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The Effect of Optimal Placement of Distributed Generation Units on Voltage Profile Considering Faults in the Network

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ABSTRACT: Recently, there has been great interest in the integration of Distributed Generation units (DG) at the electric distribution network. The foreseeable large use of DG in the future requires the electrical distribution network planners to properly take into account its impact in the distribution network planning. Distributed generation units are widely used for power loss reduction, voltage profile improvement and increasing the reliability of distribution network. Having no attention to appropriate site and size of DG may result in loss of aforementioned advantages. Many different methods are proposed to solve the problem of finding optimal location and size of DG, however, this problem become more complicated in the presence of network faults. This paper proposes a novel method for determining the location, size, and type of DG considering network faults to improve the voltage profile. Cumulative voltage deviation is used to investigate changes in the voltage profile. PSO algorithm is employed to achieve an optimal solution for this problem. With a numerical example on unbalanced IEEE 36 bus system as a test case, the superiority of the proposed algorithm is demonstrated. The effects of faults, DG placement, and simultaneous effect of faults and DG in this network are analyzed.

Keywords: Electrical distribution network, Distributed generation, Voltage profile, PSO

INTRODUCTION

Recent advances in distributed generations' technology have taken attentions toward them. Large power plants are located in the areas far from load centers, however, main advantage of DGs units are that they are located near the load centers (consumers) leads to reduce development costs of transmission lines. DGs are directly connected to either distribution networks or to the consumers. DGs can be of renewable or non-renewable energy sources (Ackerman et al., 2000; Srivastava et al., 2012; Moradi and Abedini, 2012; Borges, 2012; Zangiabadi et al., 2011).

Despite many advantages of distributed generation sources, there are some drawbacks for these sources such as problems associating to protection coordination, complexity of control and operation of network, harmonic issues, voltage and frequency problems, and network security. For simplicity, electrical distribution system is considered to be radial in operation. Radial distribution systems are fed from single feeder, and power flow is unidirectional. Distributed generation integration makes distribution system to have bidirectional (or more) power flow (Moradi and Abedini, 2012; Atanasovski and Taleski, 2011).

To achieve the benefits of DG, they must be coordinated with distribution system and they should be installed with proper size in the right location. Many studies have been conducted to find the appropriate size and location of DG. (Moradi and Abedini, 2012) used a hybrid method of GA and PSO is presented to find the optimal location and size of DG in distribution system. In this paper genetic algorithm is used for siting of DG, and PSO algorithm is used for sizing of DG. The paper aims were to reduce losses, improve voltage stability and voltage regulation. The drawback of the proposed method is high computation time compared with each of the two algorithms (GA and PSO). Also the authors have not mentioned the type of DG. (Kotamarty et al., 2008) studied the effect of the size and location of existing DG in the network is analyzed on the network circumstances. The effect of size and location of DG is studied on voltage profile. An unbalanced load flow program is used to find the location and size of DG. The effect of DG and the faults on unbalanced system nodes are not included in results. (Singh et al., 2007) worked on the effect of different types of loads for DG planning in the distribution network. It is shown that the load models have influence on reaching the appropriate size and location of DGs. In this paper, the effect of DG on different parameters such as ILP (active power index), ILQ (reactive power index), and IVD (voltage profile index), have been studied. The proposed method has been tested on a 38 bus test system, and it was shown that considering fixed model for load in DG placement cannot be useful for a system with different load models. Also, it is obvious that power loss is reduced with the integration of DG. It has been found that inappropriate size and location of DG leads to violation of nodes constraints. There were no remark on DG types and the impact of load models on the voltage of nodes. (Ghosh et al., 2010) presented an approach using Newton-Raphson's method was used for optimal placement of DG to achieve maximum profit. The aim of paper is to simultaneously reduce the power loss and DG investment cost. Weighting coefficients are used for the optimum balance between cost and loss, also to achieve the maximum profit. The work was tested on 6, 14 and 30 buses test systems. Further, a comparison has been done between the results obtained from the proposed method and the results of the Power World Simulator software. The results reveal that appropriate DG placement improve voltage of buses and reduce losses. (Borges and Falcao, 2006) did optimal placement of DG is conducted using genetic algorithms to reduce losses, increase reliability and improve voltage of distribution systems. Here, an approach is proposed to reach maximum profit by reducing power losses and investment cost. In this method, objective function is managed in way such that the maximum profit is achieved by DGs placement (due to the power loss reduction, reliability increase and voltage profile improvement) and investment as well as maintenance cost of DG. (Acharya et al., 2006) presented an analytical method for the placement of DG. In this paper, sensitivity factor is introduced to reduce candidate points for DG installation. Further, a method is proposed to decrease performed computation. The main objective is to reduce power loss, and the proposed method is tested on some test systems. (El-Zonkoly, 2011) used a hybrid objective function is presented to find the location and size of DGs. In this method, different models have been considered. The objective function is a combination of indices corresponding to the active and reactive power, loss and voltage profile as well as MVA capacity of conductors. The PSO algorithm is used to solve the objective function and find optimum solution. The proposed method has been studied on the typical 38 bus radial test system. The results of the proposed method are compared with the results of GA. Based on the obtained results; it was shown that the proposed method achieves better solution requiring less computation time. Also, according to the results, it is apparent that DG placement results in reducing losses and improving voltage profile.

