The Optimal Placement of Distributed Generation (DG) to Improve the Voltage Profile and Reduce Losses in Radial Distribution Networks Using PSO

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Abstract

Voltage profile and losses are important factors in a distribution network in which there are variety of ways to improve them. In this paper, distributed generation (DG) is used as a solution to improve the above characteristics. Backward/Forward Sweep load flow algorithm is used due to the inefficiency of usual load flow algorithms because of high R/X ratio and their lack of convergence in distribution networks. This algorithm is applied to the system and the best place to install DG is selected by Particle Swarm Optimization (PSO).

Keywords: Voltage profile, distributed generation, PSO algorithm

1. Introduction

Distributed generation (DG) resources are small generators that deliver electrical energy to the consumer across the networks and locally. Due to the use of modern technology, high reliability and simple measurement, DG can be a viable Substitution to traditional electrical systems for industrial, commercial and large residential units' users [1]. Power plant economic problem and also the problem of power transmission in long-distances cause engineers to think about the use of distributed generation [2]. Inappropriate placement and size of distributed generation resources cause problems in the network [3] ,therefore, applying load flow algorithm to calculate and investigate the static behavior of the network is essential. In the presence of DG, usual load flow methods are not so effective in distribution networks due to the fact that, distribution networks generally have radial or nearly radial structure and the R/X ratio is high in comparison with transmission networks. Accordingly, DGs are classified in poor-condition systems for the above algorithms and computationally has lack of convergence. So, in this article backward/forward sweep algorithm is used. The main idea of this method was presented by Mr. Shirmohammadi and colleagues in 1988 [4], [5]. In fact, in the design of DG resources, three types are considered as follows:

1. DG is only able to supply active power.
2. DG is only able to supply reactive power.
3. DG is able to supply the active and reactive power [1].

2-PSO Algorithm

PSO algorithm is a general method that can be used to minimize the problems and also dealt with problems which their solution are a point or surface in n-dimensional space. In such an atmosphere, some assumptions arises and an initial velocity assigned to them. Additionally, communication channels between the particles are considered. Then the particles move in the space, and the results are calculated based on a criterion of merit after each period. By elapsing time, the particles move toward the particles with higher eligibility criteria and accelerated. Although each method is effective on a range of issues but this method has shown its success in solving continuous optimization problems [6], [7].

(1)and (2) show the velocity and position of the particles .

$$vij^{n+1} = c_1 * v_{ij}^n + c_2 * rand * (Pbest_{ij}^n - P_{ij}^n) + c_1 * rand * (Gbest_j^n - P_{ij}^n) \quad (1)$$

$$P_{ij}^{n+1} = P_{ij}^n + V_{ij}^{n+1} \quad (2)$$

To get to the optimal point, velocity should not be too high or too low. So each particle must be moved between the minimum and maximum velocity. C_1 and C_2 are selected to achieve the best point [8].

