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Optimal Placement of Distributed Generation Sources in Order to Reduce Loss and Improve Voltage Profiles in Power Distribution Networks Using Genetic Algorithms

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Abstract

In this paper, an optimal placement undertaken by the DGs in radial distribution system was presented and optimization parameters in determining the optimal placement of DG reducing losses and improving the increase of voltage profiles were reliable. To solve the problem, genetic algorithm with real codes and backward – forward power-flow method based on the distribution network was used. All cases were analyzed and calculated by the MATLAB programming software and on the IEEE 20-bus network. Finally, the losses with and without DG insertion were shown which confirmed we worked properly.

Keywords: voltage profiles of loss - distribution network - genetic algorithm

Introduction

Electricity generation and consumption of electrical energy initially started by applying small and dispersed sources such as rivers and small water turbines. The idea of distributed generation is an old idea to the late 19th century (Philipson, 1999). Soon, with the rapid development of power industry and manufacturing giant machines generating and receiving electricity, small and local power generators were changed into a few hundred megawatt power plant covering large numbers of consumers near and far from them. Now, after nearly a century of human utilization of electrical energy, to provide more welfare, the planners of electricity industry around the world have turned to the idea of distributed generation, and tried to miniaturize the volume of production centers and their covering production surfaces. In this paper, the DGs as an efficient way in providing energy needs of consumers are introduced. Using DG generators in distribution system brings about benefits for companies, electricity consumers and generally to the public. Reducing line losses, improving voltage profile, reducing emissions, improving safety and network reliability, improving power quality, distribution and transmission system capacity release, the postponement of investments for network expansion, improving productivity and increasing security for sensitive and important loads of distribution networks are the positive consequences of applying DG for manufacturers and network operators. Energy consumers also benefit the benefits of this technology. In this paper, photovoltaic systems, evaluation of loss reduction, voltage profile and minimizing pollutant index, and also genetic algorithms will be briefly explained. Finally, by designing the IEEE 20-bus network, the simulation of load distribution in the environment, a graph of reducing energy loss, reducing voltage loss, diagram of reducing pollution and network loss with and without DG are shown.

Photovoltaic systems

The phenomenon of generating electricity from light without using incentive mechanism is called photovoltaic system which is one of the most practical uses of renewable energy.

Reasonable current and voltage can be achieved by paralyzing solar cells and making them in series. Therefore, a set of cells in series and paralyzed is called photovoltaic. These cells are typically made of silicon material and required silica is prepared in sand found in abundance in deserts. So, in terms of supplying the raw material of these cells there's no shortage in Iran, but the process of making purified silicon cells silicon, is really expensive (El- khattam & salama, 2004). Solar panels, interfaces, and consumers are three main components of photovoltaic systems.

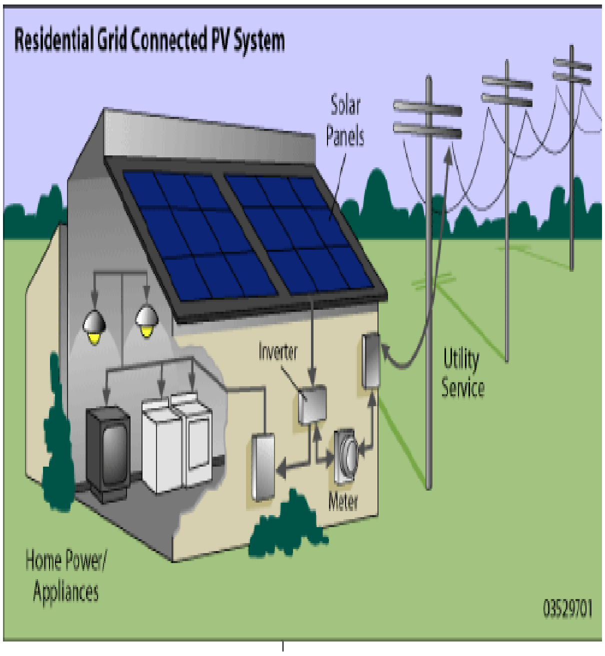

Figure 1: Overview of network-connected photovoltaic systems

Evaluation indices

In this paper, to evaluate the impact of the installation place and the installed capacity of generators on the network technical characteristics including voltage profile, network losses, and reducing emissions some indices are defined and their values were calculated and studied in different scenarios. In the following the indices will be introduced then by selecting the model network, and introducing different scenarios and modes, DGs performances in the network will be evaluated.

