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Comparison of Shuffled Complex Evolution Algorithm and Modified Shuffled Frog Leaping Algorithm for Optimal Allocation and Sizing of Distributed Generation

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Abstract: In this study, we present a method for optimal allocation of Distributed Generator (DG) in distributed systems. Today Distributed generation (DG) is used in distributed systems in order to power loss reduction, environmental friendliness, voltage improvement, postponement of system upgrading, and increasing reliability. Here our aim would be optimal DG allocation for loss reduction and voltage profile improvement in distribution network. This paper proposed to use Shuffled Complex Evolution Algorithm (SCE-UA) to solve the problem of optimal allocation of DGs. The SCE-UA method is tested on the IEEE 34 bus system to show its effectiveness. Finally the performance of SCE-UA will be compared with Modified Shuffled Frog Leaping Algorithm (MSFLA) and we will show that the performance of the MSFLA has better than SCE for Optimal Allocation and Sizing of DG units in radial distributed systems.

Keywords: Distributed generation (DG); Shuffled Complex Evolution Algorithm (SCE-UA); Modified Shuffled Frog Leaping Algorithm (MSFLA)

1 INTRODUCTION

Nowadays, Interest in renewable energy in the world has increased in recent years, the studies on distributed generation have quickly increased because the DGs play an important role in the distribution networks [1-2].

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The DG benefits can be divided into technical, economic and environmental advantages. Technical advantages are included many of advantage such as efficiency, power loss reduction, reliability, eliminating, improving load factors and voltage profile and also improved power quality. The economic advantages are required the decreasing of transmission and distribution operating cost, to declining in electricity price. Environmental benefits are reductions in emission of greenhouse gases.

The most important part of DG research study is related to its proper siting at strategic points of power systems that allows energy companies to decrease investments in power system development such as reducing additional control equipment and the reinforcement of transmission and distribution lines.

After connecting DG the behavior of a power system may be changed strongly as compared to the base case. The installation of DG must be consider several factors such as which technology is the best for used or how many units of DG and of what capacities [12].

Some optimization methods have been applied to DG placement and sizing, such as heuristic algorithms and analytical based methods. The optimal DG allocation can be sampled as optimal reactive power restitution. DGs can reduce losses and improve voltage profile. Non-optimal locations and non-optimal sizes of DGs causes lead to increase losses and bad effect on voltage profile [3-4].

This paper proposes a Shuffled Complex Evolution Algorithm (SCE-UA) for DGs placement and sizing in order to reduce line losses and improve Voltage Profile. The Shuffled Complex Evolution Algorithm developed by Duan [5]. This algorithm is based on genetic algorithm method. It shuffles the best features of multiple complex combining and competitive evolution based on simplex search method [6].

2 PROBLEM FORMULATION

In order to discuss and determine the advantages of DG in the distributed network suitable math models could be used along with distribution system models and power flow computations to arrive at indices of advantages. The two most important advantages of DGs are improving voltage profile and reducing line loss.

2.1 The Objective Function

The objective function used in order to Improvement of Voltage profile and Loss Reduction. Mathematical form of the objective function is given as:

$$\mathrm{MinF_{total}} = \mathrm{P_{loss}} + \sum_{p=1}^{n} \lambda_p (V_p)^2 \quad (1)$$

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λ_p is the penalty factor of bus voltages and generally assigned as assigned as 1, P_{loss} is the real power loss calculated from the load flow solution at the base case, V_p is the voltage profile of the buses.

2.2 Index of Line Loss Mitigation

The greatest advantage of connection of DG in power network is decrease in electrical line losses [6]. By installing DG line currents could be reduced flowing through the line and it helps to decrease the electrical line losses. The offered index of line loss mitigation (ILLM) is given as:

$$ILLM = \frac{LLw/_{DG}}{LLwo/_{DG}} \qquad (2)$$

Here $LLw/_{DG}$ is the total of line losses in the network with the use of DG and $LLw/_{DG}$ is the whole line losses in the network without DG and it will be defined as:

$$LLw/_{DG} = 3 \sum_{i=1}^{M} I_i^2 \times R \times D_i \qquad (3)$$

I_i is the per unit line current in distribution line I, with the use of DG
D_i (km)is the length of line
R (pu/km) is the resistance of line
M is the number of lines in the network. $LLwo/_{DG}$ is described as:

$$LLwo/_{DG} = 3 \sum_{i=1}^{M} I_i^2 \times R \times D_i \qquad (4)$$

I_i is the per-unit line current in distribution line i without the use of DG.
When ILLM < 1, the connection of DG increases the line losses, when ILLM=1 indicates that DG cannot influence on line losses. Also when ILLM > 1 then DG causes more line losses.
This index will be calculated to assign the optimum location and capacity to install DG to maximize the reduction of line loss.