In this paper, finding the optimum size, location and type of DG to achieve optimum voltage profile with respect to the faults in the network is performed by PSO algorithm. To investigate the effect of aforementioned parameters on the voltage profile, the cumulative voltage deviation is used. In addition, all nodes' voltage in an unbalanced three-phase network is regulated before and after faults such that all voltages are in desirable range. In spite of fault occurrence, the voltages of nodes are not violated, because by fault occurrence it is possible that some voltages of nodes are sharply increased due to the load decrease which inappropriate DG placement intensifies this phenomenon.

The rest of paper is organized as follows: in Section 2, problem formulation is presented. PSO algorithm is discussed in Section 3. Section 4 presents DG types and models. In Section 5, implementation of the proposed method is presented on a typical distribution system and the results are presented. Finally, conclusion is presented in Section 6.

Problem Formulation

Most of distribution systems normally operate with one energy source and in unidirectional fashion. With the integration of DG, changes are occurred in the radial configuration and power flow of distribution systems. Power flow is changing with the change of location, size and type of DG as well as load model. Location and size of DG may be changed after faults occurrence and load changes. In this paper, the study has been conducted on voltage profile. Also, the impact of faults on DG size and location as well as DG types is analyzed. PSO algorithm is used to reach proper voltage profile. It was also shown that the type of DG (PV or PQ) has different effects on network performance, and DG type is selected according to the network conditions.

Objective Function

Results are examined for system using cumulative voltage deviation norm for node (CVD) as follows (Kotamarty et al, 2008)

$$\mathrm{CVD} = \frac{\sum_{n=1}^{k}|v_n - 1|}{k} \quad \text{without fault} \tag{1}$$

$$\mathrm{CVD} = \frac{\sum_{n=1}^{k}|v_n - 1|}{k - n_r} \quad \text{with fault} \tag{2}$$

Where,
V_n: positive sequence of voltage in nth node
k: number of nodes in each feeder
n_r: number of nodes interrupted due to network faults
The more this criterion is decreased, the optimum is the location of DGs and the appropriate is the system voltage profile.

Constraints

Voltage limitation

Since DG allocation is performed in the presence of network faults, voltage limitation is of great importance, in other words lacking this limitation may be harmful to the network and costumers. Then,

$$V_{min} < V_n < V_{max} \tag{3}$$

V_n: nth node voltage
V_{min} and V_{max}: minimum and maximum voltages
Usually, ±5% base voltage is considered for upper and lower boundaries.

Current limitation

Due to the thermal constraints, current flows through feeders cannot exceed acceptable amount.

$$I_k \leq |I_k^{max}| \tag{4}$$

In this paper, the effect of DG placement and occurred faults in network are analyzed on unbalanced network nodes' voltage, and each phase voltage is calculated as V_a, V_b and V_c.

Fault Effect

This paper discusses the effect of fault when part of network load is interrupted due to the fault occurrence in network. For instance, when a fault is occurred in line 703-727 of a typical distribution system as shown in Fig.1, the nodes of 728, 744, 727 and 729 are interrupted. In Table 1, interrupted nodes due to faults in various lines for typical system are given.

Table 1. Fault effect on 36 bus system

Fault	Interrupted nodes
720-704	706,720,707,724,722,725
727-703	729,727,744,728
710-734	710,736,735

PSO Algorithm

Original PSO Algorithm

This optimization technique was first proposed by Eberhart and Kennedy (Kennedy and Eberhart, 1995). This algorithm is inspired by the swarm movement of bird flock looking for food. PSO algorithm is initiated by a group of random solutions (particles). Then, to find the optimal solution the search space is explored by updating generations. The main reason for suitability of PSO is its simplicity which has only two equations. In PSO, each particle coordination indicates a feasible solution has two vectors of position (S_i) and velocity (V_i). In each state of swarm movement, each particle is updated by two best quantities. First is personal best called p_best, other is global best obtained by swarm called g_best (Abdelaziz et al., 2005; Amraee et al., 2007). Each particle is updated using following equations:

$$V_i^{k+1} = w * V_i^k + C_1 * \mathrm{rand} * (p_{best_i\_}S_i) + C_2 * \mathrm{rand} * (\mathrm{g\_best} - S_i) \tag{5}$$

$$S_i^{k+1} = S_i^k + V_i^{k+1} \tag{6}$$

V^k_i: ith particle velocity in iteration k.
rand: a random number in [0, 1].
S^k_i: ith particle position in iteration k.
C_1 and C_2: acceleration coefficients of particles in [0, 2]. Their values are considered to be same (C_1=C_2).
p_best_i: best individual position of ith particle
g_best: best global position of particles
w: weighting inertia.

