REAL POWER LOSS AND ENHANCEMENT OF VOLTAGE STABILITY USING CLPSO AND SLPSO

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Abstract: *This paper presents a modified Particle Swarm Optimization approach for optimal placement and sizing of multi type FACTS devices to minimize the real power loss in the transmission system and thereby enhancing its voltage stability. The optimal placement, number, type of FACTS devices and its size are found out using comprehensive Learning Particle Swarm Optimization (CLPSO) and Social Learning Particle Swarm optimization (SLPSO) techniques. Using this approach the percentage of real power loss reduction for different types of FACTS devices placed at different locations is determined. Also, the voltage stability of the transmission line and load bus is assessed using Line Voltage Stability Index (LVSI) and Bus voltage stability index (BVSI). The multi type FACTS devices used in this work is SVC, TCSC and UPFC. The proposed technique is implemented in MATLAB platform and the results are compared with Particle swarm optimization (PSO) approach. The test systems considered are IEEE 14 bus system and IEEE 57 bus system. The analysis in this work reveals that SLPSO approach is best suitable for the enhancement of voltage stability in transmission system.*

Keywords: *Particle Swarm Optimization (PSO), Comprehensive Learning Particle Swarm Optimization (CLPSO), Social Learning Particle Swarm Optimization (SLPSO), Line Voltage Stability Index (LVSI) and Bus Voltage Stability Index (BVSI)*

1. Introduction

In modern day's power system, the transmission lines are loaded to its maximum capacity. Due to the maximum loading of transmission lines, the stability of the power system gets affected. With the increased power demand day by day, it is essential to improve the voltage profile of the system. The transmission of electricity over long distances through transmission lines involves power loss. Moreover, the economical and environmental factors make the building of transmission lines difficult and urge better utilization of the existing transmission network. As the loading of the transmission lines is increased the amount of real power loss incurred is also increased.

The advances in power electronics have led to the development of electronic controllers in transmission lines that provide controllability and flexibility of power transmission. These electronic controllers are termed as Flexible AC Transmission System controllers (FACTS) [1]. FACTS devices are helpful in controlling the transmission line impedance, shunt admittance, bus voltage and phase angle thereby improving the system security, increasing steady state and transient state stability limits, system loadability and decrease the generation cost [2]. The minimization of losses in the system contributes much to the improved performance of the system. However, the benefits of these FACTS controllers depend on the location, sizing and number of the devices. Therefore, optimal location of these types of devices has to be found [3].

Normally, the location of FACTS devices in the transmission line is obtained using two methods namely Heuristic Optimization algorithm method and analytical techniques method. In Heuristic Optimization Algorithms**,** Optimization algorithms like Genetic Algorithm [4]-[7], Tabu search [8], Simulated Annealing, Particle swarm optimization [9]-[10], Bacterial foraging algorithm, Harmony search algorithm [11] are used to find out the suitable location of FACTS devices. In Analytical Techniques**,** Jacobian matrix method [12], Line Flow Index, Extended voltage phasors approach, mixed integer liner programming [13]-[15] and

Locational Marginal Price [16]-[18] are applied to determine the suitable location of FACTS devices.

Some of the literatures using evolutionary algorithms for the related works are given as below. Gerbex et.al [19] has used genetic algorithm to find the optimal location of multi type FACTS devices such as TCSC, TCPST, TCVR and SVC. These FACTS devices are used in combination to find out the maximum loadability of the transmission line. The test system used is 118 bus power system. Preetha Roselyn et.al [20] has discussed two control strategies to improve the voltage stability under different operating conditions. The first approach involves the minimization of voltage stability index and the second approach is used to determine the location of FACTS devices with generator rescheduling using genetic algorithm. The test system used are IEEE 30 bus test system and IEEE 57 bus test systems. Ravi et.al [21] has proposed an improved particle swarm optimization approach to locate STATCOM in power system to minimize the voltage deviations in the buses. IEEE 30 bus system is used as the test system. And modified PSO approach has been applied to improve the convergence rate of the proposed algorithm. Imran Khan [22] et.al has investigated the enhancement of power system security by FACTS devices. The series compensated device TCSC, the shunt compensated device SVC and the combined controller UPFC were used to solve line congestions and low voltage problems in the system. The test system used in his work is IEEE 14 bus system.