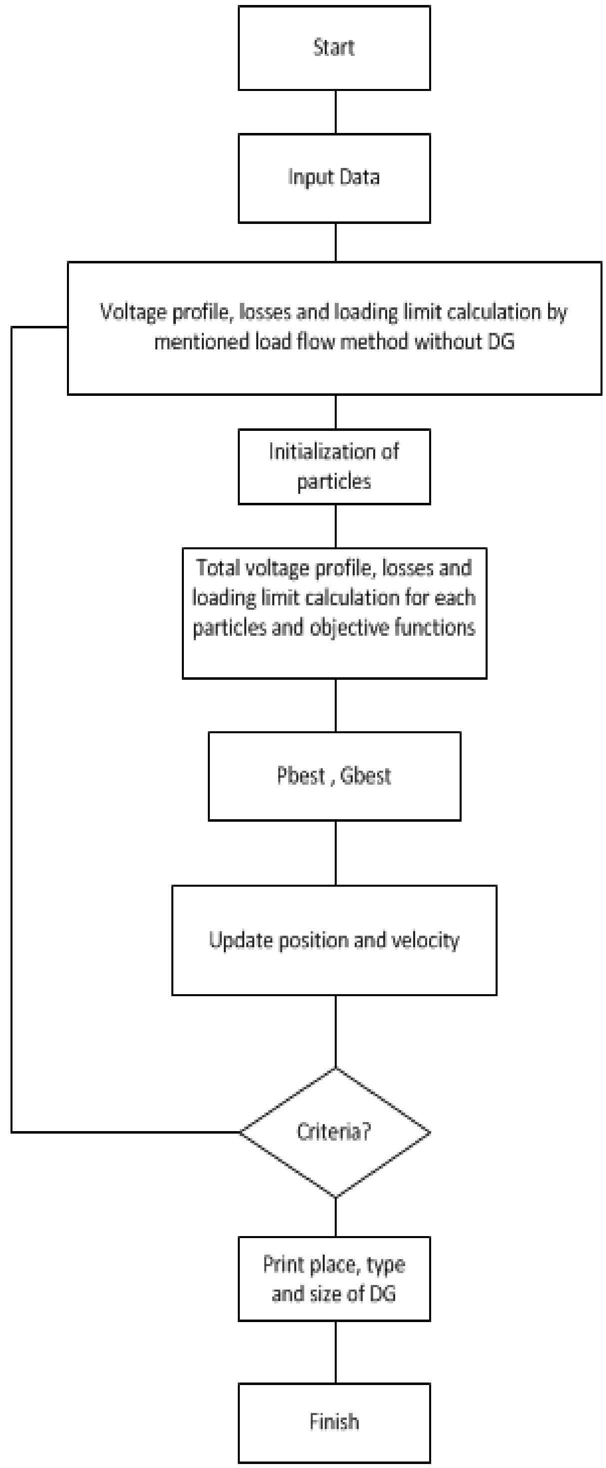

Fig. 1. PSO flowchart

3- Voltage profile

Voltage profile from sender terminal to the receiver terminal is declining in a line. The voltage drop in the distribution lines is associated with the line reactive current and also the line reactance.

Line reactance is associated by line length and increases by it. Voltage and current control is an issue that should be considered to improve the voltage profile [9], [10]. Considering, DG resources provide some of the local active and reactive power so it would reduce the current in transmission lines and boost voltage range of consumer and thus will improve voltage profile.

$$VPII = \frac{VP_{\text{with DG}}}{VP_{\text{without DG}}} \qquad (3)$$

$$VP = \sum_{i=1}^{N} V_i L_i K_i \qquad (4)$$

V_i: ith bus voltage

L_i : ith bus inductance

K_i : weight factor

$$\sum_{i=1}^{N} K_i = 1$$

Considering the voltage profile improvement equations:

VPII<1: Voltage profile attenuates by applying DG.

VPII=1: Voltage profile does not change

VPII>1: Voltage profile enhances[11].

4- Network losses

Since a significant share of net losses is related to power transmission lines, the efficient use of DG has dramatic effect in decreasing of losses.

$$LLRI = \frac{LL_{\text{with DG}}}{LL_{\text{without DG}}} \qquad (5)$$

$$LL_{\text{with DG}} = 3\sum_{i=1}^{M} I_i^2 R_i D_i \qquad (6)$$

$LL_{\text{with DG}}$: losses in the presence of DG

I_i :(pu)ith line current

R_i : Line resistance (pu/km)

D_i : Line length (km)

M: Lines numbers

The equation related to line losses is as same as equation 6 but calculation will be considered without DG.

Considering the above equations:

LLRI<1: line losses decreases by applying DG

LLRI=1:line losses does not change

LLRI>1: line losses increases

These equations can be used to optimal placement of DG and minimize the losses. Minimum LLRI is related to the best location of DG for maximum reduction of line losses. [11].

5- Backward/Forward Load Flow Algorithm

Backward/forward load flow algorithm is a dynamic method. This method, which widely used in distribution network problems, is based on the radial structure of distribution networks and has been established accordingly. In this method, the problem is solved by calculating branches current using a compensation technique and Kirchhoff current law [5]. This method because of high speed, less computer memory requirement and good convergence characteristics, is widely used in load flow problems of distribution networks. Two basic steps of this method can be simply stated as follows:

a. Forward Sweep

The forward sweep is basically a voltage drop calculation with possible current or power flow updates. Nodal voltages are updated in a forward sweep starting from branches in the first layer toward those in the last. The purpose of the forward propagation is to calculate the voltages at each node starting from the feeder source node. The feeder substation voltage is set at its actual value. During the forward propagation the effective power in each branch is held constant to the value obtained in backward walk.

b. Backward Sweep

The backward sweep is basically a current or power flow solution with possible voltage updates. It starting from the branches in the last layer and moving towards the branches connected to the root node .The updated effective power flows in each branch are obtained in the backward propagation computation by considering the node voltages of previous iteration. It means the voltage values obtained in the forward path are held constant during the backward propagation and updated power flows in each branch are transmitted backward along the feeder using backward path. This indicates that the backward propagation starts at the extreme end node and proceeds towards source node.

