I J C T A, 10(5) 2017, pp. 727-741

Optimal Placement of Capacitors for Loss Reduction in Distribution System Using EPSO

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Abstract: This paper proposes the optimal placement and sizing of reactive power devices in a distribution system in order to reduce the active power losses. In this work, the Backward/Forward Sweep load flow is used to solve the distribution load flow of the system. Enhanced Particle Swarm Optimization (EPSO) is proposed for optimal sizing and placement of reactive power devices. The enhancement of PSO is done by using Levy Flight (LF) method for updating the velocity of the particles. The EPSO is tested on the standard 33bus and 69 bus distribution systems for different load levels and the results are compared with PSO.

Keywords: Capacitor Banks, Distribution system, Particle Swarm Optimization (PSO), Levy Flights PSO (LFPSO).

1. INTRODUCTION

The distribution system is facing several problems in which one of them is power loss. The previous papers study shows that 13-18% of total power generated is wasted in the form of losses at the distribution level. In order to reduce the losses, the most commonly used device is shunt capacitors. In addition with the loss reduction they also improve the power factor, system stability and the voltage profile of the system. In radial distribution system, the capacitor placement problem includes in the process of determining the location, size and number of capacitors to be placed.

For the optimal allocation of capacitor in the distribution network, different methods have been presented, a brief discussion is presented below. Hiroyuki *et. al.,* [1] proposed Parallel Tabu Search (TS) Algorithm for loss reduction. Carlise *et. al.,* [2] Implemented a graph search algorithm for the optimal placement of fixed and switched capacitors in radial distribution system. The capacitor placement for the conservative voltage reduction on distribution feeders have been described by Borka *et. al.,* [3]. Ramachandra *et. al.,* [4] introduced a conventional approach of Index Vector based method for optimal capacitor locations in agricultural distribution. The Branch and Bound Algorithm for optimal placement of capacitors was presented by Hogan *et. al.,* [5]. In radial distribution system a Fuzzy -Genetic Algorithm (GA) is developed by Das *et. al.,* [6] for the optimal capacitor placement. Ivochaves *et. al.,* [7] suggested a Heuristic Constructive Algorithm (HCA) for the capacitor placement in the distribution system. An algorithm for optimal cost benefit has been developed by Khodr *et. al.,* [8]. The ant Colony Optimization Technique for minimising the total active power losses of the system was employed by Pimentel *et. al.,* [9]. Tabatabaei *et. al.,* [10] adopted a Bacterial Foraging based solution for optimal capacitor allocation in the distribution system. The optimal allocation and sizing of capacitors for minimizing the transmission line loss and for the improvement of profile voltage by using Discrete Particle Swarm Optimization (DPSO) was employed by Ziari *et. al.,* [11]. A Real Coded Genetic Algorithm (RGA) is carried out by using Queen Bee Assisted Genetic Algorithm for the capacitor sizing and placement by Mohamed *et. al.,* [12]. In the distribution system for the loss reduction and minimization of annual cost Srinivasarao *et. al.,* [13] implemented a plant growth simulation

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algorithm. Gary *et. al.,* [14] investigated on the Fuzzy Logic and Immune Based Algorithm for the placement and sizing of shunt capacitor banks in distorted power network. Nayak *et. al.,* [15] reported on an Adaptive Invasive Weed Optimization Algorithm for the optimal reactive power dispatch by minimising the real power loss, improving the voltage profile and the voltage stability margin. By using a multi objective fuzzy approach Goroohi *et. al.,* [16] delineated a Modified Shuffled Frog Leaping Algorithm for the optimal switch placement in the distribution automation system. The Genetic Algorithm (GA) is used for the optimal capacitor allocation in the distribution system by hiring a dimension reducing approach for different load levels by Neelima *et. al.,* [17]. A Pseudo Polynomial Algorithm for the optimal placement of capacitors in electric power distribution networks by using Extended Dynamic Programming (EDP) approach have been determined by Jose *et. al.,* [18]. By applying Fuzzy and Hybrid Genetic Algorithm, Dinakara *et. al.,* [19] developed the optimal capacitor placement for the loss reduction. Abdollah *et. al.,* [20] reported a novel self adaptive modification method based on Honey Bee Mating Optimization (HBMO) for the multi objective stochastic allocation of capacitors in the distribution system. For the reduction of loss and improvement of voltage profile Ihsan *et. al.,* [21] applied particle swarm optimization technique. A Two Stage method for the loss reduction was implemented by Ahmed *et. al.*[22] for the capacitor optimal allocation at the distribution level. Attia *et. al.,* [23] suggested the Cuckoo Search based Algorithm (CSA) for the optimal allocation of shunt capacitors in the distribution network. A discrete imperialistic competition algorithm was considered by Arash *et. al.,* [24] for the optimal allocation of DG and capacitors for loss reduction in distribution system. Zeinal *et. al.,* [25] presented a paper on unbalanced distribution networks contaminated by harmonic through Imperialist Competitive Algorithm (ICA) which is based on human's socio political evolution algorithm for the reduction of losses. Dinakara *et. al.,* [26] attempted a cuckoo search algorithm for the sensitivity based capacitor placement for maximum annual savings. A novel optimization algorithm is implemented by Vinod *et. al.,* [27] for the optimal placement and sizing of capacitor banks for power loss minimization and maximization of net saving. Tamilselvan *et. al.,* [28] suggested the Clonal Selection Algorithm (CSA) for the optimal capacitor placement and sizing in radial distribution system. Meenakshi *et. al.,* [29] hired Harmony Search Algorithm (HSA) for the capacitors optimal placement for reduction of power loss in the distribution system. Sudha *et. al.,* [30] implemented an improved harmony search algorithm for loss reduction.

2. PROBLEM FORMULATION

Objective Function

The main objective of this paper is to minimize the active power loss in radial Distribution System by optimal placement of reactive power devices at potential location with appropriate size.

$$p_{\text{loss}} = \sum_{i=1}^{nl} \mathrm{I}_i^2 \mathrm{R}_i \tag{1}$$

Fitness function = Minimize (Power loss)

nl is number of lines,

Where, P_{loss} is the total active power loss in the distribution system,

I_i is the current flowing through the i^{th} line and

R_i is the resistance of the i^{th} branch.

