Optimum Location and Size of DG based on GA to Enhance the Voltage Profile and Losses Reduction in Radial Distribution Network

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Abstract

This paper presents an effective and robust approach based on Genetic Algorithm (GA) in order to achievement of the optimal size of active and reactive power of the Distributed Generation (DG) sources in radial distribution network. On the other hand, aforementioned approach inspects optimal size and placement of DG to alleviate losses as well as to improve the voltage profile in studied power system. This subject which is formulated as an optimization problem has been perfectly solved by GA technique. Also, the backward-forward power flow algorithm which is based on distribution network has been applied for this study. The simulation of the IEEE 33 bus network has been performed in MATLAB environment. The results of simulation unveil the good efficiency of proposed approach.

Keywords: Distributed Generation, Voltage Profile, Genetic Algorithm, Losses Reduction

1. Introduction

Due to continuous growth of sharing the Distributed Generations (DGs) in the field of industrial electric energy, programming of these units is one of the main subjects in power systems. Nowadays, unraveling the weakness problem of the voltage distribution networks using DGs is one of the main targets in distribution networks. Therefore, it needs to more attention to apply different technical to optimal tune the of network's parameters.

Connecting these power stations to the distribution networks affects some scales of the network such as losses reduction, voltage profile improvement and increase of the reliability. Lack of suitable placement of distributed generation in networks causes the incremental losses, energy production magnification and transferring expenses. Because of some factors namely small size, less bioenvironmental effects and high ability; it is necessary to use the best process to make size and do placement. It is on the unsatisfied conditions of absence of adequate current production in overall the world [1].

2. Distributed Generation

Many definitions of DGs have been presented in literatures. In general, the phrase of "the electric energy source with direct connection to the distribution network" is good definition for it. Lower and higher generation capacity of these units is about few kilowatts to 10 megawatt, respectively. But different nominal value of generation is taken into account in many literatures. These units place in posts and distribution network feeders beside the consumption centers [3]. IEEE defines electricity generation by equipments which are smaller than central power stations, and also are installable in consumption places as distributed generation. EPRI institution defines it as generation from a few kilowatts to 50 megawatts [2]. Furthermore, IEA institution defines it as units which can be directly injected inside the network or in consumption places. Also, CIGRE institution defines distribution generation as follows:

1. Its size must be between 50 to 100 megawatts.
2. Generally, must be connected to distribution network.
3. It doesn't involve central programming.
4. It doesn't involve central Transferring [7].

To sum up, there are more definitions and comments related to the DG in literatures [3-6].

2.1. Introduction of proposed Power Flow with Presence of DG

Power flow problem is one of the main affairs in distribution networks like as designing, developing and etc. In viewpoint of network, DG acts as sources which have fed the network's buses.

In other words, there is just one trail to flow the power in each electric load. The simple radial network is shown in Figure 1.

Mostly, dropping of the voltage will occur in far places from main source. It should be mentioned that if voltage falls in network, it means that the length of lines has been expanded, so voltage losses will be increased. Voltage profile in radial distribution network which has not any distributed generation, is deducing. It means that voltage near the source is near to one per unit and if we take distance from the source, voltage will be deduced. Thus aforementioned sentence of "system's radial network will be fed by one source" has been well approved [8, 9].

2.2. *Forward and Backward Power Flow*

If we presume that all loads are fixed, consideration of this procedure is acceptable. Of course, this theory can be done, because most of the great loads in distribution system are electric motors and they have been seen as fixed power loads.

