PSO BASED MULTI-OBJECTIVE OPTIMIZATION FOR DISTRIBUTION PLANNING WITH DISTRIBUTED GENERATION

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Abstract

This paper presents a multi-objective function for optimal placement of distributed generation (DG) resources in distribution systems in order to minimize the power losses and improve voltage profile. Particle swarm optimization (PSO) and weight method are applied to the proposed technique to obtain the best compromise between these costs. Simulation results on IEEE 30-bus test system are presented to demonstrate the usefulness of the proposed procedure.

Keywords: multi-*objective function, DG, PSO, IEEE 30-bus test system.*

1. Introduction

The integration of renewable DG units into distribution systems offers many advantages. The injections of power from near located of renewable DG units to the loads offer the chance for energy losses reduction and system voltage provision [1-2]. Therefore, DG units' placement should be thoroughly decided with the concern of different planning inducements. The effect of placing a renewable DG on distribution grid indices usually differs on the basis of its type, location and load at the connection point [3-4].

Renewable DG placement problems of can be described as a single objective (SO) optimization problem, such as voltage stability and whole energy losses [5-6]. They are considered as the self-determining objectives respectively for the optimization studies. In its place, the renewable DG placement problems are confirmed as a multi-objective (MO) problem, wherein different objectives such as power losses, reliability, and voltage profile are reflected and concurrently optimized in the procedure [7-8].

The optimal placement of renewable DG units in distribution grid can be modelled as a non-deterministic polynomial optimization problem. The heuristic methods are more appropriate to resolve such complex problems [9]. Particularly, the intelligent search based population methods has been studied to solve obtaining multi-objective problems [10]. Particle swarm optimization (PSO) is proposed to find solutions with faster convergence compared than other population based algorithms. Then, the benefits of PSO are easy to implement and only a few parameters to adjust [11].

This paper is organised as follows: A research method is offered on Section 2. Section 3 presents research and analysis, whereas the conclusion followed by the references is described on Section 4.

2. Research Method

The reduction of real power loss in general illustrates more attention for the utilities because it decreases the proficiency during delivering energy to customers. Nevertheless, reactive power loss is apparently not less important because it makes the possibility to deliver real power through lines to customers. Hence the flow of reactive power has to be preserved in the system at a guaranteed amount for sufficient the level of voltage.

The real power flow and reactive power of power system flow in a line *l* connecting two buses (bus *i* and bus *j*) and can be described as:

$$P_{ij} = V_i V_j Y_{ij} \cos(\theta_{ij} + \delta_{ij}) - V_i^2 Y_{ij} \cos\theta_{ij}$$
$$Q_{ij} = V_i V_j Y_{ij} \sin(\theta_{ij} + \delta_{ij}) - V_i^2 Y_{ij} \sin\theta_{ij} - \frac{V_i^2 Y_{sh}}{2} \quad \ldots(1)$$

From these equations power flow sensitivity factor can be evaluated using Eq. 2.2 and Eq. 2.3 [12].

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$$\begin{bmatrix} \frac{\partial P_{ij}}{\partial P_n} \\ \frac{\partial P_{ij}}{\partial Q_n} \end{bmatrix} = \begin{bmatrix} F_{P-P} \\ F_{P-Q} \end{bmatrix} = [J^T]^{-1} \begin{bmatrix} \frac{\partial P_{ij}}{\partial \delta} \\ \frac{\partial P_{ij}}{\partial V} \end{bmatrix} \quad \text{... (2)}$$

$$\begin{bmatrix} \frac{\partial Q_{ij}}{\partial P_n} \\ \frac{\partial Q_{ij}}{\partial Q_n} \end{bmatrix} = \begin{bmatrix} F_{Q-P} \\ F_{Q-Q} \end{bmatrix} = [J^T]^{-1} \begin{bmatrix} \frac{\partial Q_{ij}}{\partial \delta} \\ \frac{\partial Q_{ij}}{\partial V} \end{bmatrix} \quad \text{... (3)}$$

The real power loss and reactive power loss a line *l* of power system in connecting two buses (bus *i* and bus *j*), can be stated as:

$$P_{L(ij)} = g_{ij}\left(V_i^2 + V_j^2 - 2V_iV_j \cos \delta_{ij}\right)$$

$$Q_{L(ij)} = -b_{ij}^{sh}\left(V_i^2 + V_j^2\right) - b_{ij}\left(V_i^2 + V_j^2 - 2V_iV_j \cos \delta_{ij}\right) \quad \text{... (4)}$$

From these equations power loss sensitivity factor can be assessed using Eq. 2.5 and Eq. 2.6 [12].