Operational Constraints

While minimizing the active power loss, it has to obey the equality and inequality constraints.

i) Voltage constraints: After placement of reactive power devices, voltage at each bus must be within the specified limits.

$$V_{\min} \leq V_j \leq V_{\max} \quad (2)$$
$$j = 1, 2, ..., nb$$

Where, V_j is the voltage at j^{th} bus,

nb is number of buses,

$V_{\min}$ is the minimum voltage of the buses and

$V_{\max}$ is the maximum voltage of the buses

ii) Loading capabilities: The current flowing through each branch must be within the specified limit.

$$I_i \leq I_{i\max} \quad (3)$$
$$i = 1, 2, ..., nl$$

Where, I_i is the current flowing through the i^{th} line and $I_{i\max}$ is the maximum current carrying capability of the i^{th} line.

iii) Reactive power constraint: Total reactive power compensation Q_c is less than total reactive power demand Q_d.

$$\sum_{i=1}^{\text{NC}} Q_{ci} \leq \sum_{j=1}^{nb} Q_{dj} \quad (4)$$

Where, NC is number of capacitors.

Meta-heuristic Techniques

An iterative generation process that which directs a subordinate heuristic by combining many different concepts for exploring and exploiting in the solution search space. These techniques are called as Meta heuristic techniques. Many learning strategies can used to design structure the information in order to find the approximate optimal solutions efficiently. Meta heuristics are the techniques that which guides the search process and these methods are approximate and usually non-deterministic.

Particle Swarm Optimization (PSO) is one the meta-heuristic algorithms, which is a stochastic optimization method that depends on the population. This technique is introduced by Eberhart [31] in 1995. PSO is inspired by the behaviour of bird flocking and fish schooling. This method is used to optimize a problem to improve a candidate solution. The PSO is one of the best used evolutionary method that conduct searches by using population of the particles. Every particle corresponds to an individual and has an updating position vector and an updating velocity vector by the movement of particles within the problem search space. By using this iterative process, PSO leads towards the best solutions.

Each Particle in the swarm can be represented by its current position and current velocity of the particle where particle tracks its coordinates in the search space which are associated with the best solution (called fitness solution) that have been achieved so far by that particle. This solution is called personal best, *pbest*. Another best value that is tracked by the PSO is the best value obtained so far by any particle in the neighbourhood of that particle. This value is called g_{best}. Every particle tries to change its position using the current positions, current velocities, between the current position and p_{best} and the distance between the current position and the g_{best}. In conventional PSO technique the position of particles get changes each time with respect to time [31].

Particle Swarm Optimization techniques has got the problem of the premature convergence and also trapping in local minima. Different techniques were designed to improve the velocity updating in PSO technique. To improve the performance of PSO algorithm Enhance Particle Swarm Optimization (EPSO) technique [32] is designed which aims at the updating velocities using Levy Flight method. In the similar way as PSO algorithm the particles are distributed randomly within the search space and fitness values of particles are evaluated and p_{best} of particles, g_{best} of swarm were determined.

Enhanced PSO:

Let us consider 'u' is the corresponding position of particle and 'v' denotes the flight speed of the particle. From the considerations the position vector and velocity vector of 'i^{th}' particle in n dimensional search space can be given by 'u_i' and 'v_i' as:

$$u_i = (u_{i1}, u_{i2}, \ldots, u_{\text{in}}) \tag{5}$$

$$v_i = (v_{i1}, v_{i2}, \ldots, v_{\text{in}}) \tag{6}$$

The best previous position of the 'i^{th}' particle and the index of the best particle among all the particles in the group are recorded in PSO.

Best previous position of the 'i^{th}' particle (*pbest*):

$$p_{\text{best}} = (u_{i1}\, p_{\text{best}}, u_{i2}\, p_{\text{best}}, \ldots, u_{\text{in}}\, p_{\text{best}}) \tag{7}$$

Best particle among all the particles in the group (g_{best}):

$$g_{\text{best}} = (u_{i1}\, g_{\text{best}}, u_{i2}\, g_{\text{best}}, \ldots, u_{\text{in}}\, g_{\text{best}}) \tag{8}$$

The modification of the particle's position can be mathematically modelled according the following equation:

$$\text{Velocity}_{\text{modified}} : \text{V}_{i(k+1)} = \omega \times \text{V}_{i(k)} + \text{C}_1\text{V}_1 \times (p_{\text{best}}^{(k)} - u_i^{(k)}) + \text{C}_2\text{V}_2 \times (g_{\text{best}}^{(k)} - u_i^{(k)}) \tag{9}$$

Above equation has three parts. $\omega v_i^{(k)}$ represents the previous velocity, $\text{C}_1\text{V}_1 \times (p_{\text{best}}^{(k)} - u_i^{(k)})$ represents cognitive component, $\text{C}_2\text{V}_2 \times (g_{\text{best}}^{(k)} - u_i^{(k)})$ represents social component.

Here, ω, C_1 and C_1 are of values ≤ 1

ω = inertia weight factor

C_1 and C_2 = acceleration coefficients

v_1 and v_2 = will be the random values within the range [0,1]

v_{i} = velocity of the particle 'i' in search space at k^{th} iteration

u_i = position of the particle 'i' in search space at k^{th} iteration

$$\text{Position}_{\text{modified}}: u_i^{(k+1)} = u_i^{(k)} + v_i^{(k+1)} \tag{10}$$

$$\omega(k+1) = \omega_{\max} - \frac{(\omega_{\max} - \omega_{\min})}{t_{\max}} \times k \tag{11}$$

Where, $\omega_{\max}$ is maximum Inertia weight

$\omega_{\min}$ is minimum inertia weight

$t_{\max}$ is maximum number of iterations

k is the current iteration.

Usually, $\omega_{\max}$ is set to 0.9 and $\omega_{\min}$ is set to 0.4 for providing balance between the global search and local search.