2.2.1. First step (Backward):

In this step, the injection current to the each Bus will be calculated. Injection current of nth bus will be resulted by following equation:

$$I_n = \frac{S_n^*}{V_n^*} \tag{1}$$

In above mentioned equation, n is the number of buses that injection current will be calculated from it. Where Sn^* and Vn^* are conjugation of the apparent power and voltage in nth bus, respectively. Note that with presence of DG in the bus, the total apparent power in nth bus will be obtained via distracting the load's power in that bus from the power of its installed DG. If generating power of DG be greater than connected loads, injection will be done via its bus. In this position, nth bus voltage is greater than its neighbor bus. It should be said that in first repeating $1^{p.u}$. has been taken into account for all voltages of the buses. Subsequently, the current of each line can be calculated by Eq. 2:

$$I_{Ln}= I_n + I_{Ln+1} \tag{2}$$

Where, I_{Ln}, V_n are nth line current and voltage, respectively. In Fig. 2 shows the down part of distributed network along with currents.
According to the former equation, $I_{L,27}$ is calculated as follows.

$$I_{27}= \frac{S_{27}^*}{V_{27}^*} \tag{3}$$

Firstly, the process should be started from end of the network to find the line current provided that the current of line 28 is available. Finally, using Eq.2, the current of line 27 will be obtained.

$$I_{27}= I_{27} + I_{L28} \tag{4}$$

$$I_{L27}= \frac{S_{27}^*}{V_{27}^*} + I_{L28} \tag{5}$$

2.2.2. Second Step (Forward):

In this step, according to resulted values for lines current, the bus voltage will be updateable. Updating will be started from first network bus to the last network bus which is done by using of the following equation:

$$V_n = V_{n-1} - Z_{ln} * I_{ln} \quad (6)$$

Where, Z_{ln} is nth line impedance

For example, the voltage of 28th bus can be calculated by following equation:

$$V_{28} = V_{27} - Z_{l28} * I_{l28} \quad (7)$$

According to the above mentioned explanation, for carrying out of aforementioned process, the following Algorithm is offered:

1. Supposing of initial value for all voltages of the buses.
2. Calculating the applied current of loads via Eq. 1.
3. Updating the voltages of the buses using Eq. 5.
4. Comparing the resulted voltage with the previous voltage.

The following equation controls the optimization process. If this equation cleared up, the process will be finished, if not so, it will be skipped and sets to the second step.

$$V^{new} - V^{new} \le \varepsilon \quad (8)$$

Where, ε is a fixed small value that was considered with different values according to the required accuracy.

3. Description of Genetic Algorithm

GA is one of the evolutional algorithms that is widely used by researcher in different fields of power engineering. In this study, GA has been used to solve the optimization problem. The probability of mutation 0.08 is considered, and also selecting scale is done according to the manner of roulette wheel and amount of comeliness of each chromosome.

To find the best place, active and reactive powers of best source DG are divided to the 3 parts. The first part indicates the place of generation source installation, the second part shows the active power and the third part presents the generated reactive power by DG sources. In each step of GA generation, firstly each chromosome will be considered by comeliness and then it will be selected. The mutation and crossing over will be separately done.

Applied chromosome according to numbers of DG sources can be presented as follows:

[X1, X2,..,XnDG, P1,P2,..,PnDG, Q1,Q2,…, Qn_{DG}]

The above example is for two DG sources, thus, the length of each chromosome is 6.

3.1. Objective Function

For propelling to achieve both the power losses reduction and voltage profile improvement, a good relationship must be presented as objective function (cost function).

3.1.1. Reducing the Power Losses

One of main factors of suing DGs in network is supporting the generation place and reducing the power losses. Because of some factors such as: possibility of generation in consumption place, post transferring power and primary bus of feeders economical affair become very important.

The purposed formula for placement and sizing of DG sources for losses reduction is as follows:

$$F_1 = P_L + \sum_{i=1}^{N} LOSS_k \tag{9}$$

Minimizing of this function the power losses will be reduced.

Power balance constraint can be presentable by following equation:

$$\sum_{i=1}^{N} DG_i = \sum_{i=1}^{N} P_{Di} + P_l \tag{10}$$

Range of active and reactive powers is:

$$P_{DGi}^{min} \le P_{DGi} \le P_{DGi}^{max} \tag{11}$$

$$Q_{DGi}^{min} \le Q_{DGi} \le Q_{DGi}^{max} \tag{12}$$

Range of network losses is:

$$\sum_{i=1}^{N} LOSS_k(\, with\, DG\,) \le \sum_{i=1}^{N} LOSS_k(\, without\ DG\,) \tag{13}$$

Where, P_L is power losses, and also P_i and Q_i are active and reactive power, respectively.