$$\begin{bmatrix} \frac{\partial P_{L(ij)}}{\partial P_n} \\ \frac{\partial P_{L(ij)}}{\partial Q_n} \end{bmatrix} = \begin{bmatrix} S_{P-P} \\ S_{P-Q} \end{bmatrix} = [J^T]^{-1} \begin{bmatrix} \frac{\partial P_{L(ij)}}{\partial \delta} \\ \frac{\partial P_{ij}}{\partial V} \end{bmatrix} \quad \text{... (5)}$$

$$\begin{bmatrix} \frac{\partial Q_{L(ij)}}{\partial P_n} \\ \frac{\partial Q_{L(ij)}}{\partial Q_n} \end{bmatrix} = \begin{bmatrix} S_{Q-P} \\ S_{Q-Q} \end{bmatrix} = [J^T]^{-1} \begin{bmatrix} \frac{\partial Q_{L(ij)}}{\partial \delta} \\ \frac{\partial Q_{ij}}{\partial V} \end{bmatrix} \quad \text{... (6)}$$

Both power flows and power losses can be integrated into the form of factor of combined sensitivity (CSF) as follows:

$$CSF_i = \left(F_{P-P_i} \times F_{Q-P_i}\right) + \left(F_{P-Q_i} \times F_{Q-Q_i}\right) + \left(S_{P-P_i} \times S_{Q-P_i}\right) + \left(S_{P-Q_i} \times S_{Q-Q_i}\right) \quad \text{...(7)}$$

The performance calculation (MOF) of multi-objective function for renewable DG placement in distribution systems:

$$MOF = w_1 PLRI + w_2 QLRI + w_2 VPII \qquad |w_1| + |w_2| + |w_3| = 1 \quad \text{... (2.8)}$$

While real power loss reduction index (PLRI), rective power loss reduction index (QLRI), and voltage profile improvement index (PVII) are given by

$$PLRI = \frac{P_{L(base)} - P_{L(DG_i)}}{P_{L(base)}} \qquad LRI = \frac{Q_{L(base)} - Q_{L(DG_i)}}{Q_{L(base)}} \qquad VPII = \frac{1}{\lambda + \max_{1}(|1 - V(n)|)}$$

The formulated multi-objective function is minimized subject to various operational constraints so as satisfy the electrical requirements for the distribution grid, such as:

The load regulations for every bus should be achieved;

$$P_{gni} - P_{dni} - V_{ni} \sum_{j=1}^{n} V_{nj} Y_{nj} \cos\left(\delta_{ni} - \delta_{nj} - \theta_{nj}\right) = 0 \quad \text{... (10)}$$

The upper and lower real and reactive power generation limit of generators at bus-*i*;

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max}, \; i = 1,2,\dots,N_g \qquad Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max}, \; i = 1,2,\dots,N_q \quad \text{... (11)}$$

The voltage could be retained within standard limits at every bus;

$$V_i^{min} \le V_i \le V_i^{max}, \; i = 1,2,\dots,N_b \quad \text{... (12)}$$

The upper and lower real and reactive power generation limits of renewable DG connected at bus-*i*;

$$P_{DGi}^{min} \leq P_{DGi} \leq P_{DGi}^{max}\ ,\ \ i = 1,2,\ldots,N_{DG} \qquad Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}\ ,\ \ i = 1,2,\ldots,N_q \qquad \ldots..\ (13)$$

The proposed PSO based method for optimal placement of renewable DG in distribution system is shown in Fig. 1.

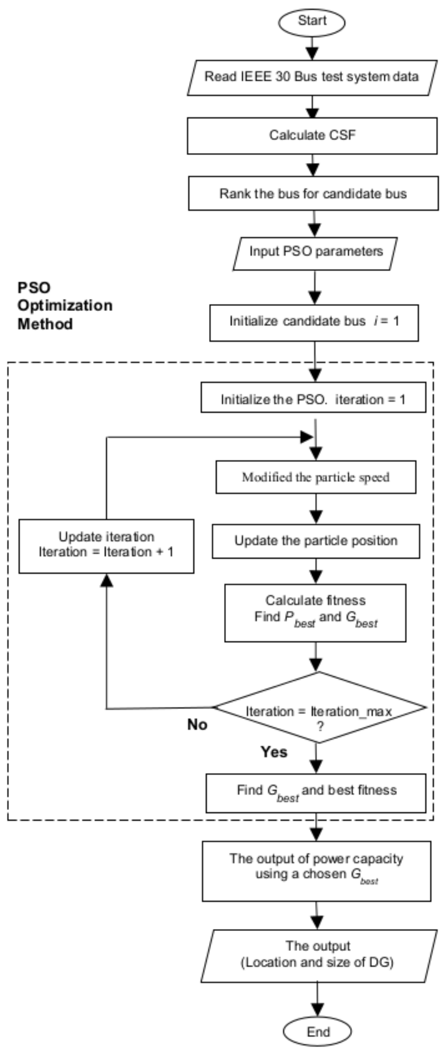

Fig. 1. Flowchart of proposed algorithm

3. Research Results

The single line diagram of IEEE 30 Bus test system is shown in Fig. 2. While grid data and line data are shown in Table 1 and 2.