By using Levy Flight method, the position and velocity of each particle is updated randomly by the below formulae:

$$\begin{aligned}\text{Velocity}_{\text{modified}}\text{: } V_i^{(t+1)} = {} & \omega \times V_{i(k)} + C_1 \times r\text{ and }(\,) \oplus \times (p_{\text{best}_i} - X_i^{(t)}) \\ & + C_2 \times r\text{ and }(\,) \oplus \times (g_{\text{best}_i} - X_i^{(t)})\end{aligned} \tag{12}$$

$$\text{Position}_{\text{modified}}\text{: } X_i^{(t+1)} = X_i^{(t)} + v_i^{(t+1)} \tag{13}$$

Here, $V_i^{(t+1)}$ is Velocity of particle at iteration '$t + 1$'

$V_i^{(t)}$ is Velocity of particle at iteration 't'

$X_i^{(t+1)}$ is Position value of i^{th} particle at iteration '$t + 1$'

$X_i^{(t)}$ is Position value of i^{th} particle at iteration 't'.

C_1 and C_1 are weighting factors.

r and ( ) is a stochastic component of algorithm in a range of [0,1]

Here, ω is defined as

$$\omega = 0.1 + 0.8 \times \left(1 - \frac{\text{iteration}}{\text{MaxIter}}\right) \tag{14}$$

Where, ω = inertia weight factor

ω is calculated accordingly in the similar way as in PSO.

MaxIter is maximum number of iterations.

Methodology

Optimal placement of reactive power devices problem consists of finding potential location and appropriate size capacitors to be placed in the distribution system to achieve one or more objectives. In this paper minimization of active power loss is considered as the main objective function. The capacitor placement and size are obtained by using EPSO algorithm. Each particle in EPSO is corresponds to either location or size of capacitor. For example, if number of capacitors is chosen to be three then the size of solution vector is six i.e, double the number of capacitors. The first three particles of solution vector correspond to the locations of the capacitors and the next three particles correspond to the size of the capacitors.

$$\text{Solution vector} = [C_{L1}C_{L2}C_{L3}C_{S1}C_{S2}C_{S3}] \tag{15}$$

Where, C_{Li} is the location of i^{th} capacitor,

C_{Si} is the location of i^{th} capacitor

$i = 1, 2, ..., NC$

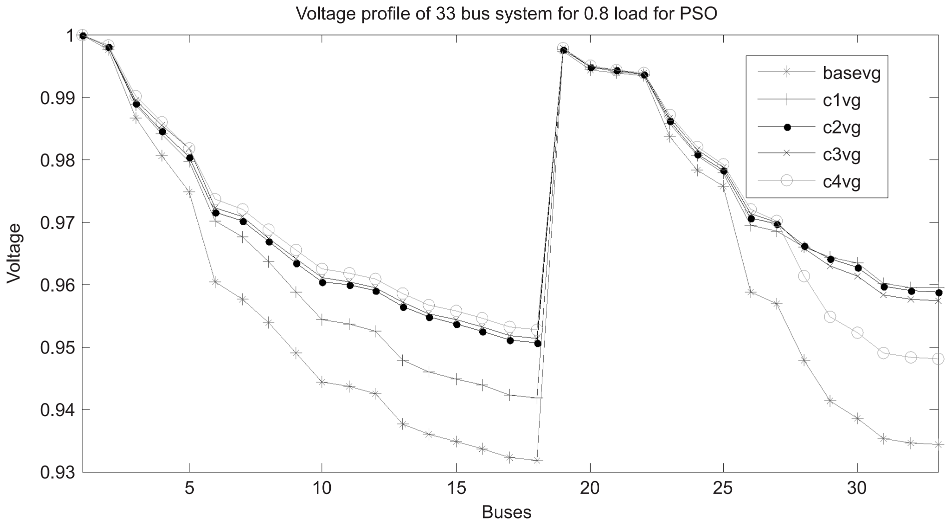
3. RESULTS AND DISCUSSION

The proposed PSO algorithm is tested on 33 bus and 69 bus system and for comparison purpose PSO algorithm is also implemented and tested on these systems.

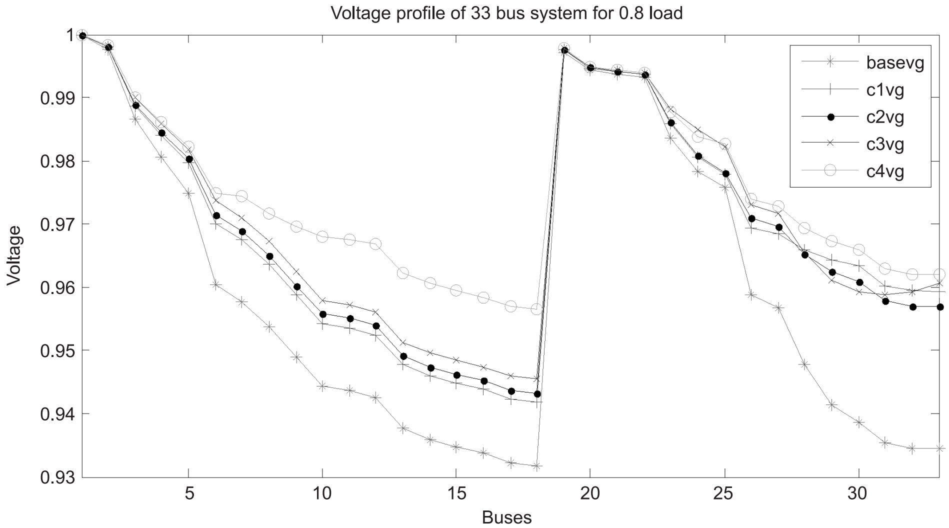
Table 2
Parameters used in the methodology

Parameters	*PSO*	*EPSO*
No. of maximum generations	200	200
No. of population	50	25
Minimum No. of capacitors (C_{min})	2	3
Maximum No. of capacitors (C_{max})	12	12
Total No. of capacitors (NC)	4	4
Minimum Voltage (V_{min})	0	0
Maximum Voltage (V_{max})	1	1

The test results of 33 bus system for the comparison of PSO and EPSO for light load (80%), base load (100%) and peak load (120%) were presented in Table 2 where as the results of 69 bus system for the comparison of PSO and EPSO for light load (80%), base load (100%) and peak load (120%) were presented in Table 3. Similarly, the improvement of voltage profiles for PSO and EPSO were also plotted below from (a) to (f).



