Particle Swarm Optimization Technique Based Power Loss Reduction in Radial Distribution System

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Summary

Fossil fuel depletion, electricity demand increment and environment degradation shift the power system network to adopt distributed generation (DG) at local grids. The optimal integration of distributed generation witnesses many benefits. However, the non-optimal integration may deteriorate the existing operation. Therefore, this paper presents the methodology to optimally integrate the distributed generation in radial distribution system. The main aim is to reduce the power losses and improve the voltage profile using particle swarm optimization technique. The proposed technique is implied on benchmark IEEE 69 bus system and compared with many optimization algorithms. The overall results shows that the proposed method gives better results as compared to literature algorithms.

Keywords:

Optimal location and sizing, particle swarm optimization, wind assessment, distribution system.

1. Introduction

Among many technical challenges, the power loss reduction and voltage profile, improvement remain the essential aspects in the radial distribution system. It is due to fact that the distribution system poses high resistance to reactance ratio, which engenders more power losses and voltage drop as compared to the transmission system. Besides, the maximum penetration of renewable generation will increase the more power losses as compared to existing one. The voltage control devices in traditional distribution system work in a sense that the voltage magnitude will decrease along the feeder, as starting from the substation to the customer's end. However, the integration of DG deviates the distribution system from one-direction to bidirectional and it is expected that power may flow in reverse direction and cause the voltage magnitude and voltage stability to overshoot or undershoot over the safe limit. The power loss minimization, and voltage profile improvement is very important factors for power quality and stability of distribution system. Many optimization algorithms such as analytical methods, heuristic methods and meta-heuristic methods have been incorporated for optimal DG integration. Among them, the analytical expressions is not capable to handle the large and complex system. Many heuristic and meta-heuristic optimization algorithms have also been proposed. These algorithms includes genetic algorithm (GA) [1], bat algorithm (BA) [2], artificial bee colony optimization algorithm (ABC) [3], back-tracking and fuzzy expert [4], bacterial foraging optimization algorithm (BFOA) [5, 6], big-bang big crunch method [7] and imperialist competitive algorithm GA [8]. However, this paper presents the optimal integration of DG in radial distribution system using particle swarm optimization method.

Moreover, the rest of paper is organized as Section 2, presents the problem formulation, Section 3 presents the particle swarm optimization method and its adobility, Section 4 shows the resutls and discussion and Section 5 concludes the research outcomes.

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2. Problem Formulation

In this paper main objective function is set as minimization of real power loss of the radial distribution system with following constraints. The objective function can be mathematically described as in Equation (1).

$$\min f = \min(T_{loss}) \quad (1)$$

Where, Tloss is the active power losses of the radial bus system.

Equality constraints:

The equality and inequality constraints are given in Equation (2-5).

The bus real and reactive power is limited to:

$$P_{DG,M} = P_{Loss} + \sum P_{D,M} \quad (2)$$

$$Q_{DG,M} = Q_{Loss} + \sum Q_{D,M} \quad (3)$$

Where $P_{DG,M}$, $Q_{DG,M}$ and $P_{DG,M}$, $Q_{D,M}$ are the active and reactive components of demand and DG at bus M.

Inequality constraints:

Along with equality constraint, the inequality constraints should not be violated, such as:

Position of DG:

$$2 \leq \mathrm{DG\ position} \leq \mathrm{nbuses} \quad (4)$$

Voltage at load bus

$$V_M^{min} \leq V_M \leq V_M^{max} \quad (5)$$

V_M^{min} and V_M^{max} are minimum and maximum voltage at bus M. The power loss, voltage and other parameters are found using backward forward load flow analysis, detail given in [9].

3. Optimization Algorithm:

Nowadays, every field of engineering and scientific area are using the optimization algorithm for prediction and forecasting, control applications, design and restructuring of electricity networks and load dispatching, combinational optimization problems, robotics, security and military applications and finance and economics. The optimization algorithms are normally inspired with the behavior of birds, insects etc. For example the particle swarm optimization algorithm is inspired by our observation in our daily life a flock of birds moving in a queue towards their destination (food). In PSO a particle is a small localized object which can have several physical or chemical properties such as mass or volume, swarm is collection of something moving somewhere in large numbers and optimization is the action of making the best or effective use of a source or situation. Here every bird is particle, flock of birds is called swarm and technique of minimizing the travel time and distance to food is called optimization.