Reduction of power loss

One of the main reasons for the use of distributed generation in the network is that the place of production has gotten closer to the place of consumption resulting in reducing power loss. As a result, the possibility of on-site consumption, the power transmission substation and primary feeder buses get reduced and according to the selection of equipment, in also economically important. The target function for locating and determining the optimal size of DG to reduce power loss used in this paper is as follows.

$$F1 = PL = \sum_{i=1}^{N} Loss_k \quad (1)$$

Minimizing the power loss is the goal of the problem.

Provisions governing the issue as follows:

Balance constraint

$$\sum_{i=1}^{N} P_{DGi} = \sum_{i=1}^{N} P_{DGi} + P_i \quad (2)$$

Range of active and reactive power generated by

$$P_{DGi}^{min} \leq P_{DGi} \leq P_{DGi}^{max} \quad (3)$$

$Q_{DGi}^{min} \leq Q_{DGi} \leq Q_{DGi}^{max}$ (4)

Range of network losses

$\sum Loos_K(with\ DG) \leq \sum\ Loss_K(with\ out\ DG)$ (5)

PL: power loss

Pi: active power at the bus i.

Qi: the reactive power at the bus i.

Voltage profile improvement

In the distribution networks with radial structures, the most voltage drop happens in the end of the network (farthest). It should be noted that the more drop in voltage lines, the more voltage loss. Voltage profile in radial distribution networks in which there is no distribution generation is decreasing which means voltage near the source is close to a PU, and how far we get from the source, the voltage decreases which could have negative effects for consumers. The target function for locating and determining the optimal size of DG used to improve the voltage profile in this paper is as follows:

F2=$\sum_{i=1}^{N} |V_i - V_{i,ref}|$ (6)

Vi: voltage at the bus i.

Vi, ref: optimal voltage considered to a PU. Voltage range at the bus i.

$| \leq |V_i| \leq V_i^{max}$ (7)

Minimizing the emissions

General pure atmospheric such as SOx and NOx based on ton/h affected by fossil fuel thermal units is calculated as follows:

$E_t = \sum_{i=1}^{m} E_i(P_i) = \sum_{i=1}^{m} (a_i P_i^2 + B_i P_i + Y_i \text{€} \exp(9 Y_i P_i))$ (8)

$f_2(x) = E_{tfc} + E_{twind} + E_{t\,pv}$

$F_2(X) = \min(f_4(X))$

Introducing the proposed power-flow in the presence of DG

In distribution networks, power-flow is one of the important issues in most tasks relating to the network such as designing, developing, etc. Due to the magnitude and shape of the load flow in radial distribution networks, they have its own characteristics. The radial distribution network is a network that the whole buses are fed from the same source. In other words, there is only one path for power delivery for each of the loads. A simple radial network is shown in figure 2.

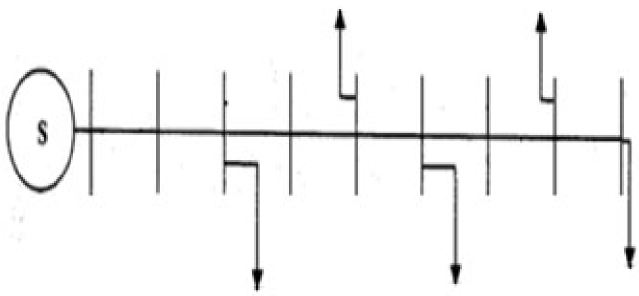

Figure 2. Typical radial distribution network

In the distribution networks, the most voltage drop happens in the end of the network (farthest). It should be noted that the more drop in voltage lines, the more voltage loss. Voltage profile in radial distribution networks in which there is no distribution generation is decreasing which means voltage near the source is close to a PU, and how far we get from the source, the voltage decreases (Peralta, 2007; Apoorvasaxena, 2008). The final power-flow method in this thesis is the forward-backward.