(a) PSO for light load

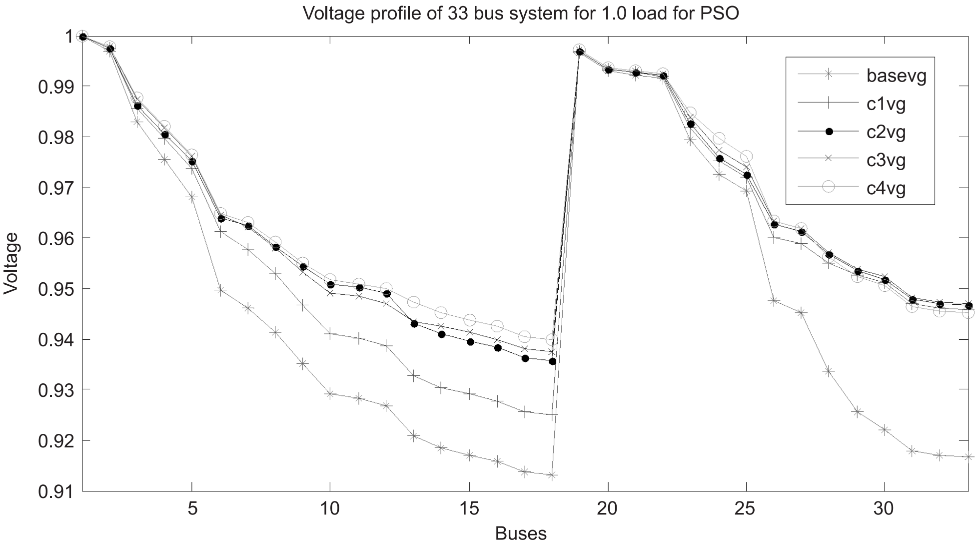


(b) EPSO for light load

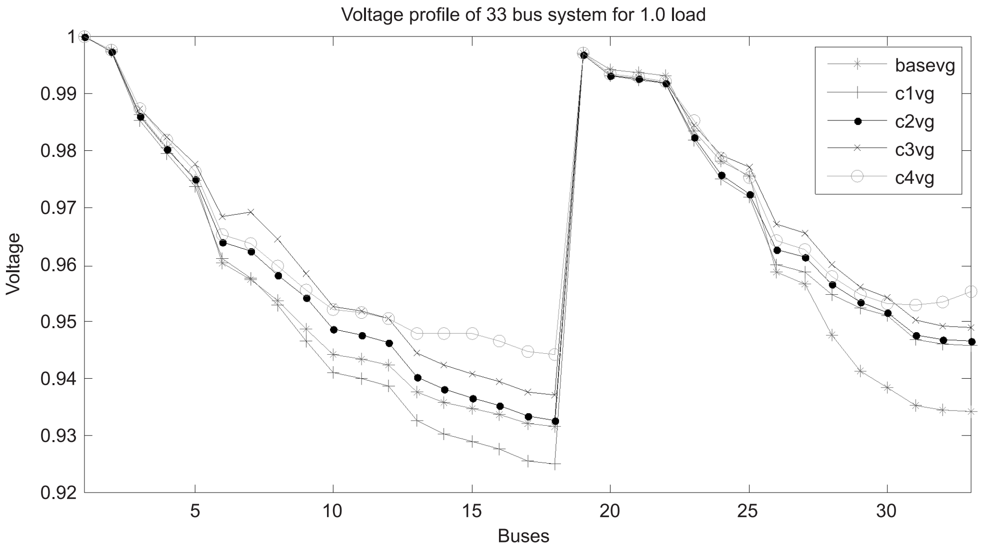
Figure 1: Voltage profile of 33 bus system at light load (0.8) for PSO and EPSO

Table 2
33 bus system at 80%, 100% and 120% loads respectively using PSO and EPSO

		Original system		*1CP*		*2CP*		*3CP*		*4CP*	
		PSO	*EPSO*	*PSO*	*EPSO*	*PSO*	*EPSO*	*PSO*	*EPSO*	*PSO*	*EPSO*
80% Load	Cp Location	-	-	30	30	30, 13	26, 30	5, 13, 30	33, 26, 24	3, 6, 13, 6	12, 30, 25, 33
	Cp Size (Kvar)	-	-	1050	1050	900, 300	450, 750	450, 300, 750	450, 900, 450	450, 300, 300, 750	600, 900, 300, 0
	Total Size (Kvar)	-	-	1050	1050	1200	1200	1500	1800	1800	1800
	Active Power Loss (Kw)	125.79	125.79	89.97	89.97	85.24	86.97	83.94	87.15	93.95	86.35
	Reacive Power Loss (Kvar)	83.90	83.90	60.47	60.47	58.94	56.24	59.16	56.29	63.73	57.65
	Min Voltage (pu) (Bus)	0.9316 (18)	0.9316 (18)	0.9418 (18)	0.9417 (18)	0.95050 (18)	0.9432 (18)	0.9512 (18)	0.9454 (18)	0.9480 (33)	0.9564 (18)
	Computation Time (Sec)	-	-	9.05	5.29	9.11	5.64	9.37	6.01	9.23	6.25
100% Load	Cp Location	-	-	30	30	12, 30	30, 9	3, 30, 14	7, 30, 25	24, 30, 3, 13	30, 23, 33, 15
	Cp Size (Kvar)	-	-	1200	1200	450, 1050	1050, 450	900, 1050, 300	1050, 900, 300	300, 900, 750, 450	450, 750, 600, 450
	Total Size (Kvar)	-	-	1200	1200	1500	1500	2250	2250	2400	2250
	Active Power Loss (Kw)	202.67	202.67	143.68	143.68	136.76	135.42	135.41	133.24	136.42	132.17
	Reacive Power Loss (Kvar)	135.23	135.23	96.37	96.37	91.62	90.05	91.41	89.07	92.51	88.47
	Min Voltage (pu) (Bus)	0.9131 (18)	0.9131 (18)	0.9251 (18)	0.9251 (18)	0.9357 (18)	0.9329 (18)	0.9374 (18)	0.9371 (18)	0.9399 (18)	0.9442 (18)
	Computation Time (Sec)	-	-	9.67	5.34	9.86	5.93	9.91	6.25	9.81	6.45
120% Load	Cp Location	-	-	30	30	30, 11	15, 30	12, 30, 25	10, 27, 33	14, 30, 3, 7	23, 29, 32, 11
	Cp Size (Kvar)	-	-	1500	1500	1200, 600	450, 1050	600, 1050, 600	450, 1050, 750	300, 1200, 600, 450	1050, 750, 600, 300
	Total Size (Kvar)	-	-	1500	1500	1800	1500	2250	2250	2550	2700
	Active Power Loss (Kw)	301.43	301.43	211.62	211.62	203.73	199.13	204.80	195.10	198.54	194.64
	Reacive Power Loss (Vkvar)	201.24	201.24	142.12	142.12	135.27	133.48	138.84	130.43	133.12	130.64
	Min. Voltage (pu) (Bus)	0.8938 (18)	0.8938 (18)	0.9094 (18)	0.9094 (18)	0.9223 (18)	0.9247 (18)	0.9226 (18)	0.9237 (18)	0.9261 (18)	0.9181 (18)
	Computation Time (Sec)	-	-	10.17	5.64	10.05	5.91	10.03	7.39	10.24	6.66