Suppose a group of birds are randomly searching for one piece of food in an area. All the birds do not know where the food is, but they know how far the food is in every iteration and after every iteration they get closer to the food. So, they develop a strategy of following the bird which is closest to the food. After some time if another bird gets closer to the food then all the birds will start following that bird. In this way personnel value of bird updates as they get closer to food. So, there are two types of values. pbest and gbest. pbest is the personnel best value of individual bird and gbest is global best value of the whole flock. If pbest of a bird is better than the previous value and gets whole flock closer to food, then this pbest will be the new gbest value of the flock. So, in every iteration they find out that how much closer is our gbest value to the food. Algorithm ends when we have followed maximum iterations and there is no further iteration or when the gbest value equals the target and the target is achieved [10]. Each particle's velocity closes to pbest and gbest is calculated by Equation (6). Each particle's current position is updated by Equation (7).

$$v_{id}^{k+1} = \omega \times v_{id}^{k} + c_1 \times rand?? \times \left(pbest_{id} - v_{id}^{k}\right) + c_2 \times rand(? \times \left(gbest_d - v_{id}^{k}\right) \quad (6)$$

$$S_{id}^{k+1} = S_{id}^{k} + v_{id}^{k+1}, i = 1, 2, \ldots..n, ?d = \ , 2\ldots, m \quad (7)$$

4. Simulation Results and Discussion

The IEEE 69 radial distribution system is used to validate the proposed method as shown in Figure 1. The bus and line parameters are taken from [11]. The optimal and sizing of distributed generation are carried out using single objective PSO optimization method.

Two case studies were performed for the proposed work. For case I, different numbers of wind turbines were connected only on one bus of the system, the best bus would be selected by PSO optimization algorithm, and for case II, the same number of wind farms were connected on two buses of the system. The following are details of the case studies. In this bus system the total active and reactive power losses are 3802 kW and 2694 KVAr respectively. The base power loss of given bus system is 225 kW. There are three types of DG units are taken for power loss reduction and voltage profile improvement, each type is tested for one, two and three number of DG units on IEEE 69 bus system with particle swarm optimization technique. The optimal location, size and objective function values are presented in Table 1.

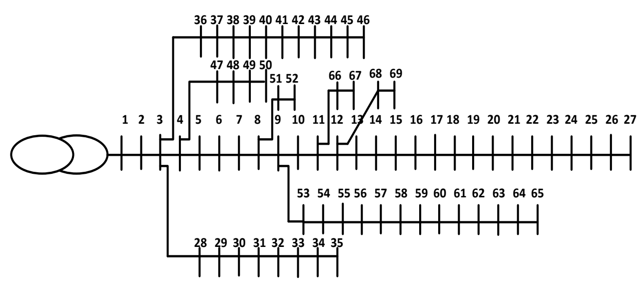

Fig. 1 IEEE 69 radial distribution system

Table 1: Location and size for IEEE 69 bus with objective function values.

DG-type	DG Nos	DG location	DG size (MW and MVar)	$Obj1$ (kW)	$Obj1$ Reduction (%)
Type-1	1 DG	61	1.8695	83.171	63.01
	2DG	18,61	0.54113,1.7893	71.600	68.16
	3 DG	18,11,60	0.3772,0.4910,1.7245	69.400	69.14
Type-2	1 DG	61	1.86956	152.00	32.41
	2 DG	61,15	1.1878,0.3525	146.80	32.72
	3 DG	61,22,11	1.3029,0.2495,0.3836	145.30	35.39
Type-3	1-1 DG(P)	61	1.82826	23.20	89.68
	1-1 DG(Q)	61	1.24681		
	2-2 DG(P)	61,24	1.70834,0.47481	13.40	94.04
	2-2 DG(Q)	69,61	0.035124,1.44839		
	3-3 DG(P)	68,24,61	0.7251,0.100,1.6593	12.40	94.48
	3-3 DG(Q)	69,02,63	0.5834,1.5876,1.01653		

With the use of 1 DG, the size of DG unit is 1.8695 MW and it is connected at bus number 61. After few iteration the power losses in radial distribution system are reduced to 83.171 kW (63.01% power loss reduction).

With the use of 2 DG, the size of each DG unit is 0.54113 MW and 1.7893 MW are connected at bus number 18, 61, respectively. The losses in radial distribution system are reduced to 71.600 kW (68.16% power loss reduction).

With the use of 3 DG units, the size of each DG unit is 0.3772 MW, 0.4910 MW and 1.7245 MW are connected at bus number 18, 11 and 60 respectively. The losses in radial distribution system are reduced to 69.400 kW (69.14 % power loss reduction).