2.3 Index of Voltage Profile Improvement

The use of DG results in improved voltage profile at various buses in power systems. The Index of Voltage Profile Improvement (IVPI) is defined as the voltage profile of the system with DG to the voltage profile of the system without DG [7].

$$IVPI = \frac{VPw/_{DG}}{VPwo/_{DG}} \qquad (5)$$

Here $VPw/_{DG}$ and $VPwo/_{DG}$ are the voltage profile system with DG and without DG. The VP is given as:

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$$VP = \sum_{i=1}^{N_{bus}} |V_i - V_{i,ref}| \quad (6)$$

Where: V_i is the voltage amplitude of bus i and $V_{i,ref}$is the voltage amplitude of slack bus. This equation must be used only after assuring that the voltages at all the load busses are within permissible minimum and maximum constraints. At this situation all the load buses are given the same importance. Actually DG can be connected to every bus in the network. Thus, VPII will be used to choose the best place for DG [13].

2.4 Constrains

The constraints are listed below:

- Distribution line absolute power constraints

$$|P_{ij}^{Line}| \leq P_{ij.max}^{Line} \quad (7)$$

$|P_{ij}^{Line}|$ And $P_{ij.max}^{Line}$ are the absolute powers flowing over the distribution lines and the maximum transmission power maximum permissible amount flowing in between nodes i to j respectively. Bus voltage magnitudes are constrained as:

$$V_{min} \leq V_i \leq V_{max} \quad (8)$$

The second constraint involves a voltage magnitude at bus i. In which V_{min} and V_{max} are the minimum and maximum amounts of bus voltage magnitudes, respectively.

- Radial structure of the network

$$M = N_{bus} - N_f \quad (9)$$

N_{bus} is the number of buses, M is the number of branches and N_f is the number of power plants.

- DG Power limits

$$Q_{DGi}^{min} \leq Q_{DGi} \leq Q_{DGi}^{max} \quad (10)$$

$$P_{DGi}^{min} \leq P_{DGi} \leq P_{DGi}^{max} \quad (11)$$

P_i and Q_i are the transmitted active and reactive power of DG components at the i_{th} bus.

- Subject to power balance limits

$$\sum_{i=1}^{N_{sc}} P_{DGi} = \sum_{i=1}^{N_{sc}} P_{Di} + P_L \quad (12)$$

N_{sc} is the whole number of parts, P_L is the real power loss in the system, P_{DGi} is the active power generation DG at bus i, P_{Di} is the demand of power at bus i.

3 The introduced Shuffled Complex Evolution Algorithm (SCE-UA) for optimal location and sizing of DG in a distribution network

The SCE-UA method is a general purpose global optimization program. It was originally developed by Dr. Qingyun Duan as part of his doctoral dissertation work at the Department of Hydrology and Water Resources, University of Arizona. The local search block in the flowchart is illustrated later in Figure1 [4] [10].