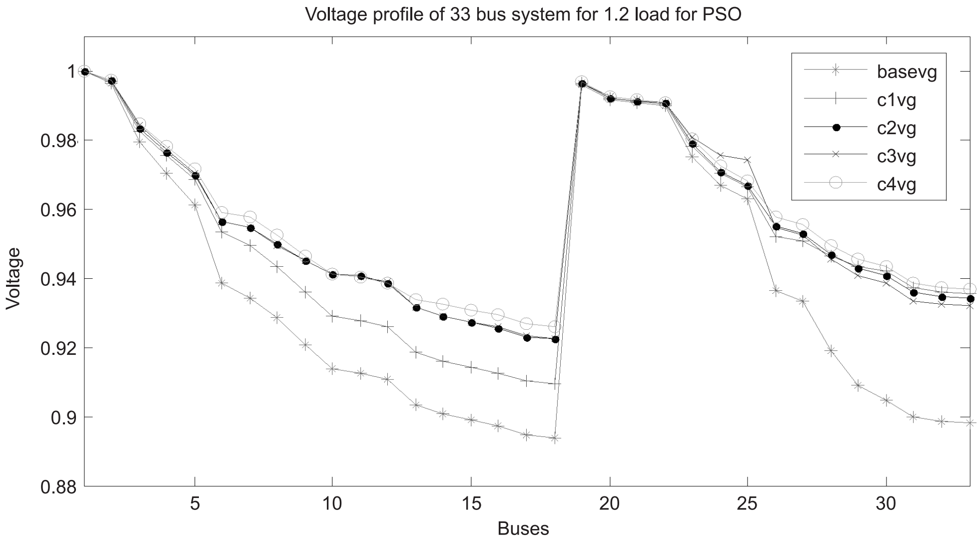


(c) PSO for base load

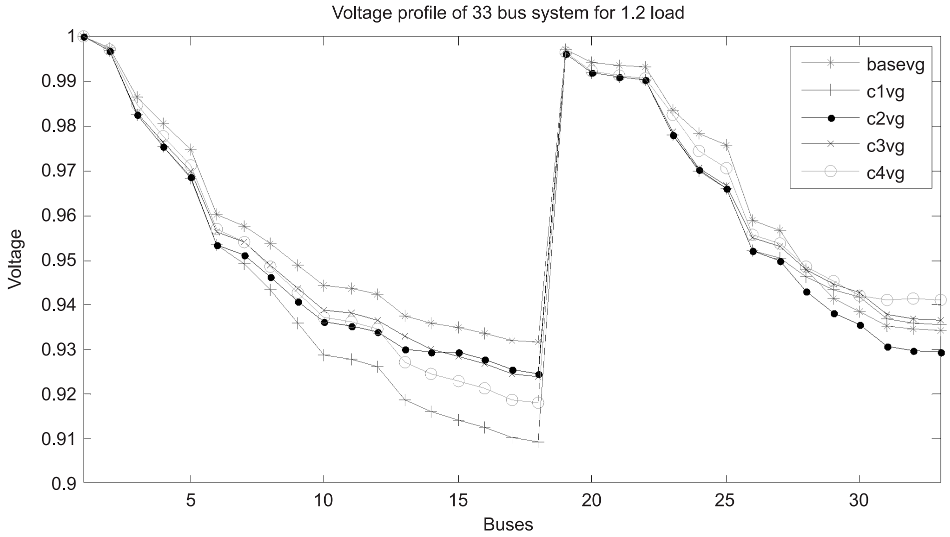


(d) EPSO for base load

Figure 2: Voltage profile of 33 bus system at base load (1.0) for PSO and EPSO

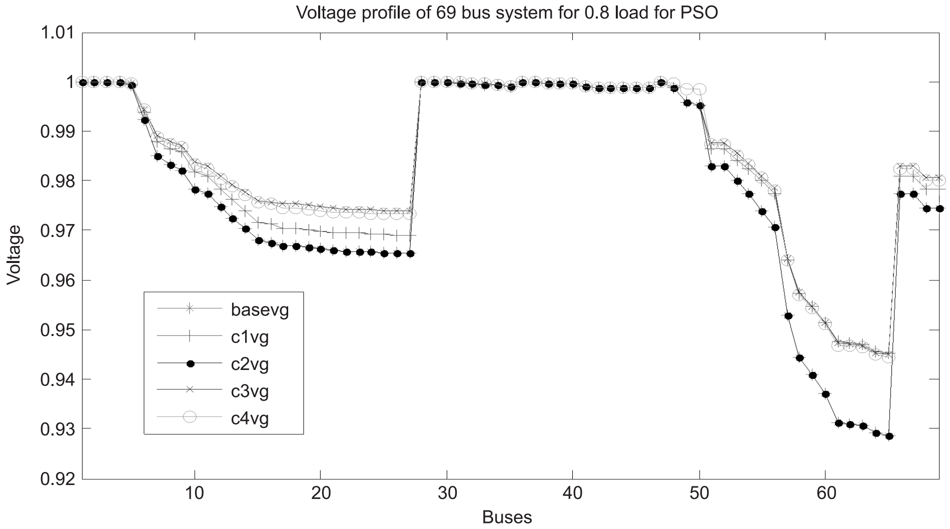


(e) PSO for peak load

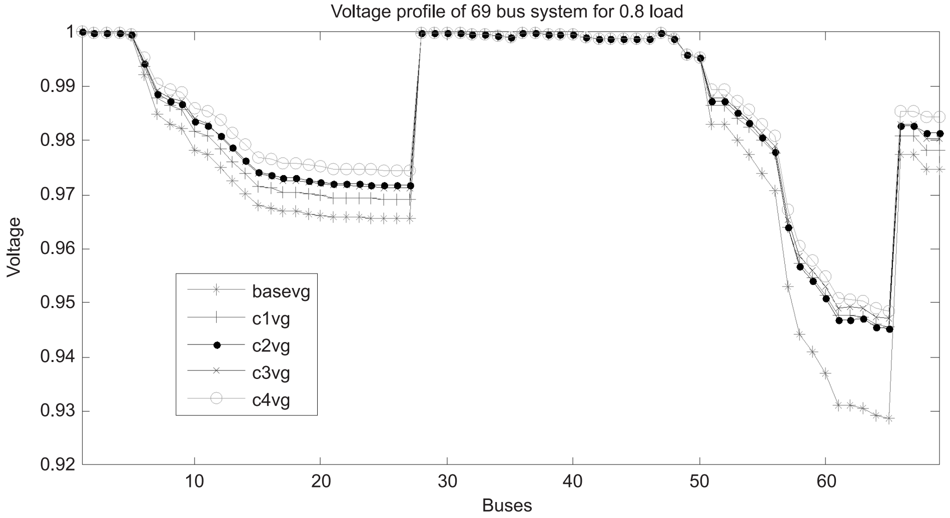


(f) EPSO for peak load

