International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-4, February 2019

Monarch Butterfly Optimization Algorithm for Capacitor Placement in Radial Distribution Systems

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***Abstract*: Monarch butterfly optimization (MBO) is used for the optimal capacitor placement problem. Loss Sensitivity method is used for optimal locations of capacitors. Capacitor sizes by MBO algorithm in radial distribution systemscorresponding to maximum loss reductions are determined in this paper. The results are presented with test system15-bus, 34-bus and 69-bus.**

***Index Terms*: Monarch butterfly optimization algorithm, Loss Sensitivity Method.**

I. INTRODUCTION

The reactive power compensation usually made through capacitors in distribution systems. The primary and secondary distribution losses are 70%. The targeted losses in distribution are 7.5% out of 15.5%.

Authors proposed genetic algorithm [1], new improved hybrid algorithm [2], modified Crow search algorithm [3] for reactive compensation in radial distribution systems.

Authors, [4] proposed new graph theory based load flow method. Dinakara Prasad reddy et al [5-7] proposed flower pollination algorithm, Ant Lion optimization algorithm, Whale optimization algorithm, cuckoo search algorithm algorithms for placement of compensating devices in distribution systems.

However, GCMBO is one the new optimization algorithm proposed by Gai-Ge Wang et al [8]. In this paper MBO is used to find the optimal capacitor size.

II. LOSS SENSITIVITY METHOD

Distribution line with an impedance is shown in Figure.1.

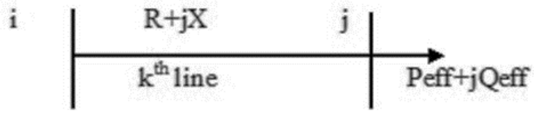

Figure 1. Load connected to distribution line.

The losses in distribution line are given as PL and QL. Where active power loss is denoted by PL and reactive power loss is denoted by QL. Loss sensitivity is denoted by LS.

$$PL[j]=\frac{(P^2[j]+Q^2[j])*R_k}{(V[j])^2} \quad (1)$$

$$QL[j]=\frac{(P^2[j]+Q^2[j])*X_k}{(V[j])^2} \quad (2)$$

$$LS_j=\frac{(2*Q_{eff}[j])*R_k)}{(V[j])^2} \quad (3)$$

The buses are ratedproduced on LSj in descending order of its values. The first node for capacitor placement is the bus having top numeric value and with the condition V/0.95>1.1.

The optimal locations are {6, 3} for 15 bus, {19, 20, 22} for 34 bus and {57, 58, 61} for 69 bus respectively.

III. MONARCH BUTTERFLY OPTIMIZATION

MBO is a metaheuristic Algorithm developed based on the migration behaviour of the monarch butterflies [8] located in the Northern USA. In this method the migration behaviour of monarch butterflies is considered along with rules as stated below

1. Land 1 and land 2 gives the whole population of the monarch butterflies located in land 1 and land 2
2. Butterfly in Land 1 or in Land 2 produces individual offspring.
3. The population is unchanged during the process by rejecting an old monarch butterfly after producing a child, this can be achieved by substituting its parent with newly generated offspring. On the other hand if the fitness of the offspring is low when compared to that of the parent, the offspring may be rejected. parent is kept intact and unaffected.
4. Thus the fittest monarch butterflies will only be available for the next generation and they cannot be changed be any operator.

Manuscript published on 28 February 2019.
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A. Migration operator

Land 1 and Land 2 monarch butterflies number are given by ceil(p *NP) (NP1) and NP – NP1 (NP2) where the Population in Land 1 is defined as subpopulation 1 and Population in Land 2 is defined as subpopulation 2. This procedureis as follows

$$x_{i,k}^{t+1} = x_{r1,k}^{t} \quad (4)$$

Where $x_{i,k}^{t+1} = x_{r1,k}^{t}$ represents the kth element of xi at generation t+1 that presents the position of the monarch butterfly i. When r ≤ p, the element k in the newly generated monarch butterfly. r can be considered as

$$r = rand * peri \quad (5)$$

rand is the random number drawn from uniform distribution.peri is set to 1.2 which indicate migration period. If r > p, the element k in the newly generated monarch butterfly is generated by

$$x_{i,k}^{t+1} = x_{r2,k}^{t} \quad (6)$$

Where $x_{r2,k}^{t}$ indicates the kth element of x_{r2} ..r2 is randomly selected from subpopulation 2

B. Butterfly adjusting operator

For updating the positions of the monarch butterflies, for all the elements in butterfly j, if a randomly generated number rand ≤ p, it can be updated as

$$x_{j,k}^{t+1} = x_{best,k}^{t} \quad (7)$$

Where $x_{j,k}^{t+1}$ indicates the kth element of xj at generation t+1 . Similarly, $x_{best,k}^{t}$ indicates the kth element of xbest which is the fittest butterfly in Land 1 and Land 2. If rand is greater than p. It can be updated as

$$x_{j,k}^{t+1} = x_{r3,k}^{t} \quad (8)$$

Where $x_{r3,k}^{t}$ indicates the kth element of xr3 , and r3 is randomly selected in Land 2. Here r3 Ɛ {1,2,-----,NP2}

it can be further updated as follows, if randomly generated number rand is greater than butterfly adjusting rate (BAR). Smax is max walk step. α is the weighting factor $\alpha = S_{max} / t^2$.

$$x_{j,k}^{t+1} = x_{j,k}^{t+1} + \alpha * (dx_k - 0.5) \quad (9)$$

dxcan be calculated by Levy flight

$$dx = Levy(x_j^t) \quad (10)$$

IV. RESULTS

Maximum loss reduction by the proposed methodfor capacitor placement is tested on IEEE 15 bus, 34 bus and 69 bus radial distribution systems and base case losses are 61.79kW, 221.7kW and 225kW respectively. The constants used are capmin=60 kvar, capmax=1500 kvar, nog=40, Itmax =500.

The proposed method gave total active power loss as 32.2kW for 15- bus, 168.6 for 34 bus and 151.02 for 69 bus test systems. The minimum voltages before and after compensations are 0.9445 and 0.9645 for 15 bus, 0.9417 and 0.9658 for 34 bus and 0.9092 and 0.9300 for 69 bus respectively. Tables I, II and III respectively shows results by proposed method.

TABLE I. Results For 15 Bus System.

Proposed method[5]		Proposed Method	
Bus No	**Size (kvar)**	**Bus No**	**Size (kvar)**
15	143	3	419
6	438	6	816
4	558	--	--
TPL(kW)	32.5	TPL(kW)	32.2

TABLE II. Results For 34 Bus System.

Proposed method[5]		Proposed Method	
Bus No	**Size(kvar)**	**Bus No**	**Size(kvar)**
19	957	19	648.0141
22	861	22	664.2296
20	229	20	735.5998
TPL(kW)	168.8	TPL(kW)	168.6

TABLE III. Results For 69 Bus System.

Proposed method[5]		Proposed Method	
Bus No	**Size(Kvar)**	**Bus No**	**Size(Kvar)**
57	206	57	132.84284
58	100	58	67.087309

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61	1130	61	1142.1723
TPL(kW)	151.3	TPL(kW)	151.02

V. CONCLUSION

Total real power loss of the system has been reduced significantly and bus voltages are improved by installing shunt capacitors at all the possible locations. MBO algorithm is proposed to find the optimal capacitor sizes and sensitivity method is used to find the optimal capacitor locations. IEEE 15, 34 and 69 bus radial distribution systems were taken to test the proposed method. The proposed two-stepmethodology determines the optimal capacitor sizes at less number of locations with maximum loss reduction.

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