In case of type-1 (1 DG, 2 DG, 3 DG) power loss reduction is 63.01 percent, 68.16 percent and 69.14 percent respectively. From the above discussion it is observed that power loss reduction is improved by increasing number of DG units.

TYPE-2 DG:-

With the use of 1 DG unit, the size of DG unit is 1.86956 MVar and it is connected at bus number 61. The losses in radial distribution system are reduced to 152 kW (32.41% power loss reduction).

With the use of 2DG units, the size of each DG unit is 1.1878 MVar and 0.3525 MVar are connected at bus number 61, 15 respectively. The losses in radial distribution system are reduced to 146.80 kW (32.72% power loss reduction).

With the use of 3 DG units, the size of each DG unit is 1.3029 MVar, 0.2495 MVar and 0.3836 MVar are connected at bus number 61, 22 and 11 respectively. The losses in radial distribution system are reduced to 145.30 kW (35.39% power loss reduction).

In case of type-2 (1DG, 2DG, 3DG) power loss reduction is 32.41 percent, 32.72 percent and 35.39 percent respectively. From the above discussion it is observed that power loss reduction is improved by increasing number of DG units.

TYPE-3 DG:-

With the installation of 1 DG unit, the size of DG unit is 1.82826 MW @ 61 for active power and 1.24681 MVar at bus 61 for reactive power loss. The losses in radial distribution system are reduced to 23.20 kW (89.68 % power loss reduction).

With the installation of 2 DG units, the active power size and location of each DG unit is 1.70834 MW and 0.47481 MW at bus numbers 61 and 24 respectively. The reactive power size and location of each DG unit is 0.035124 MVar and 1.44839 MVar at bus numbers 69 and 61 respectively. The losses in radial distribution system are reduced to 13.4 kW (94.04 % power loss reduction).

With the installation of 3 DG units, the active power size and location of each DG unit is 0.7251 MW, 0.10 MW and 1.6593 MW at bus numbers 68, 24 and 61 respectively. The reactive power size and location of each DG unit is 0.5834 MVar, 1.5876 MVAr and 1.01653 MVAr at bus numbers 69, 02 and 63 respectively. The losses in radial distribution system are reduced to 12.40 kW (94.48 % power loss reduction).

In case of type-3 (1DG, 2DG, 3DG) power loss reduction is 89.68 percent, 94.04 percent and 94.48 percent respectively. From the above discussion it is observed that power loss reduction is improved by increasing number of DG units.

From the Table 1 it is cleared that by installation of increased number of DG unit’s losses in radial distribution system are reduced and losses are also reduced with the use of type-3 DG unit(s) as compare to type-1 and type-2 DG unit(s). Moreover, the results of one, two and three number of DG unit(s) of type-1 are compared with other optimization algorithm such as MTLBO [12] and Ant colony optimization with artificial bee colony (ACO-ABC) [13] as given below in Table 2.

From the above Table 2 it is observed that with the use of only 1 DG unit power loss for proposed PSO technique is 83.171 kW, whereas, the power loss reduction from MTLBO [12] and ACO-ABC [13] is observed as 83.189 kW and 83.323 kW respectively. It can be further noticed that the proposed technique gives higher power loss reduction as compared to other two techniques.

Whereas with the use of 2 DG units power loss for proposed method, MTLBO [12] and ACO-ABC [13] technique, the power loss reduction is noticed as 71.60 kW, 71.657 kW and 71.776 kW respectively. Power loss in case of proposed technique is small as compare to other two techniques.

With the use of 3 DG units power loss for proposed PSO, MTLBO [12]] and ACO-ABC [13] technique is 69.400 kW, 69.429 kW and 69.539 kW respectively. Power loss in case of proposed technique is small as compare to other two techniques.

Hence, from the above discussion it is cleared that proposed technique gives better power loss reduction as compare to MTLBO [12] and ACO-ABC [13] techniques.

Voltage profile and voltage stability:

Similarly the values of voltage profile and voltage stability for IEEE 69 test system by considering three types and maximum three number of DG unit(s) are shown in Table 3. The value of voltage profile is 0.9090 pu at bus number 65 before installing DG unit(s). For type-1 with 1DG, 2DG and 3DG unit(s) voltage profile can be maximized up to 0.9778 p.u (7.03% rise), 0.9782 p.u (7.07% rise) and 0.9789 pu (7.14% rise) respectively.