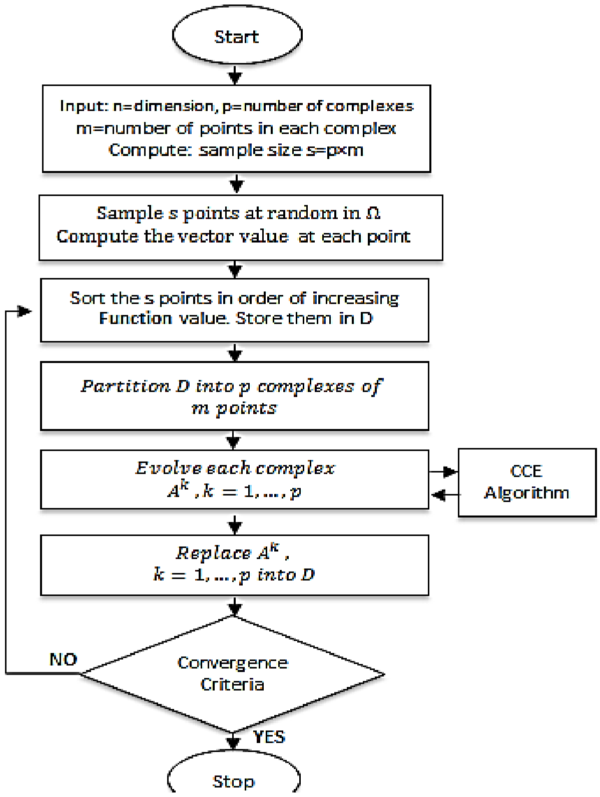

Figure.1. Flowchart of the SCE

Duan developed SCE algorithm using the best features of multiple complex Shuffling and competitive evolution based on the simplex search method. A general description of steps of the SCE method is given below. [11]

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Step1. Sample points are produced from the feasible space. The criterion function values are computed using these sampled points.

Step2. The selected points are sorted and ranked in ascending order according to the scale function values. It causes smallest scale function value generating parameters at the top of the sampled parameter list.

Step3. The sampled points are divided into complexes with predefined size of the complex population.

Step4. Any complex is evolved apart a predefined number of times. The evolution of the complexes takes place using three steps reflection, contraction and mutation.

Step5. The evolved complexes from the step 4 are shuffled into a single sample population .It is sorted in order of increasing criterion value. Step3 to step5 is ingeminated until conditions as defined in step6 are met.

Step6. The evolutionary procedure that has run reproduction, crossover, and mutation operations once is called a generation. Check convergence. If convergence criteria are satisfied, stop; otherwise, return to step2. The algorithm description is shown in Figure2 [14].

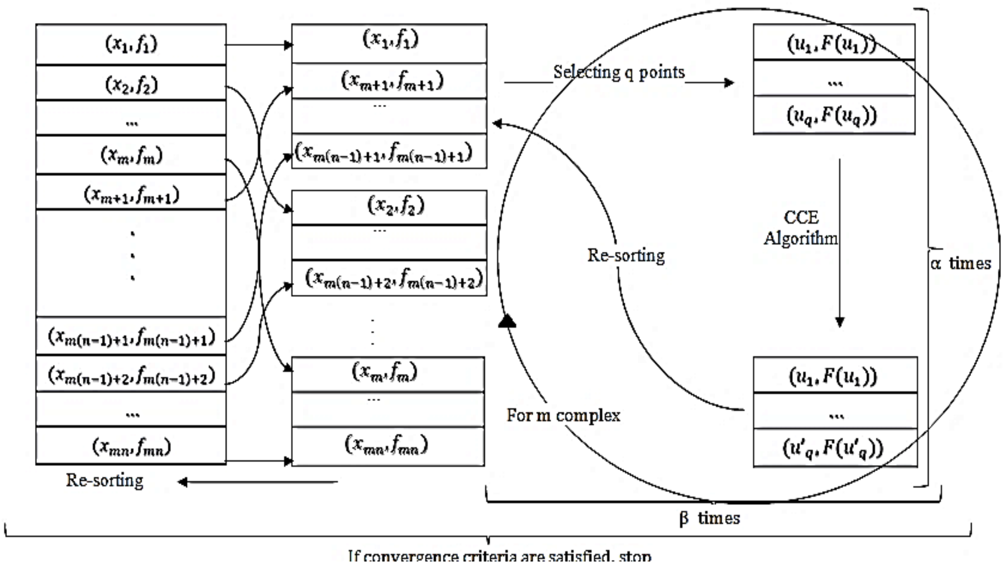

Figure.2. Overview of the SCE algorithm

4 Application study and numerical results

The proposed method for optimal place and sizing of DG has been done in the MATLAB and tested on distribution test system.

4.1 Bus radial distribution system

This distribution test system is the 34 bus system. The original total real power loss and reactive power loss in the system are 3.5718 MW and 2.252

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MVar, respectively. The 34 bus system has 33 parts with the general load of 29.31 MW and 22.82 MVar. It is shown in Figure3. Also you can get the extra information such as line data and load data of the 34 bus system in the Table1 and Table2 [8].