Javaheri et.al [23] has proposed the use of series FACTS devices to relieve congestion by locating the FACTS devices using Harmony search algorithm. Line outage sensitivity factors are used to find out the optimal placement of FACTS devices. The congestion cost and generation cost are minimized in this work and the results are validated using IEEE 14 bus test system. Nireekshana et.al [24] employed SVC and TCSC to enhance the Available Transfer Capacity of the deregulated power system using Cat swarm optimization method. The ATC of the power system is enhanced by considering the thermal limits and voltage profile of the system.

In this paper, analytical method namely Sensitivity Factors method has been used to find the optimal location of FACTS devices. Using Sensitivity indices like line flow Stability index and Bus flow stability index, the weak buses are identified in the test system. On these weak buses, FACTS devices like SVC, TCSC and UPFC are connected. After obtaining the suitable location of these devices, the number, sizing and loss reduction are calculated using optimization algorithm. Heuristic Evolutionary optimization algorithms like PSO, CLPSO and SLPSO are used to meet out these objectives.

PSO is the most popular heuristic algorithm used for solving single and multi objective functions. But, when solving complex multi modal problems in many cases pre mature convergence may result. So, new learning strategies are introduced for the swarm and two kinds of approaches namely comprehensive learning PSO and Social Learning PSO are used for solving multi objective functions. In this paper, the effectiveness of the two algorithms is discussed in solving a multi objective function for the performance enhancement in transmission lines.

2. Problem formulation

2.1. Objective function

The objective function of this work is to find the optimal rating of FACTS devices which reduces real power loss and also enhances the voltage stability as given by,

$$\min f = \sum_{l=1}^{n} P_L^l + \sum_{i=1}^{n-g} V_{D_i} + \sum_{j=1}^{n-g} L_j \quad (1)$$

where P_L^l - real power in a line l

V_{D_i} - Voltage deviation of load bus i

L_j - Bus Voltage Stability Index (BVSI) of load bus j

In equation (1) the first term is related to real power loss in the transmission line, the second term is related to voltage deviation in the transmission line and the third term is related to the Bus Voltage Stability Index of the load bus.

2.1.1. Modeling of FACTS devices

SVC is modeled as a variable susceptance with the rating of,

$$B_{svc}^{min} \le B_{SVC} \le B_{svc}^{max} \quad (2)$$

where B_{svc}^{min} - Minimum susceptance value of SVC

B_{SVC} - Susceptance added to the bus by SVC

B_{svc}^{max} - Maximum susceptance value of SVC

TCSC is modeled as a variable reactance with the rating of,

$$-0.8X_L \le X_{TCSC} \le 0.2X_L \text{p.u} \quad (3)$$

where X_L - Reactance of the line where TCSC is located

X_{TCSC} - Reactance added to the line by TCSC

In this paper, a combination of Static Var Compensator (SVC) and Thyristor Controlled Series Capacitor (TCSC) is considered as UPFC and it is modeled with the rating as quoted in equations (2) and (3).

2.1.2. Line Voltage Stability Index (LVSI)

LVSI can be calculated as,

$$L_{mn} = \frac{4X_n Q_n}{(V_m \sin(\theta_{mn} - \delta_m))^2} \quad (4)$$

where X_n - Reactance at receiving end

Q_n - Reactive power at receiving end

V_m - Sending end voltage

θ_{mn} - Impedance angle

δ_m - Angle difference between the supply voltage and the receiving end voltage

When the stability index L_{mn} is less than 1, the system is stable and when this index exceeds the value 1, the corresponding line loses, its stability and voltage collapse occurs.