Forward-backward power-flow method

In this paper, forward-backward method was used for power-flow of radial distribution networks. This method is formulated as a set of duplicate equations from the look of power and voltage networks. In this method 1PU bus voltage is initially considered, and then by the help of following backward equations, power and voltage at each bus to the first bus will be measured by knowing the power of loads and values of the lines. Forward movement begins after the arriving the first bus which is the main bus. Since the voltage and angle of bus are determined on forward direction, the voltage of each bus to the final bus will be achieved by the help of equation 12 and from the powers obtained from backward direction. This process is repeated until obtaining the convergence.

$$P_{j-1}=P_j+r_j\frac{P_j'^2+Q_j'^2}{V_j^2}+P_{Lj} \quad (9)$$

$$P_{j-1}=P_j+r_j\frac{P_j'^2+Q_j'^2}{V_j^2}+P_{Lj} \quad (10)$$

$$P_{j-1}=P_j+r_j\frac{P_j'^2+Q_j'^2}{V_j^2}+P_{Lj} \quad (11)$$

$$Q_{j-1}=Q_j+x_j\frac{P_j'^2+Q_j'^2}{V_j^2}+Q_{Lj} \quad (12)$$

$$V_{j-1}^2=V_j^2+2(r_jP_j'+x_jQ_j')+(r_j^2+x_j^2)\frac{P_j'^2+Q_j'^2}{V_j^2} \quad (13)$$

$$V_{j+1}^2=V_j^2-2(r_jP_j+x_jQ_j)+(r_j^2+x_j^2)\frac{P_j^2+Q_j^2}{V_j^2} \quad (14)$$

In which:

$$P_j'=P_j+P_{Lj} \ , \ Q_j'=Q_j+Q_{Lj}$$

In systems with branching path, for each sub- track, the same procedure mentioned above is used except that the primary bus voltage is not 1pu. In fact, the obtained voltage from backward direction for the backward direction and forward direction for the forward direction is the criterion. Forward-backward process is repeated until obtaining the convergence on the direction. Convergence condition can be considered as follows:

1. There should be voltage differences between any buses of the forward and backward directions, so that the differences become smaller than the defining errors.
2. The PLoss differences of the forward and backward directions should be the smaller difference value than the defining error value.

The proposed algorithm

In this paper, genetic algorithm is used to achieve optimal response. This approach modeled by the principles of natural evolution of genes is based on more chances for selecting members with higher target function (Sedighizadeh &.Rezazadeh, 2008). Due to the flexibility of its implementation on various networks, good convergence rate, reducing the computational side, good capability to find absolute optimal and different ways to encode, genetic algorithm was used. Genetic algorithms begin with initial population composed of early chromosomes, and then according to the limitations and restrictions with respect to the subject matter and target function, the fitness of each chromosome is evaluated. . Then for production of the next generation of the crossover operator (combination of two parents sequences) and mutation (random changes to one or more sequences) is performed and the new offspring are produced. This process continues to a halt conditions and optimal algorithm response (Mithulananthan & Acharya, 2007; Kaymaz, Valenzuela, and Park, 2007). Optimal positioning is given in the flowchart below:

Numerical studies and simulation results

Network Introduction

In order to evaluate the proposed network method, the distribution of 20-bus test was simulated. Figure 3 and 4 are linear diagrams of the network. Basic values of system were considered as 20 KV and 20 MVA. This network is made up of 20 distribution transformers with different buses. Transformers' details are shown in table. The details of distribution conductors are shown in table 2. The length of each feeder is shown in table 3, and connected load of transformer is shown table 4.

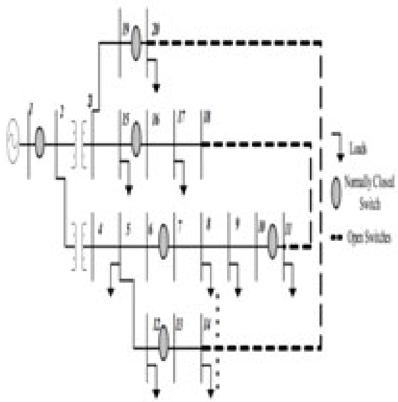

Figure 4: Test network of 20-bus sample

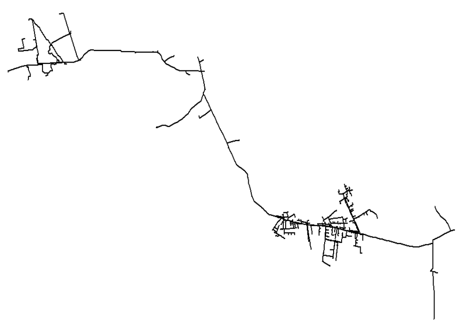

Figure 5: Single- line diagram

Table 1: Transformer details

Rating [KVA]	50	100	250
Number	5	9	6
No load losses [watts]	150	250	480
Impedance [%]	4.5	4.5	4.5