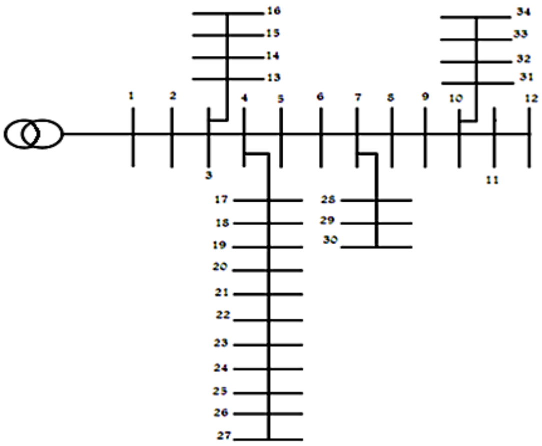

Figure.3.the 34 bus radial distribution system

Line no	From bus	To Bus	R^{ohm}	X^{ohm}
1	1	2	0.0440	0.0345
2	2	3	0.0440	0.0345
3	3	4	0.0113	0.0088
4	4	5	0.0222	0.0173
5	4	6	0.0113	0.0088
6	6	7	0.0290	0.0227
7	7	8	0.0182	0.0182
8	8	9	0.0185	0.0145
9	9	10	0.0233	0.0233
10	10	11	0.0158	0.0125
11	11	12	0.0170	0.0133
12	9	13	0.0155	0.0133
13	13	14	0.0253	0.0268
14	13	15	0.0161	0.0222
15	15	16	0.0208	0.0216
16	16	17	0.0244	0.0285
17	17	18	0.0280	0.0166
18	17	19	0.0292	0.0255
19	19	20	0.0215	0.0254
20	20	21	0.0139	0.0184
21	21	22	0.0141	0.0219
22	20	23	0.0161	0.0127
23	23	24	0.0270	0.0123

Line no	PL	QL
1	0	0
2	0.8900	0.4680
3	0.6280	0.4700
4	1.1120	0.7640
5	0.6360	0.3780
6	0.4740	0.3440
7	1.3420	1.0780
8	0.9200	0.2920
9	0.7660	0.4980
10	0.6620	0.4800
11	0.6900	0.1860
12	1.2920	0.5540
13	1.1240	0.4800
14	0.9570	0.7690
15	1.0869	0.7632
16	0.3429	0.7289
17	1.3190	0.9593
18	1.4208	0.9771
19	1.1145	0.6121
20	1.2093	0.7939
21	1.1918	0.7674
22	0.7707	0.8878
23	1.0866	0.9256

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24	23	25	0.0161	0.0212
25	25	26	0.0265	0.0259
26	26	27	0.0159	0.0288
27	27	28	0.0287	0.0137
28	28	29	0.0178	0.0219
29	25	30	0.0150	0.0201
30	30	31	0.0160	0.0115
31	31	32	0.0228	0.0176
32	31	33	0.0202	0.0143
33	33	34	0.0179	0.0262

Table.1. Line Data

24	0.5054	0.9528
25	1.1473	0.6656
26	0.3382	0.9078
27	0.6323	0.8931
28	0.3554	0.5976
29	0.4166	0.5714
30	1.2881	0.7990
31	1.1338	1.0758
32	0.6805	0.7042
33	1.4403	0.8512
34	0.3413	0.6343

Table.2. Load Data

4.2 Optimal allocation and sizing of distributed generation

Table 3 shows the 34 bus radial system optimal allocation and sizing of DG by MSFLA (mentioned in reference [9]) and presented method (SCE). It is worth mentioning, the population value of SCE is 100, the number of maximum iteration for the SCE is 1000, the number of DG units is 10 and the maximum active power of DG is 5 MW in the simulation.