2.1.3. Bus Voltage Stability Index (BVSI)

The Voltage Stability index for load buses is to be computed as

$$L_j = \left|1 - \sum_{i=1}^{g} F_{ji} \frac{V_i}{V_j}\right| \quad (5)$$

where L_j - Bus Voltage Stability Index (BVSI) of load bus j

V_i - Voltage at bus i

V_j - Voltage at bus j

The values of F_{ji} can be obtained from Y bus matrix.

$$F_{ij} = [Y_{LL}]^{-1}[Y_{LG}] \quad (6)$$

where Y_{LL} and Y_{LG} are corresponding partitioned portions of the Y-bus matrix

When this index value moves away from zero, the stability of the system relatively decreases and then the system is considered as unstable.

2.1.4. Real power and bus voltage constraints

$$J = \prod_{LINE} OVL_{LINE} * \prod_{BUS} VS_{BUS} \quad (7)$$

J indicates violation of line flow limits and bus voltage limits, where OVL denotes line overload factor for a line and VS denotes voltage stability index for a bus.

$$OVL = \begin{cases} 1; & \text{if } P_{pq} \leq P_{pq}^{max} \\ e^{\left(\mu\left|1 - \frac{P_{pq}}{P_{pq}^{max}}\right|\right)}; & \text{if } P_{pq} > P_{pq}^{max} \end{cases} \quad (8)$$

$$VS = \begin{cases} 1; & \text{if } 0.9 \leq V_b \leq 1.1 \\ e^{(\lambda|1 - V_b|)}; & \text{Otherwise} \end{cases} \quad (9)$$

where P_{pq}-Real power flow between buses p and q

P_{pq}^{max} - Thermal limit for the line between buses p and q

V_b - Voltage at bus b

λ and μ Positive constants both equal to 0.1

2.1.5. Constraints of FACTS devices

$$-0.8X_L \leq X_{TCSC} \leq 0.2X_L \text{p.u} \quad (10)$$

$$-0.9 \leq B_{SVC} \leq 0.9 \text{ p.u} \quad (11)$$

3. Particle Swarm Optimization

Particle Swarm Optimization algorithm is used to obtain the optimal solution of the particular problem using the schooling behaviour of fishes or flocking behaviour of birds. Initially in this algorithm each bird called the particle is used to fly over the search space to find the Global best position by performing iterations. During the iteration, the current position and velocity of all the particles gets changed till the global best is achieved.

Velocity of each particle can be modified by equation

$$V_i^{k+1} = w \times v + c_1 \times rand_1 \times \left(P_{best_i} - s_i^k\right) + c_2 \times rand_2 \times \left(G_{best_i} - s_i^k\right) \quad (12)$$

where V_i^{k+1} - Velocity of particle i at iteration k+1

W - Weight function

c_1,c_2 - Weight coefficient

$rand_1$,$rand_2$ - Random number between 0 and 5

s_i^k - Current position of particle i at iteration kP_{best_i} Best position of particle i upto current iteration

G_{best_i} Best overall position found by the particle upto current iteration

Weight function is given by,

$$w = w_{max} - \frac{w_{max} - w_{min}}{iter_{max}} iter \quad (13)$$

where w_{max} - Initial inertia weight

w_{min} - Final inertia weight

$iter_{max}$ – maximum iteration number

New position is obtained using,

$$s_i^{k+1} = s_i^k + V_i^{k+1} \quad (14)$$

4. Comprehensive Learning PSO

Premature convergence is the disadvantage of conventional PSO. In conventional PSO, each particle learns from its pbest and gbest simultaneously. In CLPSO, by making the particle to learn only from the gbest the convergence becomes faster and also much reliable [25].

The procedure of CLPSO is as follows:

1. Randomly choose two particles from the population.
2. Compare the pbest of the two particles and select the better one.
3. Larger the fitness value better the convergence.
4. Winner's pbest is taken as exemplar for that dimension
5. All the pbest strive for the new positions in the search space using its own pbest or the others as exemplar.