3.1.2. Voltage Profile Improvement

In radial networks which have radial construction, the most voltage dropping will be occurred at the end of network. It should be mentioned that if voltage falls in network, it means that the length of lines has been expanded, so voltage losses will be increased. Voltage profile in radial distribution network which has not any distributed generation, is deducing. It means that voltage near the source is near to one per unit and if we take distance from the source, voltage will be deduced. The purposed formula for locating and sizing is shown as follows:

$$F_2 = \sum_{i=1}^{N} \left| V_i - V_{i,ref} \right| \tag{14}$$

Where, V_i and $V_{i,ref}$ are bus voltage and Optimal voltage, respectively.

Range of bus voltage is:

$$|V_i|^{min} \le |V_i| \le |V_i|^{max} \quad (15)$$

4. Numerical Studies and Simulation Results

4.1. Power System

Single line diagram of IEEE 33 bus system is considered for this study which is shown in Fig. 3. This system includes: 12/66 KV transformer, 4 Feeders and 32 load lots. The other relevant system's parameters are given [12].

4.2. Simulation Software

The program of the offered algorithm has been carried out in MATLAB environment.

4.3. Best Placement and Size of DG

After evaluating the objective function by GA in order to acquire the wanted targets, the following results have been unraveled. As can be seen, the high efficiency of application of DG in studied power system is really approved.

4.3.1. Installation of one DG source to reduce the power losses and analyzing the other system's scales

Refer to the tables 1, 2 and figures 4, 5

4.3.2. Installation of one DG source to improve the voltage profile and analyzing other system's scales

Refer to the tables 3, 4 and figures 6, 7

4.3.3. Installation of two DGs to reduce the losses and analyzing the other system's scales

Refer to the tables 5, 6 and figures 8, 9

4.3.4. Installation of two DG to improve the voltage profile and analyzing the other system's scales

Refer to the tables 7, 8 and figures 10, 11

5. Conclusion

In this paper, a novel and effective approach based on GA technique is dedicated to acquire the optimal size of active and reactive power of the DG sources in radial distribution network. By the way, the proposed approach deals with the optimal size and location of DG to reduce the power losses as well as to improve the voltage profile in radial network. Likewise, the backward-forward load distribution algorithm has been taken into account for this work. The simulation results unveil that with utilizing proposed approach, all pursued targets of paper have been perfectly achieved.

6. References

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Table1: place and size of a DG for reducing the losses.

One DG	Reactive power (KVar)	Active power (KW)	Location
	198.7362	475.8244	21

Table2: system's scales for reducing the losses

One DG	Reactive power(KVar)	Active power (KW)	Voltage profile(pu)
	84.1360	135.8489	1.1302

Table1: place and size of a DG for voltage profile improvement.

One DG	Reactive power(KVar)	Active power (KW)	location
	54.5989	489.3543	21

Table4: system's scales in terms of improving the voltage profile by installation of a DG.

One DG	Voltage profile(pu)	Reactive power(KVar)	Active power (KW)
	1.1052	87.6902	141.7678

Table5: place and size of two DG for reducing losses.

Two DG	Reactive power(KVar)	Active power (KW)	location
DG.no.1	198.4772	418.9752	31
DG.no.2	154.9519	421.9295	25

Table6: system's scales for reducing the losses

Two DG	Voltage profile(pu)	Reactive power(KVar)	Active power (KW)
	0.9828	62.7218	102.4931

Table7: place and size of two DG to improve voltage profile.