The CSF all buses of test system were calculated based on Eq. 7. Candidate buses were chosen by selecting CSF values more than 0.8. The optimal locations of the DGs could be able to choose by carefully looking at all the candidate buses, shown in Table 3.

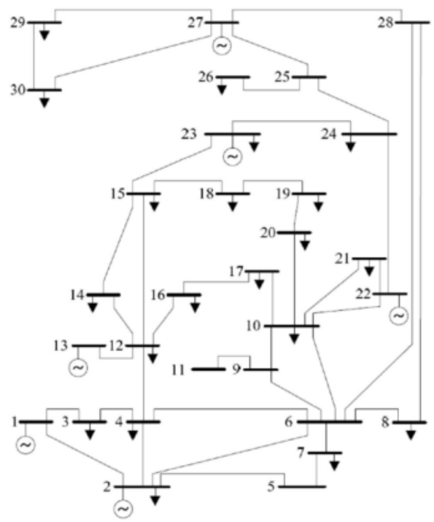

Fig.2. Single line diagram of Test System

Table 1: Bus Data of IEEE 30 Bus System

Bus No.	Type	Bus Voltage		Generation		Load		Reactive Power Limit	
		Mag. (pu)	Angle (°)	Active Power (pu)	Reactive Power (pu)	Active Power (pu)	Reective Power (pu)	Q_{min} (pu)	Q_{max} (pu)
1	Swing	1,060	0	0	0	0	0	0	0
2	PV	1,043	0	40	50	21,7	12,7	-40	50
3	PQ	1,00	0	0	0	2,4	1,2	0	0
4	PQ	1,06	0	0	0	7,6	1,6	0	0
5	PV	1,01	0	0	37,0	94,2	19,0	-40	40
6	PQ	1,00	0	0	0	0	0	0	0
7	PQ	1,00	0	0	0	22,8	10,9	0	0
08	PV	1,01	0	0	37,3	30	30	-10	40
9	PQ	1,00	0	0	0	0	0	0	0
10	PQ	1,00	0	0	19,0	5,8	2,0	0	0
11	PV	1,082	0	0	16,2	0	0	-6	0
12	PQ	1,00	0	0	0	11,2	7,5	0	0
13	PV	1,071	0	0	10,6	0	0	-6	24
14	PV	1,00	0	0	0	6,2	1,6	0	0
15	PQ	1,00	0	0	0	8,2	2,5	-6	24
16	PQ	1,00	0	0	0	3,5	1,8	0	0
17	PQ	1,00	0	0	0	9,0	5,8	-6	24
18	PQ	1,00	0	0	0	3,2	0,9	0	0
19	PQ	1,00	0	0	0	9,5	3,4	0	0
20	PQ	1,00	0	0	0	2,2	0,7	0	0
21	PQ	1,00	0	0	0	17,5	11,2	0	0
22	PQ	1,00	0	0	0	0	0	0	0
23	PQ	1,00	0	0	0	3,2	1,6	0	0
24	PQ	1,00	0	0	4,3	8,7	6,7	0	0
25	PQ	1,00	0	0	0	0	0	0	0
26	PQ	1,00	0	0	0	3,5	2,3	0	0
27	PQ	1,00	0	0	0	0	0	0	0
28	PQ	1,00	0	0	0	0	0	0	0
29	PQ	1,00	0	0	0	2,4	0,9	0	0
30	PQ	1,00	0	0	0	10,6	1,9	0	0