Velocity of each particle is modified by equation

$$V_i^{k+1} = w \times v + c_1 \times rand_1 \times \left(P_{best_i} - s_i^k\right) \quad (15)$$

5. Social Learning PSO

Social learning plays an important role in behavior learning. In this type of learning, the individuals learn the good traits alone from the others without taking into account their shortcomings.

A swarm p (t) consists of m number of particles with generation index t. Fitness value is calculated for each particle in the swarm. Then, the swarm is sorted in the increasing order of fitness values. As a result, each particle will correct its behavior by learning from the particles called demonstrators which have better fitness values. In each generation, a particle can serve as a demonstrator for different imitators more than once [26]. An imitator will learn the best from the demonstrators in the following manner

$$X_{i,j}(t+1) = \begin{cases} X_{i,j}(t) + \Delta X_{i,j}(t+1). \text{if } pi(t) \leq P_i^L \\ X_{i,j}(t), \text{Otherwise} \end{cases} \quad (16)$$

where Xi,j (t) is the j th dimension of particle I's behaviour in generation t. The motivation of learning varies from individual to individual and is based on learning probability P_i^L

$$\Delta X_{i,j}(t+1) = r_1(t). \Delta X_{i,j}(t) + r_2(t). I_{i,j}(t) + r_3(t). \epsilon. C_{i,j}(t) \quad (17)$$

with

$$\begin{cases} I_{i,j}(t) = X_{k,j}(t) - X_{i,j}(t) \\ C_{i,j}(t) = \overline{X_j}(t) - X_{i,j}(t) \end{cases} \quad (18)$$

6. Results and Discussion

6.1. Base case results

The IEEE 14 bus system consists of 5 generator buses, 9 load buses and 20 transmission lines. The load flow is performed in the test system using Newton Raphson load flow analysis, since it is faster, reliable, gives more accurate results, requires less number of iterations and does not depend on size of the system. From the load flow results, LVSI and BVSI are determined for all lines and load buses using equations (4) and (5), respectively to find the stability level of the system. Table 1 show the real power loss in the test system without using any compensating devices like FACTS.

Table 1
Real Power Loss for Base Case (Without FACTS)

Type of Bus System	Real Power Loss (Mw)
IEEE 14 Bus System	13.593
IEEE 57 Bus System	22.703

6.2. Ranking of Transmission Lines and Load Buses using LVSI and BVSI for locating FACTS devices

The LVSI values are computed for all branches in the test system and are arranged in descending order. The top five ranked branches are chosen as branches suitable for locating the FACTS devices TCSC and UPFC since these places are more prone to voltage instability. Table 2 and 3 shows the five possible locations for placing TCSC and UPFC in the branches of the IEEE 14 bus and IEEE 57 bus system to reduce the real power loss and enhance voltage stability of the transmission system.

Table 2
Five possible locations of TCSC and UPFC in IEEE 14 Bus System

Rank	Branch No.	From Bus	To Bus	LVSI
1	10	5	6	0.2658
2	8	4	7	0.1458
3	14	7	8	0.1430
4	9	4	9	0.0880
5	1	1	2	0.0715

Table 3
Five possible locations of TCSC and UPFC in IEEE 57 Bus System

Rank	Branch No.	From Bus	To Bus	LVSI
1	66	13	49	0.6387
2	59	14	46	0.5685
3	19	4	18	0.5244
4	54	11	41	0.4167
5	65	10	51	0.4086

Similarly the BVSI values are computed for all load buses in the test system and are arranged in descending order. The top five ranked load buses are chosen as buses suitable for locating the FACTS devices SVC since these places are more prone to voltage instability.

Table 4

Five possible locations of SVC in IEEE 14 Bus System

Rank	Bus No.	BVSI
1	12	0.9797
2	13	0.9796
3	11	0.9796
4	7	0.9796
5	9	0.9793

Table 5
Five possible locations of SVC in IEEE 57 Bus System

Rank	Bus No.	BVSI
1	31	0.9999
2	33	0.9999
3	32	0.9999
4	30	0.9999
5	25	0.9998

Tables 4 and 5 shows the five possible locations for placing SVC in the buses of the IEEE 14 bus and IEEE 57 bus system to reduce the real power loss and enhance voltage stability of the transmission system.