Table 2: Conductors details

Type	R [Ω/Km]	X [Ω/Km]	Cmax [A]	A [Mm2]
Hyena	0.1576	0.2277	550	126
Dog	0.2712	0.2464	440	120
Mink	0.4545	0.2664	315	70

Table 3: The length of feeders

From	To	Length (Meters)
1	2	80
2	3	80
3	4	80
4	5	60
5	6	60
6	7	60
7	8	60
8	9	60
9	10	60
10	11	60
11	12	60
12	13	60
13	14	60
14	15	60
14	16	60
16	17	60
17	18	60
18	19	60
19	20	60

Table 4: Connected loads of transformers

Transformer No	Load [Kva]
1	35
2	245
3	85
4	165
5	50
6	85
7	180
8	35
9	35
10	90
11	85
12	75
13	200
14	73
15	35
16	85
17	98
18	230
19	220
20	85

Simulation software

In order to implement the proposed algorithm some computer programs written in the environment of MATLAB software were applied.

Simulation result

Locating optimal PV sources considering the cost per unit

According to khosravi (2014), there are no size constraints for PV sources and with respect to the number of plates installed and the available inverters different powers can be achieved.

Optimal positioning of these sources with certain target function is done in equation (4-5) with the help of genetic algorithms.

$$\text{Objective Function} = 15\, P_{Loss,all} + 10 \sum_{Bus} (V_b - V_i)^2 + Cost\,(PV) \quad (15)$$

$$Cost(PV) = P_{PV} * 1000(\frac{\$}{KW}) + 0.4(P_{PV} * 1000(\frac{\$}{KW})) \Big/ Cost(S_b) \quad (16)$$

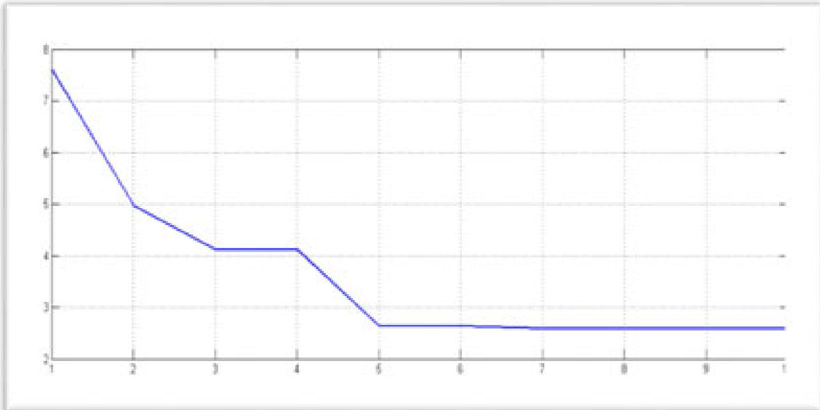

Figure 6: Movement of the target function to locating optimal sources in the process of convergence of solving problem PV

Table 5: Conditions of active and reactive power at selected buses

Bus type	**Reactive power (kvar)**	**Active power (KW)**
2	- 2.260	953.080
5	553.400	122.530
9	-135.760	709.020
12	285.500	560.880
18	535.010	553.280