For type-2 with 1DG, 2DG and 3DG unit(s) voltage profile can be maximized up to 0.9303 p.u (2.28% rise), 0.9309 pu (2.35% rise) and 0.9399 pu (3.28% rise) respectively. For type-3 with 1DG, 2DG and 3DG unit(s) voltage profile can be maximized up to 0.9960 p.u (8,73% rise), 0.9976 p.u (8.88% rise) and 0.9984 p.u (8.95% rise) respectively. From the simulation results shown in Table 2 it is observed that the performance of voltage profile and voltage stability for IEEE 69 bus system is improved by increasing type and number of DG unit(s).

The response at each bus can be seen in Figure 2 and Figure 3 respectively.

Table 2: Comparison of advanced-PSO for IEEE 69 bus with one parameter (using only type-I DG)

No. of DGs	***Method***	***DG location***	***DG size (MW)***	***Total DG capacity (MW)***	$Ploss(kW)$
1 DG	(Proposed) PSO	61	1.86956	1.8695	83.171
	ACO-ABC [13]	61	1.87260	1.8726	83.189
	MTLBO [12]	61	1.81970	1.8197	83.323
2 DGs	(Proposed) PSO	18	0.5411	2.330	71.60
		61	1.7893		
	ACO-ABC [13]	18	0.5309	2.3127	71.657
		61	1.7818		
	MTLBO [12]	17	0.5197	2.2517	71.776
		61	1.7320		
3 DGs	(Proposed) OPSO	18	0.3772	2.5927	69.400
		11	0.4910		
		61	1.7245		
	ACO-ABC [13]	11	0.5597	2.6224	69.429
		21	0.3468		
		61	1.7159		
	MTLBO [12]	11	0.4938	2.5447	69.539
		18	0.3720		
		61	1.6725		

Table 3: The voltage profile and voltage stability of IEEE 69 bus system

DG Type	***DG Nos***	***Voltage (p.u)***		***Rise (%)***
		Min	***Max***	
	Base case	0.9090 @ 65	1.00 @ 1	
Type-1 DG	1 DG	0.9778 @ 65	1.00 @ 1 & 2	7.03
	2 DG	0.9782 @ 65	1.00 @ 1 & 2	7.07
	3 DG	0.9789 @ 65	1.00 @ 1, 2 & 3	7.14
Type-2 DG	1 DG	0.9303 @ 65	1.00 @ 1	2.28
	2 DG	0.9309 @ 65	1.00 @ 1	2.35
	3 DG	0.9399 @ 65	1.00 @ 1	3.28
Type-3 DG	1 DG	0.9960 @ 65	1.00 @ 1,2 ,3,28 & 36	8.73
	2 DG	0.9976 @ 65	1.00 @ 1, 2, 3, 28 & 36	8.88
	3 DG	0.9984 @ 65	1.00 @ 1,2, 3,4,28 & 36	8.95

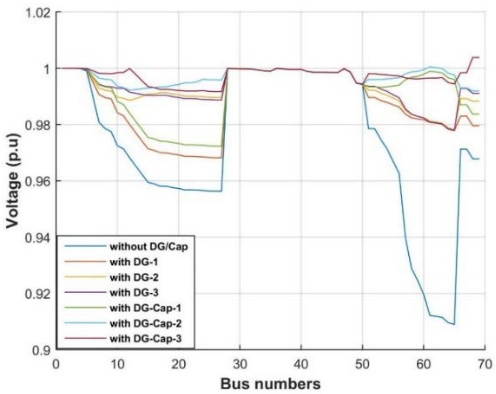

Fig. 2 Voltage profile for 69 bus with type-I & type-III DG

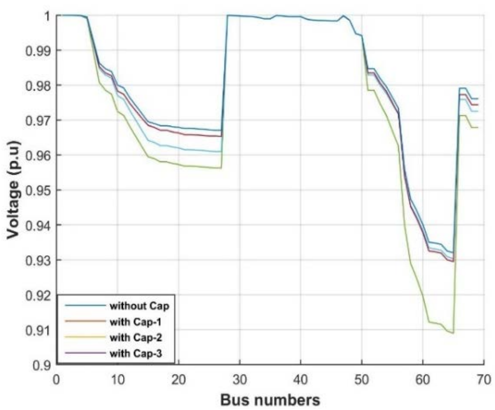

Fig. 3 Voltage profile for 69 bus with type-II

5. Conclusion

This paper presents the assessment of wind energy output from wind turbines as distributed generations. The wind data was gathered from an area in Pakistan. Data was further explored to build different wind farm capacities. The output power of these wind farms was added into the distribution system in order to reduce power losses and improve voltage profile of the system. The optimal location for the wind farm was pinpointed using PSO optimization technique. The validity of the proposed model was also compared with other optimization techniques. On the whole, it can be concluded that the proposed method provided better results.