6.4 Determination of Optimal sizing of FACTS devices using PSO, CLPSO and SLPSO

After finding optimal location of various FACTS devices, optimal rating of FACTS devices has been obtained using PSO, CLPSO and SLPSO by placing various combinations of SVC, TCSC and UPFC at their suitable locations in IEEE-14 bus system and IEEE 57 bus system.

Table 6
Rating of FACTS devices obtained from PSO, CL-PSO & SL-PSO in IEEE 14 Bus System

No of FACTS devices	Type of FACTS device	Count	Location	PSO Rating (p.u)	CL-PSO Rating (p.u)	SL-PSO Rating (p.u)
3	TCSC	1	Branch- 10	-0.2255	-0.0214	-0.4789
	SVC	1	Bus-12	-0.5459	-0.4896	-0.8800
	UPFC	1	Branch-10	-0.6980 -0.8978	0.2178 -0.5761	0.4963 -0.1508
4	TCSC	2	Branch-10 Branch-8	-0.0121 -0.4806	-0.1266 0.4398	0.1547 -0.8956
	SVC	1	Bus-12	-0.5493	-0.0568	-0.0553
	UPFC	1	Branch-10	-0.3900 -0.8986	0.1178 -0.1263	-0.2176
4	TCSC	1	Branch-10	-0.1555	0.0974	-0.8635
	SVC	1	Bus-12	0.0590	0.1005	-0.6128
	UPFC	2	Branch-10	-0.6985 -0.7942	0.6643 0.0123	-0.0053 -0.4987
			Branch-8	-0.6403 -0.8984	-0.7542 -0.1150	-0.3698 -0.3747
4	SVC	2	Bus-12 Bus-13	-0.3007 0.0856	-0.2780 -0.5561	-0.4000 -0.7630
	UPFC	2	Branch-10	-0.5268 -0.4907	-0.2179 -0.6999	-0.8214 0.2199
			Branch-8	-0.5101 -0.8954	0.2344 -0.1005	-0.3687 -0.0879
4	TCSC	2	Branch-10 Branch-8	-0.7984 -0.3025	-0.2996 -0.8832	-0.6781 0.2145
	SVC	2	Bus-12 Bus-13	-0.8700 -0.5070	0.5478 0.6773	0.7264 -0.0158

Table 7
Rating of FACTS devices obtained from PSO, CL-PSO & SL-PSO in IEEE 57 Bus System

No of FACTS devices	Type of FACTS device	Count	Location	PSO Rating (p.u)	CL-PSO Rating (p.u)	SL-PSO Rating (p.u)
3	TCSC	1	Branch- 66	-0.4621	0.1289	-0.05678
	SVC	1	Bus-31	-0.2564	-0.4763	0.0563
	UPFC	1	Branch-66	0.0631 -0.8935	-0.4433 -0.7531	0.3100 -0.2864

4	TCSC	2	Branch-66 Branch-59	-0.4634 0.6333	0.1247 0.6180	0.1301 0.7516
	SVC	1	Bus-31	-0.5507	-0.2188	0.0421
	UPFC	1	Branch-66	-0.7265 -0.7311	0.4677 -0.0890	0.3054 -0.8169
4	TCSC	1	Branch-66	-0.6312	0.7845	-0.8157
	SVC	1	Bus-31	0.0890	-0.6111	-0.2525
	UPFC	2	Branch-66	0.6798 -0.2111	-0.7621 -0.9425	-0.0719 -0.3372
			Branch-59	-0.7895 -0.1025	-0.7852 -0.1267	-0.5000 -0.6100
4	SVC	2	Bus-31 Bus-33	-0.8521 0.2133	-0.5413 -0.0266	-0.4405 0.3156
	UPFC	2	Branch-66	-0.7530 0.2315	0.4210 0.7521	-0.8509 -0.0764
			Branch-59	0.1434 -0.7895	-0.0056 0.8915	-0.4260 0.0519
4	TCSC	2	Branch-66 Branch-59	0.2989 -0.7300	-0.5617 -0.2444	0.1456 -0.8964
	SVC	2	Bus-31 Bus-33	-0.1200 0.8609	0.6856 -0.7887	0.3617 -0.6300