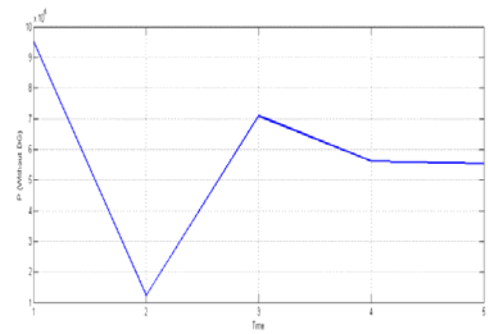

Figure 7: The values of active power without applying DG

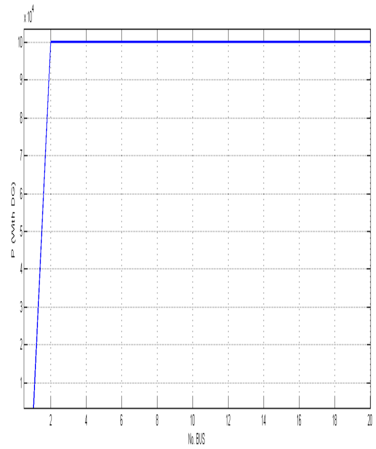

Figure 8: The buses active power optimality after installing DG

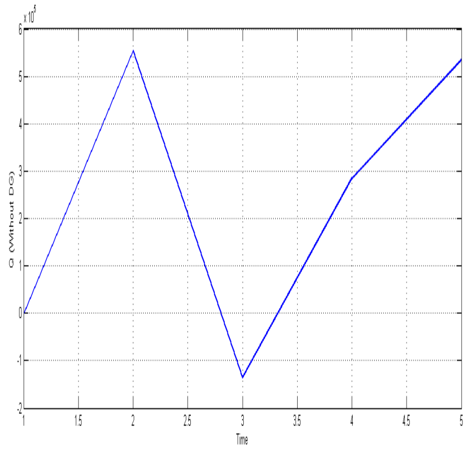

Figure 9: The values of reactive power without applying DG

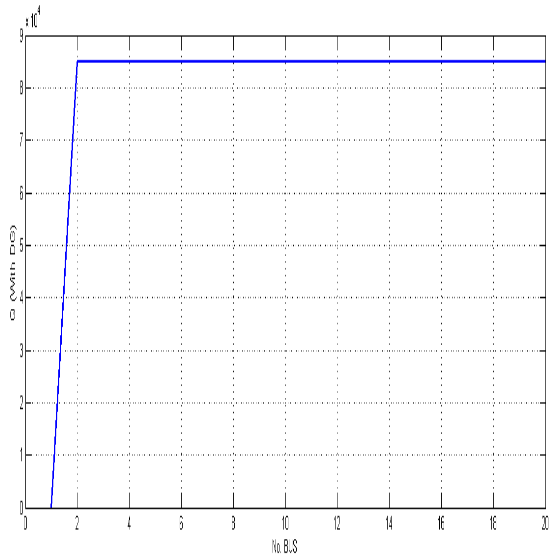

Figure 10: The buses reactive power optimality after installing DG

Calculating the reliability of the system under study

Radial distribution system is composed of a series of equipment including lines, cables, breakers (or separators) bus bar, etc.

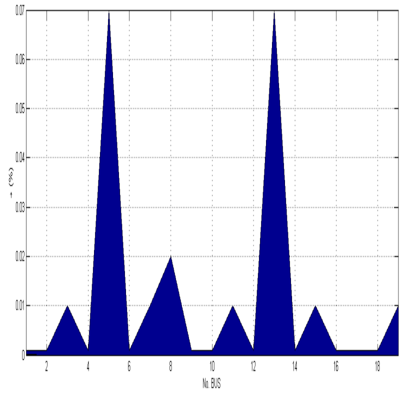

Figure 11: Failure rate curve of distribution network under study

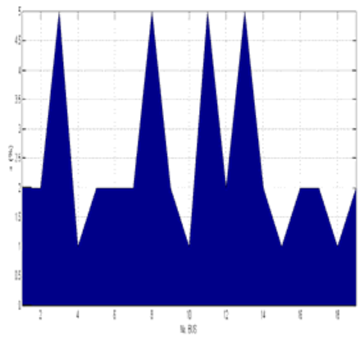

Figure 12: Outage time curve of distribution network under study

The installation of distributed generation sources to reduce pollution

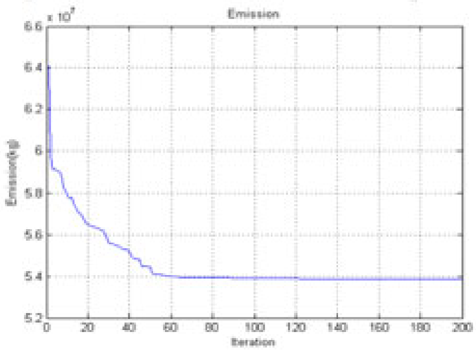

Figure 13: Diagram of reducing pollution in distribution networks with DG

A consumer attached to any point in the system needs all of the equipment between themselves and the power supply of operating point. The three main parameters of the reliability-the average failure rate λS, average outage time rS, and the US average annual outage time are as follow:

$$Y_s = \sum_i Y_i \quad (17)$$
$$U_s = \sum_i Y_i r_i \quad (18)$$
$$r_s = \frac{U_s}{Y_s} = \frac{\sum_i Y_i r_i}{\sum_i Y_i} \quad (19)$$