Figure 3: Voltage profile of 33 bus system at peak load (1.2) for PSO and EPSO



(g) PSO for light load

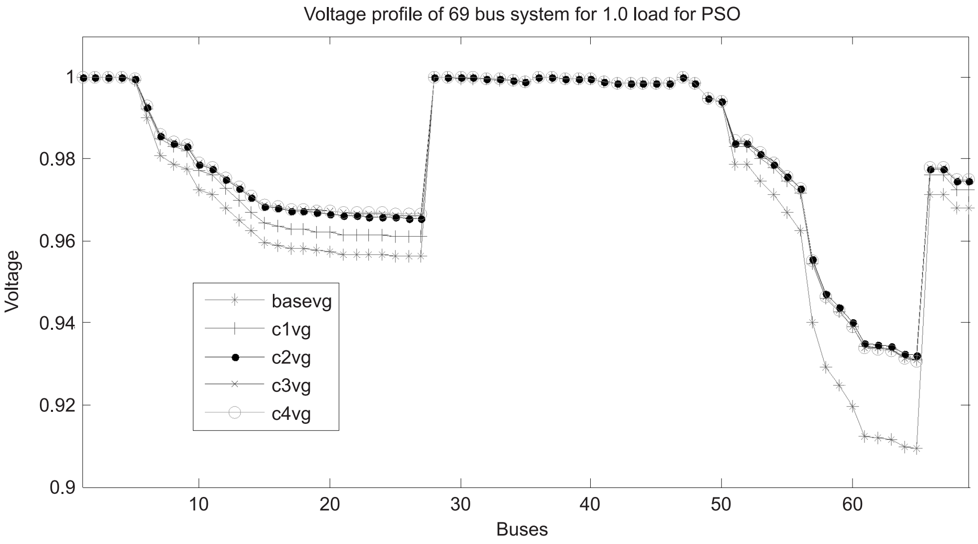


(h) EPSO for light load

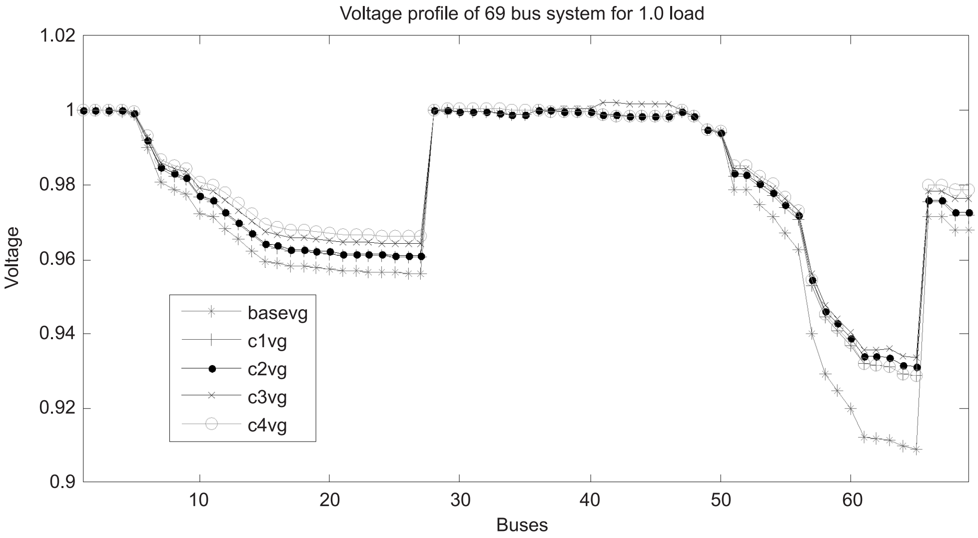
Figure 4: Voltage profile of 69 bus system at light load (0.8) for PSO and EPSO

Table 3
69 bus system at 80%, 100% and 120% loads respectively using PSO and EPSO