Table 8
Real Power Loss using PSO, CL-PSO & SL-PSO in IEEE 14 Bus System

Multi type FACTS	Using PSO		Using CLPSO		Using SLPSO	
Type of FACTS	Power loss (Mw)	% of Power Loss reduction	Power loss (Mw)	% of Power Loss reduction	Power loss (Mw)	% of Power Loss reduction
Without FACTS	13.593	---	13.593	---	13.593	---
1 TCSC, 1 SVC, 1 UPFC	5.709	58.00	5.043	62.89	5.092	62.53
2 TCSC, 1 SVC, 1 UPFC	5.764	57.60	5.471	59.74	5.464	59.80
1 TCSC, 1 SVC, 2 UPFC	3.535	73.99	2.396	82.36	2.306	83.03
2 SVC, 2 UPFC	3.712	72.69	3.003	77.90	2.683	80.26
2 TCSC, 2 SVC	6.562	51.72	5.661	58.35	5.596	58.83

Table 9 shows the real power loss in the five optimal locations of IEEE 57 bus system using PSO, CLPSO and SLPSO algorithms with different types and number of FACTS devices. The table also shows the percentage of real power loss reduction in these locations using different algorithms.

Table 9
Real Power Loss using PSO, CL-PSO & SL-PSO in IEEE 57 Bus System

Multi type FACTS	Using PSO		Using CLPSO		Using SLPSO	
Type of FACTS	Power loss (Mw)	% of Power Loss reduction	Power loss (Mw)	% of Power Loss reduction	Power loss (Mw)	% of Power Loss reduction
Without FACTS	22.703	---	22.703	---	22.703	---
1 TCSC,	13.982	38.4134	13.440	40.8008	12.908	43.1441

1 SVC, 1 UPFC						
2 TCSC, 1 SVC, 1 UPFC	13.790	39.2591	12.507	44.9104	12.193	46.2934
1 TCSC, 1 SVC, 2 UPFC	10.925	51.8786	10.751	52.6450	10.166	55.2218
2SVC, 2UPFC	12.005	47.1215	11.622	48.8085	11.454	49.5485
2 TCSC, 2 SVC	12.374	45.4962	12.008	47.1083	11.746	48.2623

6.5 Determination of BVSI in the test system using PSO, CLPSO and SLPSO

The BVSI at various locations of FACTS using different algorithms are found out and the results are compared with base case. BVSI decreases with the usage of FACTS devices. For the combination of 1 TCSC, 1 SVC and 2 UPFC the amount of BVSI reduction is more when compared with other type of FACTS used. Also SLPSO algorithm accounts for more BVSI reduction in both the test systems when compared with PSO and CLPSO. The reduction in BVSI ensures the voltage stability of the system.

Table 10
BVSI using PSO, CL-PSO & SL-PSO in IEEE 14 Bus System

Multi type FACTS	PSO		CLPSO		SLPSO	
Type of FACTS	BVSI	% BVSI reduction	BVSI	% BVSI reduction	BVSI	% BVSI reduction
Without FACTS	10.213	---	10.213	---	10.213	---
1 TCSC, 1 SVC, 1 UPFC	8.440	17.36	8.111	20.58	8.057	21.11
2 TCSC, 1 SVC, 1 UPFC	8.769	14.13	8.201	19.70	8.035	21.33
1 TCSC, 1 SVC, 2 UPFC	8.417	17.58	7.903	22.62	7.854	23.10
2 SVC, 2UPFC	8.619	15.60	8.163	20.07	8.112	20.57
2 TCSC, 2 SVC	8.739	14.13	8.024	21.43	8.015	21.52

Table 10 shows the BVSI in the five optimal locations of IEEE 14 bus system using PSO, CLPSO and SLPSO algorithms with different types and number of FACTS devices. The table also shows the percentage of BVSI reduction in these locations using different algorithms.