Two DG	Reactive power(KVar)	Active power (KW)	location
DG.no.1	195.9902	434.3808	20
DG.no.2	164.6477	487.2687	16

Table8: system's scales to improve the voltage profile

Two DG	Voltage profile(pu)	Reactive power(KVar)	Active power (KW)
	0.9601	73.7392	115.4267

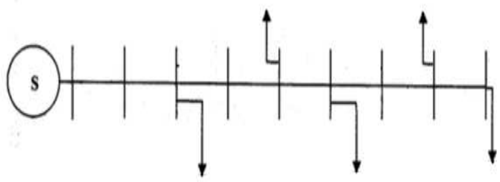

Figure1: single line diagram of radial distribution network

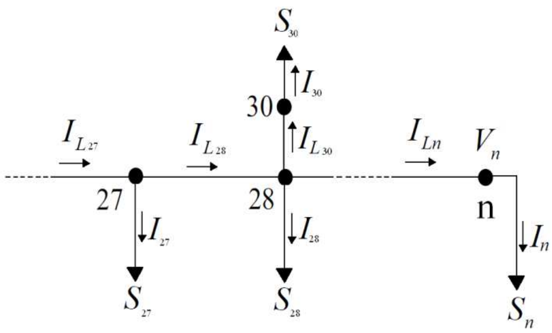

Figure2: down part of a distribution network

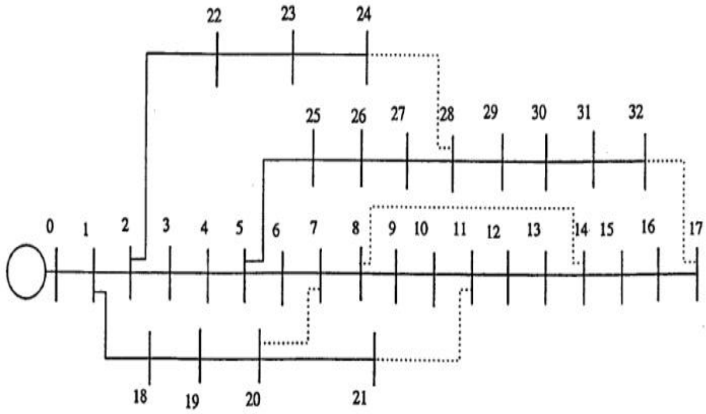

Figure 3: single line diagram of IEEE 33 bus.

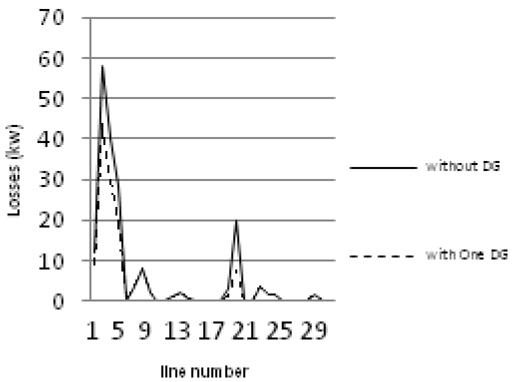

Figure 4: comparing active power losses with and without DG for reducing the losses

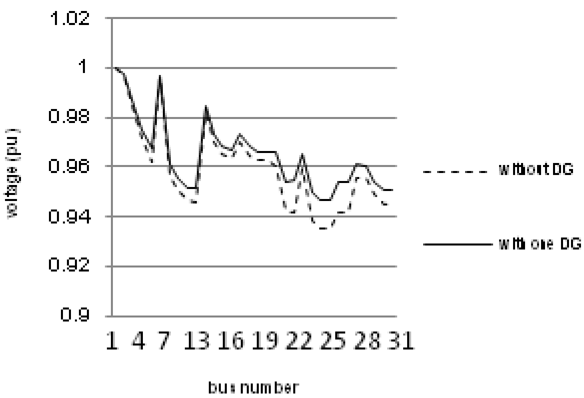

Figure 5: comparing voltage profile with and without DG for reducing the losses

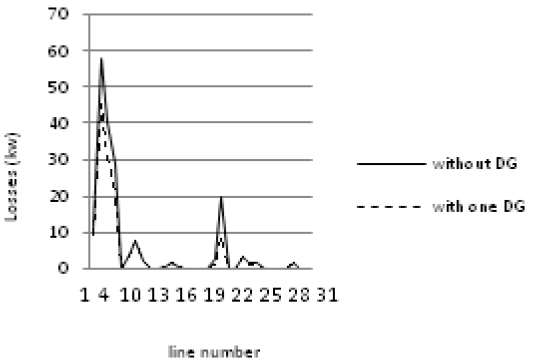

Figure 6: comparing active power losses with and without DG for improving the voltage profile.