		Original system		*1CP*		*2CP*		*3CP*		*4CP*	
		PSO	*EPSO*	*PSO*	*EPSO*	*PSO*	*EPSO*	*PSO*	*EPSO*	*PSO*	*EPSO*
80% Load	CP Location	-	-	61	62	61, 17	63, 69	17, 61, 9	47, 10, 62	6, 61, 16, 50	61, 69, 8, 69
	CP Size (Kvar)	-	-	1050	1050	1050, 300	900, 450	300, 900, 300	600, 450, 1050	300, 900, 300, 450	1050, 450, 450, 150
	Total Size (Kvar)	-	-	1050	1050	1350	1350	1500	2100	1950	2100
	Active Power Loss (Kw)	138.90	138.90	95.76	94.30	93.35	91.53	92.95	90.65	95.90	90.08
	Reacive Power Loss (Kvar)	63.20	63.20	44.032	44.30	43.63	42.51	43.47	43.08	44.45	41.12
	Min Voltage (pu) (Bus)	0.9288 (65)	0.9288 (65)	0.9452 (65)	0.9455 (65)	0.9462 (65)	0.9452 (65)	0.9450 (65)	0.9470 (65)	0.9444 (65)	0.9485 (65)
	Computation Time (Sec)	-	-	19.76	10.52	20.34	10.95	20.05	11.22	20.66	11.42
100% Load	CP Location	-	-	61	61	61, 18	36, 61	19, 61, 53	69, 63, 41	61, 52, 21, 2	68, 61, 54, 31
	CP Size (Kvar)	-	-	1350	1200	1350, 300	1350, 1350	300, 1200, 300	450, 1350, 450	1200, 300, 300, 300	750, 900, 450, 450
	Total Size (Kvar)	-	-	1350	1200	1650	2700	1800	2250	2100	2550
	Active Power Loss (Kw)	225.00	225.00	152.71	152.06	152.37	152.08	151.67	147.30	153.99	145.13
	Reacive Power Loss (Kvar)	102.16	102.16	70.94	70.49	70.80	69.55	70.88	69.93	70.99	67.62
	Min Voltage (pu) (Bus)	0.9092 (65)	0.9092 (65)	0.9310 (65)	0.9288 (65)	0.9320 (65)	0.9310 (65)	0.9310 (65)	0.9335 (65)	0.9307 (65)	0.9287 (65)
	Computation Time (Sec)	-	-	19.73	10.73	19.80	10.79	19.98	11.14	20.45	11.74
120% Load	CP Location	-	-	61	61	15, 61	62, 69	18, 61, 69	69, 63, 36	16, 62, 50, 61	47, 61, 69, 69
	CP Size (Kvar)	-	-	1650	1650	450, 1500	1500, 450	300, 1500, 300	600,1500, 600	450, 450, 450, 1200	1800, 1500, 0, 0
	Total Size (Kvar)	-	-	1650	1650	1950	1950	2100	2700	2550	3300
	Active Power Loss (Kw)	336.72	336.72	225.21	225.21	220.92	216.08	221.46	215.84	225.21	216.52
	Reacive Power Loss (Kvar)	152.56	152.56	104.16	104.16	102.86	100.12	102.24	100.89	104.35	98.41
	Min Voltage (pu) (Bus)	0.8887 (65)	0.8887 (65)	0.9163 (65)	0.91634 (65)	0.9156 (65)	0.9161 (65)	0.9161 (65)	0.9172 (65)	0.9181 (65)	0.9141 (65)
	Computation Time (Sec)	-	-	21.25	11.60	21.35	11.76	21.52	11.92	21.92	12.61