Table 11 shows the BVSI in the five optimal locations of IEEE 57 bus system using PSO, CLPSO and SLPSO algorithms with different types and number of FACTS devices. The table also shows the percentage of BVSI reduction in these locations using different algorithms.

Table 11
BVSI using PSO, CL-PSO & SL-PSO in IEEE 57 Bus System

Multi type FACTS	PSO		CLPSO		SLPSO	
Type of FACTS	BVSI	% BVSI reduction	BVSI	% BVSI reduction	BVSI	% BVSI reduction
Without FACTS	49.991	---	49.991	---	49.991	---
1 TCSC, 1 SVC, 1 UPFC	48.124	3.7347	48.004	3.9747	47.881	4.2208
2 TCSC, 1 SVC, 1 UPFC	48.056	3.8707	47.654	4.6748	47.049	5.8851
1 TCSC, 1 SVC,	46.940	6.1031	46.173	7.6374	46.004	7.9754

2 UPFC						
2 SVC, 2UPFC	48.422	3.1386	47.933	4.1167	47.466	5.0509
2 TCSC, 2 SVC	48.571	2.8405	48.117	3.7487	48.010	3.9627

The fitness curve for IEEE 14 bus system and IEEE 57 bus system using PSO, CLPSO and SLPSO is shown in figure. The minimum fitness gives the minimum real power loss.

Fig. 1 and Fig. 2 shows the fitness curves using PSO, CLPSO and SLPSO. The fitness curves reveals that SLPSO has minimum fitness for the test system when compared with PSO and CLPSO.

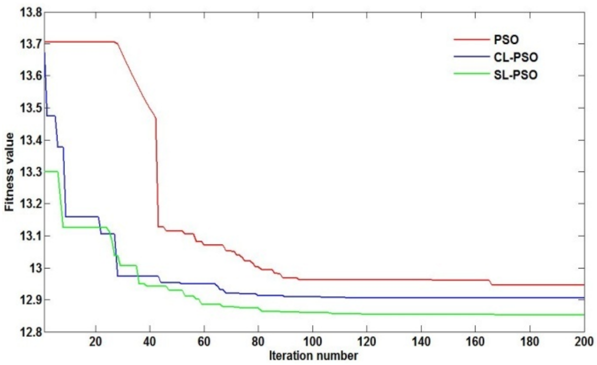

Fig 1 Fitness curve of IEEE 14 bus system for real power loss reduction, voltage deviation and BVSI reduction using PSO, CLPSO and SLPSO

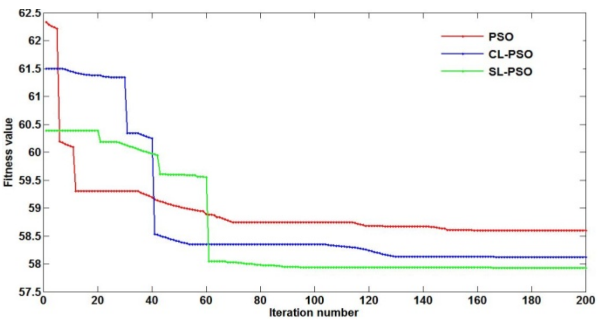

Fig 2 Fitness curve of IEEE 57 bus system for real power loss reduction, voltage deviation and BVSI reduction using PSO, CLPSO and SLPSO

7. Conclusion

The optimal location of FACTS devices is found out using sensitivity factor method. The number, type and the rating of FACTS devices for real power loss reduction, BVSI reduction and voltage deviation is found out using the optimization algorithms like PSO, CLPSO and SLPSO. The results are validated using IEEE 14 bus and IEEE 57 bus test system and the results using the above said approaches are compared. The results reveal that SLPSO performs better than PSO and CLPSO in real power loss reduction and enhancement of voltage stability of transmission system.

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