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Table A. Appendix

No.	*From*	*To*	*R*	*X*	*P*	*Q*
1	1	2	3.12E-06	7.49E-06	0	0
2	2	3	3.12E-06	7.49E-06	0	0
3	3	4	9.36E-06	2.25E-05	0	0
4	4	5	0.00015	0.00018	0	0
5	5	6	0.002284	0.001163	0	0
6	6	7	0.00237	0.00121	0.0026	0.0022
7	7	8	0.00057	0.00029	0.0404	0.03
8	8	9	0.00030	0.00015	0.075	0.054
9	9	10	0.00511	0.00168	0.03	0.022
10	10	11	0.00116	0.00038	0.028	0.019
11	11	12	0.00443	0.00146	0.145	0.104
12	12	13	0.00642	0.00212	0.145	0.104
13	13	14	0.00651	0.00215	0.008	0.005
14	14	15	0.00660	0.00218	0.008	0.005
15	15	16	0.00122	0.00040	0	0
16	16	17	0.00233	0.00077	0.0455	0.03
17	17	18	2.93E-05	9.98E-06	0.06	0.035
18	18	19	0.00204	0.0006	0.06	0.035
19	19	20	0.00131	0.00043	0	0
20	20	21	0.00213	0.00070	0.001	0.0006
21	21	22	8.73E-05	2.87E-05	0.114	0.081
22	22	23	0.00099	0.00032	0.005	0.0035
23	23	24	0.00216	0.00071	0	0
24	24	25	0.00467	0.00154	0.028	0.02
25	25	26	0.00192	0.00063	0	0
26	26	27	0.00108	0.00035	0.014	0.01
27	3	28	2.75E-05	6.74E-05	0.014	0.01
28	28	29	0.00039	0.00097	0.026	0.0186
29	29	30	0.00248	0.00082	0.026	0.0186
30	30	31	0.00043	0.00014	0	0
31	31	32	0.00219	0.00072	0	0
32	32	33	0.00523	0.00175	0	0
33	33	34	0.01065	0.00352	0.014	0.01
34	34	35	0.00919	0.00304	0.0195	0.014
35	3	36	2.75E-05	6.74E-05	0.006	0.004
36	36	37	0.00039	0.00097	0.026	0.0185
37	37	38	0.00065	0.00076	0.026	0.0185
38	38	39	0.00019	0.000221	0	0
39	39	40	1.12E-05	1.31E-05	0.024	0.017
40	40	41	0.00454	0.00530	0.024	0.017
41	41	42	0.00193	0.00226	0.0012	0.001
42	42	43	0.00025	0.00029	0	0
43	43	44	5.74E-05	7.24E-05	0.006	0.0043
44	44	45	0.00067	0.00085	0	0
45	45	46	5.62E-06	7.49E-06	0.0392	0.0263
46	4	47	2.12E-05	5.24E-05	0.0392	0.0263
47	47	48	0.00053	0.0013	0	0
48	48	49	0.00808	0.00442	0.079	0.0564
49	49	50	0.00051	0.00125	0.3847	0.2745
50	8	51	0.00057	0.00029	0.3847	0.2745
51	51	52	0.00207	0.00069	0.0408	0.0283
52	9	53	0.00108	0.00055	0.0036	0.0027
53	53	54	0.00126	0.00064	0.0043	0.0035
54	54	55	0.00177	0.00090	0.0264	0.019
55	55	56	0.00175	0.00089	0.024	0.0172
56	56	57	0.00992	0.00333	0	0
57	57	58	0.00489	0.00164	0	0
58	58	59	0.00189	0.00062	0	0
59	59	60	0.00240	0.00073	0.1	0.072
60	60	61	0.00316	0.00161	0	0
61	61	62	0.00060	0.00030	1.244	0.888
62	62	63	0.00090	0.00046	0.032	0.023
63	63	64	0.00443	0.00225	0	0
64	64	65	0.00649	0.00330	0.227	0.162
65	11	66	0.00125	0.00038	0.059	0.042
66	66	67	2.93E-05	8.73E-06	0.018	0.013
67	12	68	0.00461	0.00152	0.018	0.013
68	68	69	2.93E-05	9.98E-06	0.028	0.02
					0.028	0.02

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