Table 2: Line Data of IEEE 30 Bus System

From Bus	To Bus	R (pu)	X (pu)	B/2 (pu)	X'mer (pu)
1	2	0,0192	0,575	0,0264	1
1	3	0,0452	0,1652	0,0204	1
2	4	0,0570	0,1737	0,0184	1
3	4	0,0132	0,0379	0,0042	1
2	5	0,0472	0,1983	0,0209	1
2	6	0,0581	0,1763	0,0187	1
4	6	0,0119	0,0414	0,0045	1
5	7	0,0460	0,1160	0,0102	1
6	7	0,0267	0,0820	0,0085	1
6	8	0,0120	0,0420	0,0045	1
6	9	0,0	0,2080	0,0	1
6	10	0,0	0,5560	0,0	0,0978
9	11	0,0	0,2080	0,0	0,969
9	10	0,0	0,1100	0,0	1
4	12	0,0	0,2560	0,0	1
12	13	0,0	0,1400	0,0	0,932
12	14	0,1231	0,2559	0,0	1
12	15	0,0662	0,1304	0,0	1
12	16	0,0945	0,1987	0,0	1
14	15	0,2210	0,1997	0,0	1
16	17	0,0824	0,1923	0,0	1
15	18	0,1073	0,2185	0,0	1
18	19	0,0639	0,1292	0,0	1
19	20	0,0340	0,0680	0,0	1
10	20	0,0936	0,2090	0,0	1
10	17	0,0324	0,0845	0,0	1
10	21	0,0348	0,0749	0,0	1
10	22	0,0727	0,1499	0,0	1
21	23	0,0116	0,0236	0,0	1
15	23	0,1000	0,2020	0,0	1
22	24	0,1150	0,1790	0,0	1
23	24	0,1320	0,2700	0,0	1
24	25	0,1885	0,3292	0,0	1
25	26	0,2544	0,3800	0,0	1
25	27	0,1093	0,2087	0,0	1
28	27	0,0	0,3960	0,0	0,968
27	29	0,2198	0,4153	0,0	1
27	30	0,3202	0,6027	0,0	1
29	30	0,2399	0,4533	0,0	1
8	28	0,0636	0,2000	0,0214	1
6	28	0,0169	0,0599	0,065	1

Table 3: Resuls for CSF, Fitness, and optimal DG sizes for candidate buses

Candidate Bus	CSF	Fitness	DG ize (MW)
10	0,8808	0,9164	11,0680
11	0,9266	0,9188	11,6445
15	0,8377	0,9182	11,4582
17	0,8755	0,9151	10,7347
18	1,0218	0,9188	11,5198
19	1,0945	0,9206	11,9289
20	1,0631	0,9203	11,8929
21	0,9973	0,9093	9,2237
22	1,0554	0,9194	11,7708
23	0,9911	0,9204	11,8984
24	1,0350	0,9205	11,9112
25	0,8770	0,9155	10,7875
26	1,0086	0,9195	11,9082
30	0,8160	0,9209	11,8938

The results obtained for the real power losses and voltage levels was done using Newton-Raphson load flow. It can be seen in Table 4 that the presence of the DGs does not effect to deviation of voltage levels outside the acceptable limits [13]. Evidently, all of the bus voltages were in the range of 1.0pu to 1.1pu. Table 5 shows that renewable DG gave great reduction in real power loss. The percentage real power loss reduction was 3,859 MW or 22.02 %.

Table 4: Comparison of Bus Voltage using DG

Bus No.	Voltage without DG (pu)	Voltage with DG (pu)
1	1,0600	1,0600
2	1,0430	1,0430
3	1,0217	1,0251
4	1,0129	1,0167
5	1,0100	1,0100
6	1,0121	1,0152
7	1,0035	1,0053
8	1,0100	1,0100
9	1,0507	1,0544
10	1,0438	1,0489
11	1,0820	1,0820
12	1,0576	1,0592
13	1,0710	1,0710
14	1,0429	1,0454
15	1,0384	1,0433
16	1,0445	1,0478
17	1,0387	1,0433
18	1,0282	1,0381
19	1,0252	1,0381
20	1,0291	1,0400
21	1,0293	1,0348
22	1,0353	1,0415
23	1,0291	1,0348
24	1,0237	1,0315
25	1,0202	1,0338
26	1,0025	1,0429
27	1,0265	1,0323
28	1,0109	1,0146
29	1,0067	1,0126
30	0,9953	1,0012

Table 5: Comparison of Results using DG

Bus No.	DG size (MW)	Power Losses (MW)	Power Loss Reduction (MW)	Percentage Power Loss Reduction (%)
10	11,0680			
19	11,9289	13,669	3,859	22,02
26	11,9082			

4. Conclusion

This paper showed the implementation of a PSO based algorithm for system loss reduction and voltage profile improvement in distribution system by optimizing the location and size of renewable DG units. The combined sensitivity factors were formulated and used effectively in reducing the amount of candidate placements for renewable DG. As seen from the results of this optimization technique gave great loss reduction considered using this distribution system. The percentage real power loss reduction was 3,859 MW or 22.02 %. In addition the lowest bus voltage was improved from 0.9953 pu to 1.0012 pu while maintaining the highest voltage level at 1.0710 pu.

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