Generally, load flow calculations in the presence of DG resources can be stated as follows:

1. Voltage in all network nodes (node) is initialized for various load levels as follows:

$$V_i = (i + 0j), i = 1, 2, 3, \ldots\ldots, NN \tag{7}$$

where NN is number of nodes in the network.

2. Load equivalent current in each nodes of the network is calculated by the following equation:

$$I_i = \frac{(P_i - P_{DG\,i}) - j(Q_i - Q_{DG\,i})}{V^*} \tag{8}$$

In this equation Q_i and P_i are respectively active and reactive power in node i and Q_ (DG i) and P_ (DG i) are active and reactive power generated by the DG resources in ith node.

3. The current passing through each line is calculated by the following equation:

$$I_{j,k-1} = -I_{j,k} + \sum_{(j,k)\in SL} I_{j,k} \tag{9}$$

where I_ (j, k) is the current flows from j to k section and SL is the sections series of j-th node connected to the j and k section .

4. Each nodes voltage is calculated by the following equation:

$$V_j = V_i - Z_{i,j} \times I_{i,j} \tag{10}$$

Where Z_ (i, j) is the impedance of ith and jth section.

5. If the difference between voltages calculated in step 4 and their previous values is greater than a specified limit, the calculation is repeated from step 2. (Convergence calculations)

6. Results include nodes voltage, current and lines losses [5],[12].

6- Network study

In order to evaluate the performance and effectiveness of the proposed algorithms, numerical studies on IEEE 10-bus network has been considered. Tested 10-bus network information is based on [13]. Network voltage and apparent power are 6.5 KV and 10 MVA, respectively.

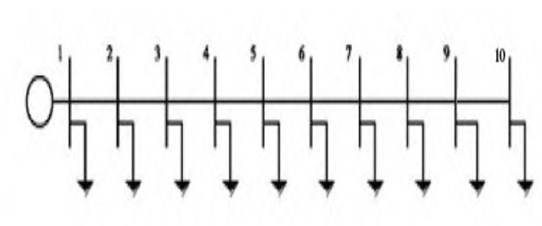

Fig 2. IEEE 10 -bus network

In order to solve the problem, voltage profile range is considered between 0.95 and 1.05. Also, in the above network, four DG with cos(φ)=0.95 is used as follows:

Table.1.DG Information used in the 10-bus network

Reactive power (KVAR)	Active power (KW)	typeDG
986	3000	1
1315	4000	2
1972	6000	3
2630	8000	4

7- Results

According to the results of PSO algorithm, selected DG is type (1) on bus (6)

Table .2.Results of objective function's various parameters before and after DG installation

After DG installation	Before DG installation	objective function's parameters
0.0627	1	normalized line losses reduction index
56,3421	719.85	Real losses
0.2081	1	normalized voltage profile improvement index
1.00229	0.89367	Real voltage profile improvement

Table .3.Voltage profile and network losses comparison before and after the installation of DG in 10-bus network

Line losses comparison(kw)			Voltage profile comparison		
after	before	Line number	after	before	bus number
0.203	0.2	1	1	1	1(slack)
1.1	1.1	2	0.999	0.999	2
0.288	0.29	3	0.995	0.995	3
0.262	0.26	4	0.994	0.994	4
31.268	695.7	5	0.993	0.9934	5
1.295	2.08	6	1.016	0.801	6
0.355	0.57	7	1.011	0.795	7
0.535	0.86	8	1.010	0.794	8
11.13	18.7	9	1.008	0.791	9
			0.993	0.771	10