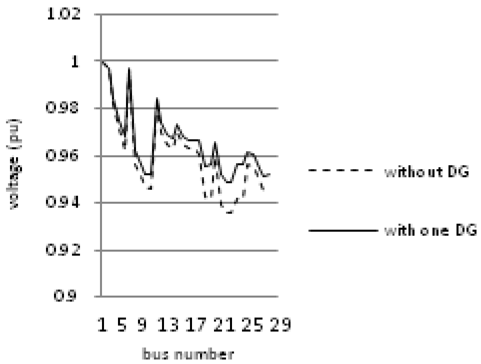

Figure 7: comparing voltage profile with and without DG for improving the voltage profile.

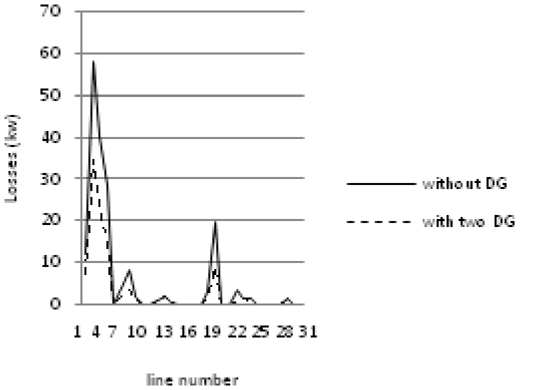

Figure 8: comparing active losses with two and without DG for reducing the losses.

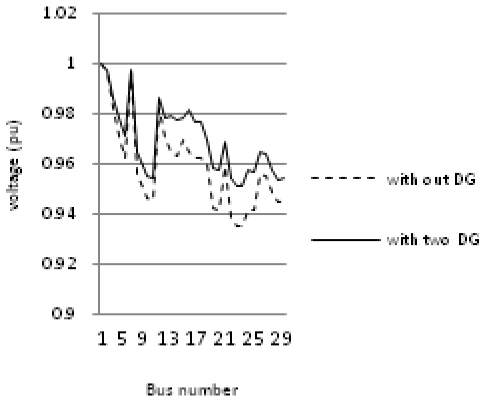

Figure 9: comparing voltage profile with two and without DG for reducing the losses.

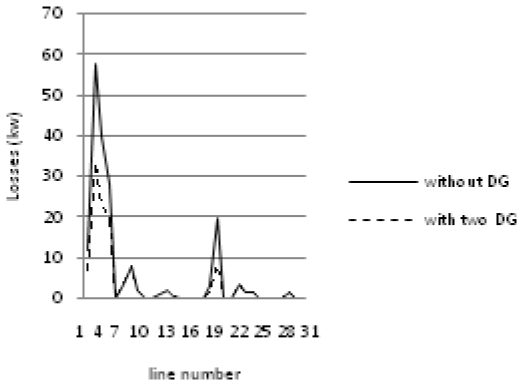

Figure 10: comparing active losses with two and without DG for improving the voltage profile.

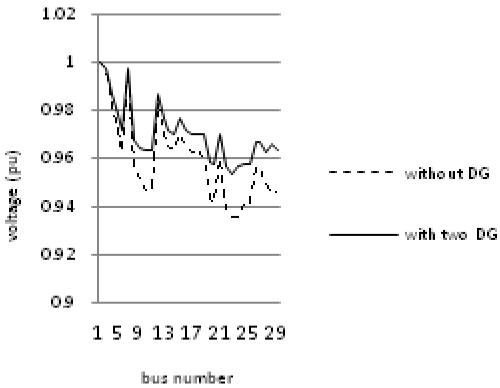

Figure 11: comparing voltage profile with two and without DG for improving the voltage profile.