SCE		MSFLA	
Bus no	DG (KW)	Bus no	DG (KW)
7	3.4251	7	-
8	-	8	4.0798
11	2.2806	11	-
12	-	12	3.4392
15	4.2405	15	4.0487
17	3.6240	17	4.8276
18	3.9909	18	-
19	-	19	1.8038
21	2.1147	21	4.4724
22	2.6769	22	-
24	-	24	2.3739
27	-	27	4.4828
28	4.6707	28	4.4828
29	-	29	1.3993
30	4.4853	30	4.5765
33	4.9155	33	-

Table.3. Optimal location and capacity of DG

4.3 Results of power Loss decrease and Improvement in Voltage Profile of the system

The reduction in power loss is obvious after the installing DG units as shown in Table 4. It shows that the decrease power losses with connection of DG units for range of 50 kW. The power loss in the base case without DG connection is computed by load flow solutions and it is found to be 3.5718 MW. For DG rating of 50 kW the amounts of power loss significantly diminishes as shown in Table .The percentage of power loss reduction is by means of (LLRI) and a reduction of 99.21% is gained with SCE and a decrease of 99.35% with MSFLA respectively.

DG rating of 50 kw			
Method	Power Loss(MW)	ILLM	Reduction (%)
Base Case	3.5718	-	-
SCE	0.025632	0.007013	99.21
MSFLA	0.023029	0.00644	99.35

Table.4. Power losses reduction results

Table5 shows that for the SCE and MSFLA methods, the amounts of the voltage profile of the network have increased obviously by installing a DG of 50 kW. The voltage profile of the base case was estimated to be 3.6218 p.u when a DG rating of 50 kW was connected for case study by SCE and MSFLA. The voltage profile of the network has enhanced which obviously shows the need of a DG. The percentage of voltage profile improvement is by means of (VPII) and an improvement of 96.13% is gained with SCE and a decrease of 96.29% with MSFLA respectively.

DG rating of 50 kw			
Method	VP	VPII	Improvement (%)
Base Case	3.6218	-	-
SCE	0.1366	0.037901	96.13
MSFLA	0.1342	0.037053	96.29

Table.5. Voltage profile improvement results

Figure4 and Figure5 show the voltage profiles of nodes after installation 10 DG on the 34 bus radial system. Figures show that the performance of the MSFLA has better than SCE for voltage improvement.

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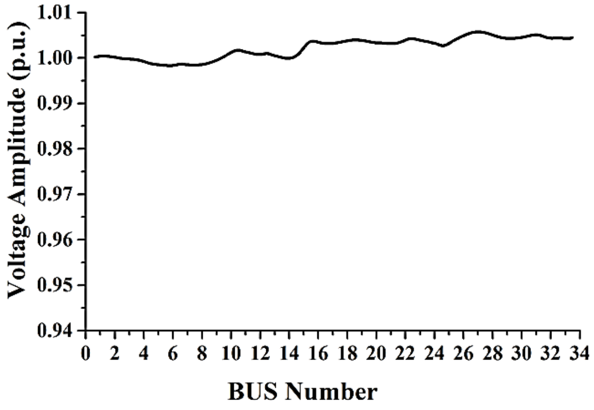

Figure.4. Voltage amplitude results by SCE

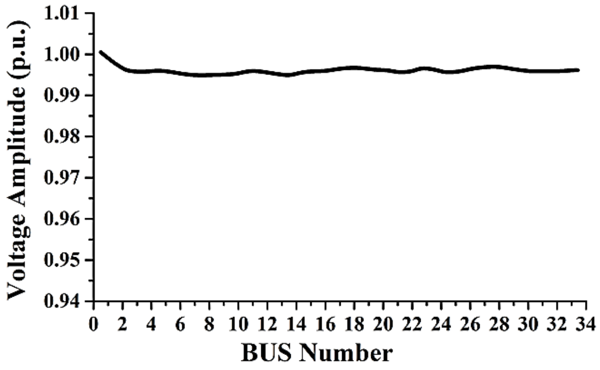

Figure.5. Voltage amplitude results by MSFLA

5 Conclusion

Nowadays many researchers presented and argued different ways for optimal placement of Distributed Generation (DG) in distribution systems. The Distributed Generation in a distribution system has many advantages such as voltage profile improvement, relieved transmission and distribution congestion, loss reduction. This paper focused on finding the optimal placement for DG units to reduce power loss and improve voltage profile. The procedure is based on SCE and MSFLA. After simulation the paper shows that the results of MSFLA are better than that in SCE.

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