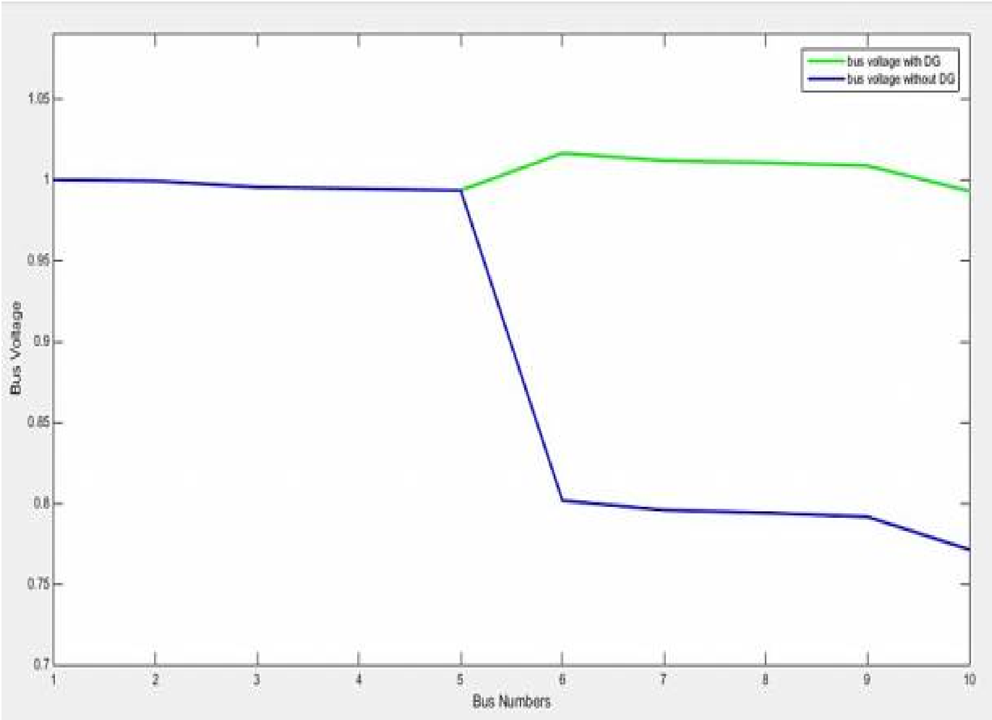

Fig .3. Voltage profile comparison before and after DG installation in 10-bus network

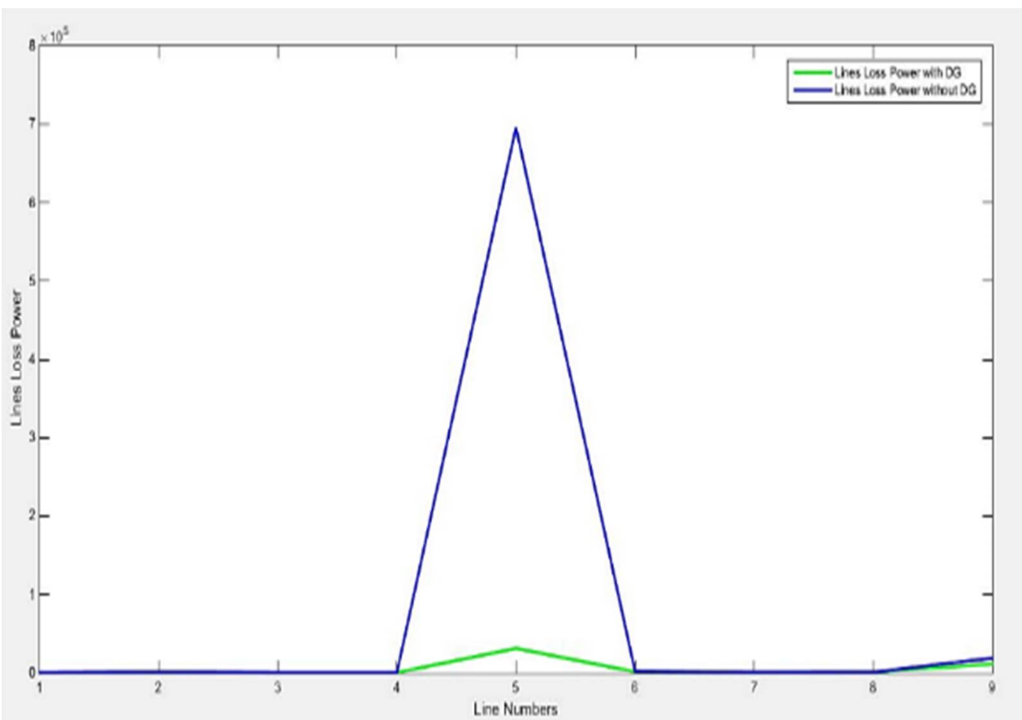

Fig.4. Line losses comparison before and after DG installation in 10-bus network

8- Conclusion

Since the voltage profiles and losses are important issues in distribution networks. In this paper, the backward/forward sweep load flow algorithm has been used in order to solve these issues and finding buses voltage and lines current. With the availability of voltage and current, optimal placement of distributed generation (DG) resources using PSO algorithm has performed and calculated. PSO algorithm has applied to IEEE 10-bus network and DG has located in 6^{th} bus. Finally, voltage profile has been placed within specified range after simulation and consequently losses have been decreased significantly.

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