Convergence of the genetic algorithm in order to reduce losses

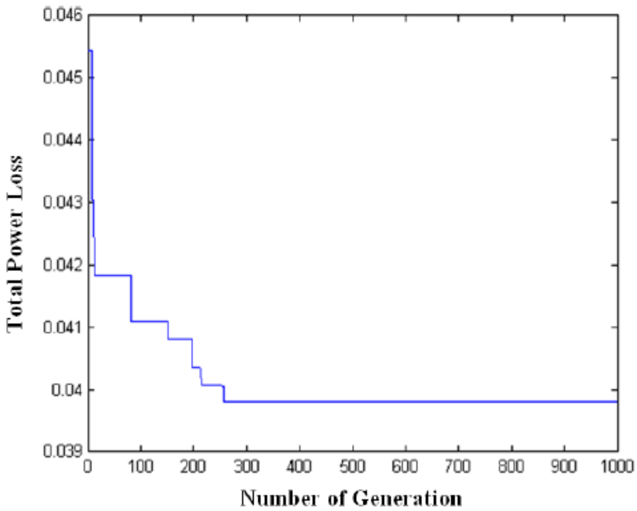

Figure 14: Convergence of the genetic algorithm with the objective of finding the optimal DGs

Comparing the total losses in the network with and without the use of DG

The total losses in the case of using DG in compare to without DG in the same intake bus, was reduced about 13 times. The results of table 7 show that the use of distributed generators has an important role in the losses of entire system which is very better and economical for system proper function in different working conditions.

Table 6 : Comparison of the losses with and without using the DG

losses without DG (KW)	losses with DG (KW)
1.0736×103	84.4297

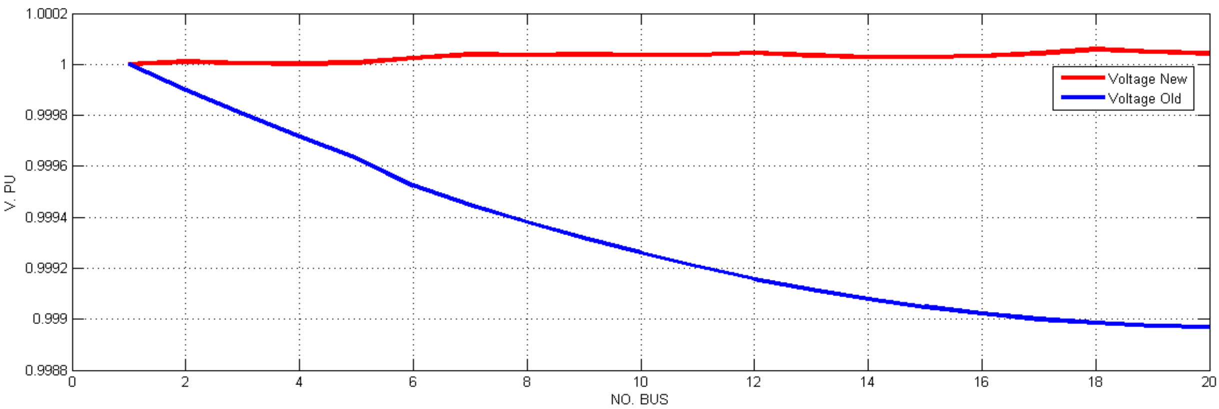

Figure 15: The losses in the case of using DG in compare to without DG in the network under study

Conclusion

Due to the development of power systems on the one hand, and interest in the use of clean energy on the other hand, the use of DGs has been increased day by day. DGs are utilized by connecting to the power network and separately. Benefits such as peak shaving , improving network reliability , reducing power transmission losses , improving voltage profile , reduction in the density of lines , privatization of power generation and etc., caused the DGs to be used more by connecting to the network (Parnandi & Choudhry, 2007). All the above benefits are associated to the DG installed in the appropriate location and optimized size of the network, otherwise it has negative consequences. In this paper, renewable sources of distributed generation (photovoltaic) were calculated and positioned by using genetic algorithm in a 20-bus distribution network aimed at minimizing the target functions of the problem (power, pollution and voltage) and increasing the reliability. The proposed genetic algorithm indicated that the use of renewable sources of distributed generation in distribution networks in addition to improve system parameters such as voltage profile and power losses can save on electricity costs. Finally, in the last section, the losses were considered in the two cases, with and without DG, in which the total losses in the case of using DG in compare to without DG in the same intake bus, were reduced about 13 times. This result shows the use of renewable resources is crucial to reduce pollution.

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