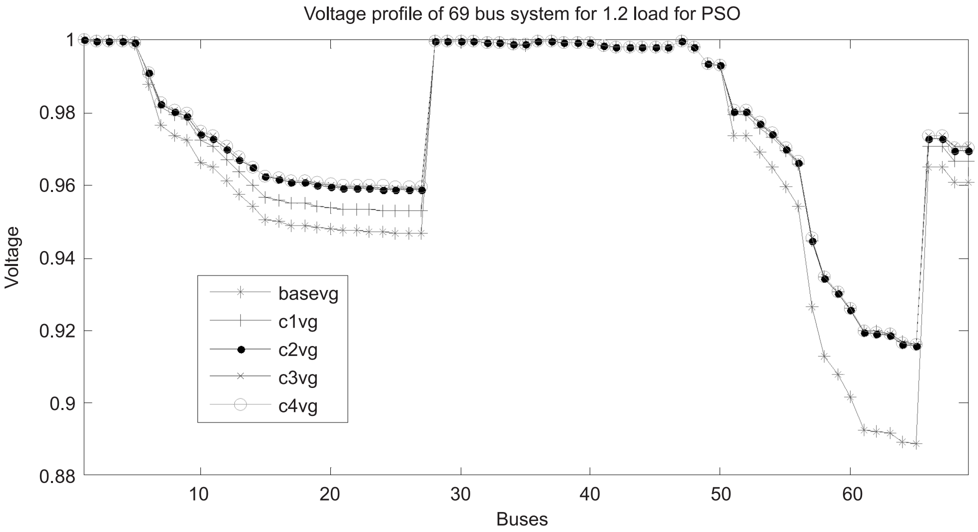


(i) PSO for base load

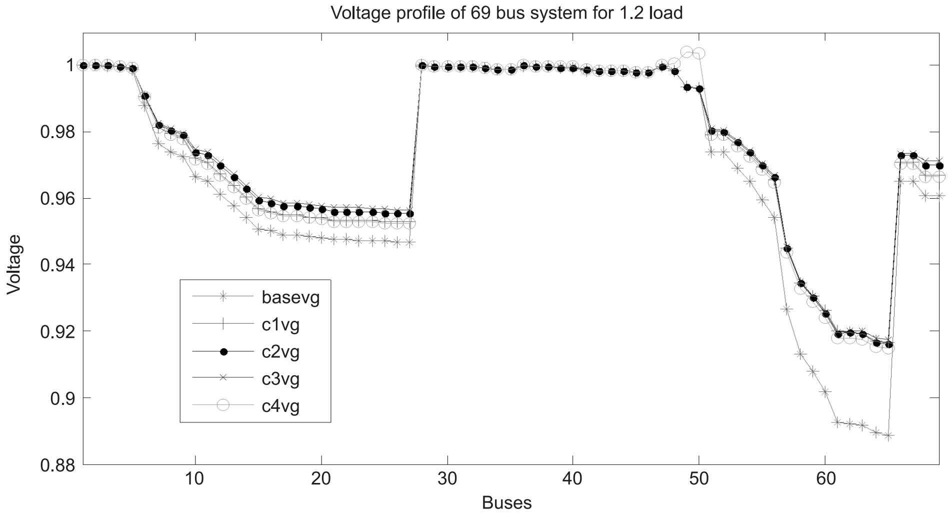


(j) EPSO for base load

Figure 5: Voltage profile of 69 bus system at base load (1.0) for PSO and EPSO



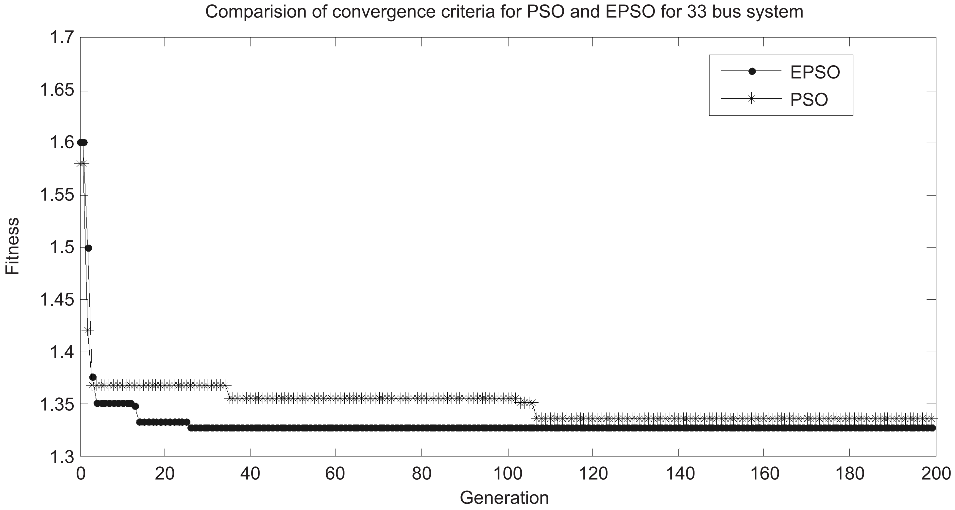
(k) PSO for peak load



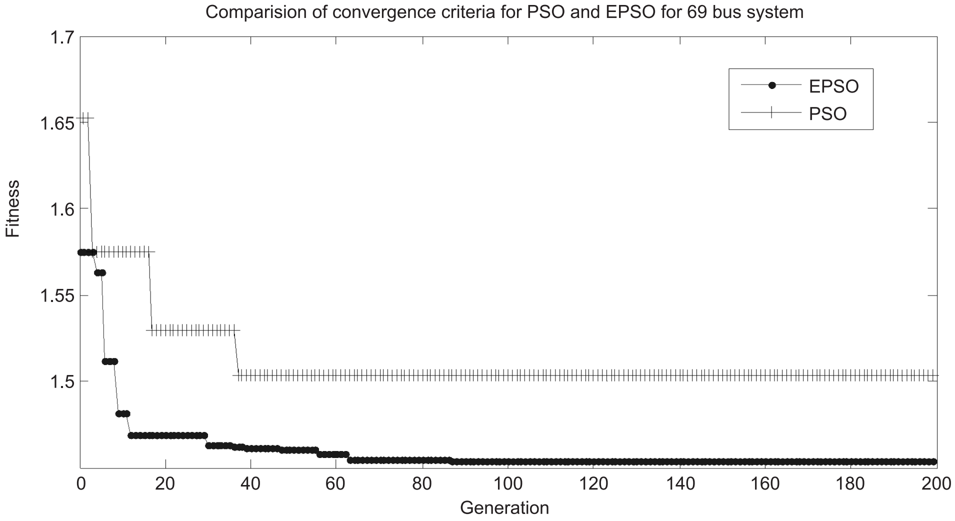
(l) EPSO for peak load

Figure 6: Voltage profile of 69 bus system at peak load (1.2) for PSO and EPSO

Convergence Characteristics



(m) Convergence characteristics for 33 bus system



(n) Convergence characteristics for 69 bus system

Figure 7: Convergence characteristics for PSO and EPSO of 33 bus and 69 system

Table 2 represents the results for 33 bus system, which contains the parameters of size of capacitor, active and reactive power losses, min. Voltage for light load (80%), base load (100%) and peak load (120%) respectively. In case of light load the minimum active power loss is 83.15kw at 3CP of EPSO and minimum reactive power loss is 56.24kvar at 2CP of EPSO. Similarly, in base load the minimum active power loss is 88.47kw obtained at 4CP of EPSO, minimum reactive power loss is 132.17kvar obtained at 4CP of EPSO. In the same way the minimum active power loss is 194.64 reached at 4CP of EPSO, minimum reactive power loss is 130.43kvar obtained at 3CP of EPSO. The improved voltage profile with the comparison of 4 capacitors with the original bus system is represented in above figures 1 to 3.

Table 3 represents the results for 69 bus system, for light load the minimum active power loss is obtained 90.08kw at 4CP of EPSO and minimum reactive power loss is 41.12kvar at 4CP of EPSO. Similarly, in base load the minimum active power loss is 145.13kw obtained at 4CP of EPSO, minimum reactive power loss is 67.62kvar obtained at 4CP of EPSO. In the same way the minimum active power loss is 215.84 is reached at 3CP of EPSO, minimum reactive power loss is 98.41kvar obtained at 4CP of EPSO. The improved voltage profile with the comparison of 4 capacitors with the original bus system is represented in above figures 4 to 6.

In Figure 7, (m) shows the convergence characteristics for 33 bus system and (n) represents the characteristics of 69 bus system. If the fitness value remain unchanged for the next 50 iterations then convergence is reached. The convergence characteristics were plotted for the base load of both 33 bus and 69 bus test systems and comparison of PSO and EPSO were presented below in (m) and (n). From these figures, it is clear that PSO is getting converge before reaching the optimal point. In order to avoid this pre-mature convergence EPSO is implemented.

4. CONCLUSION

In this paper, a modified version of PSO algorithm i.e., EPSO is used, which is suitable for solving the optimal placing and sizing of capacitors in distribution system. In this paper, the objective of loss reduction was done by using the traditional PSO in addition with Levy Flight in order to avoid the premature convergence and trapping of local minima. Here the proposed method is implemented on both 33 bus test system and 69 bus radial distribution systems by considering different load levels of 0.8, 1.0 and 1.2 respectively. The results are compared by placing the number of capacitors with load levels individually and the improvement of voltage profiles was also shown. By the comparison of the power losses of the basic PSO and EPSO, the total power loss reduced in EPSO is better than PSO.

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