Weighting inertia in improved PSO

To prevent the algorithm from diverging, final velocity of each particle is restricted in $V_i \in [-V_{max}, +V_{max}]$. If V_{max} is too large, the particles may go far away from the best solutions, while if it is too small, particles may not find best local solutions. Based on former experiences, constants C_1 and C_2 are set to 2. Proper selection of inertia weight, w, provides a balance between local and global identification. Therefore, in this paper, the value of w is linearly decreased from 0.9 to 0.4 throughout run to be fast in initial state and slow near optimal solution. w is, typically, expressed by the following equation:

$$w = w_{max} - \left(\frac{w_{max} - w_{min}}{iter_{max}}\right).iter \qquad (7)$$

w_{min}: minimum weighting inertia
w_{max}: maximum weighting inertia
$iter_{max}$: maximum number of iterations
iter: current iteration number

DG Type

DG are modeled regarding reactive power generation in two ways:
-PV
-PQ

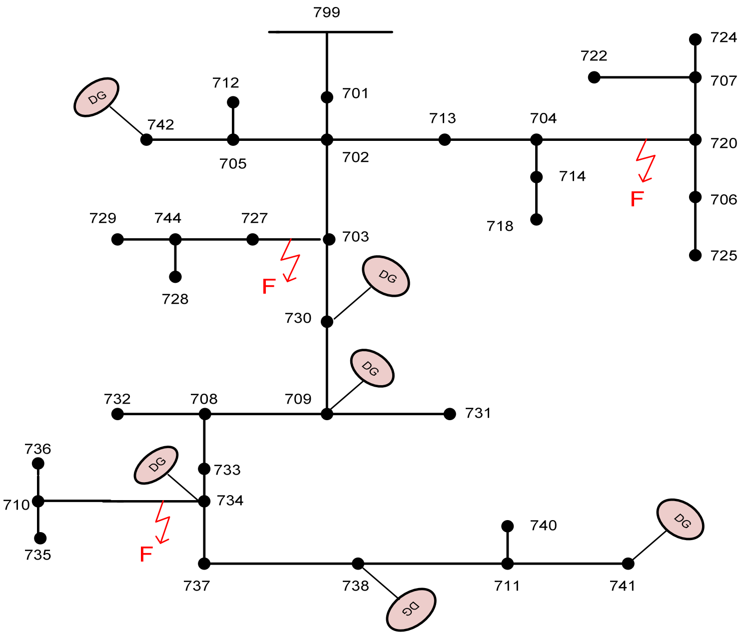

Figure1. Typical unbalanced IEEE 36 bus system

PV Model

In this model, the generator has a fixed voltage with a given phase angle. In this type of model, generating source should maintain bus voltage amplitude within the acceptable range. It is possible when the DG source is able to generate reactive power of consumer loads connected to the bus.

PQ Model

In this model, a constant active power is injected into the network and also a constant reactive power delivered/absorbed to the network. Therefore, DG supplies part of the active and reactive power of network.

Usually, due to the small capacity of distributed generation sources, a large part of the generating capacity of these generators are allotted to supply the active power (less reactive power inserted into the network) such that the use of these resources should to be economically viable, and to supply reactive power, other sources of reactive power such as capacitor or other compensating power equipment is used.

Implementation of Method on a Typical System

The goals of the paper are tested on IEEE 36 bus test case (IEEE PES Test Feeders). The schematic diagram of the system, the location of DGs, and the location of the faults are depicted in Fig. 1. Faults locations are randomly selected. The effects of location, type and size of DG are analyzed in three cases of faults occurrence and before faults. In this study, backward - forward sweep is used for power flow.

Location of faults in three parts of typical system is illustrated in Fig. 1. These faults are occurred in lines 720-704 or 727-703 or 710-734. For example, when a fault occurs in line 727-703, nodes of 727, 744, 728 and 729 are disconnected from the network. DGs have been located in the candid points. These candid points are 724,709,734,741,738 and 730. The sizes of DGs are in accordance to the total load determined from 10 to 70 percent of the total load.

The aim is to reduce CVD using PSO algorithm. It was mentioned earlier that the more decreased this criterion, the more improved the voltage profile index. The process of implementing optimization of voltage deviation begins as follows: first, power flow module is performed and CVD is calculated using Eqs. (1) and (2). In the first generation of PSO particles, location, size, and type of DGs are produced randomly. Then the load flow program is run and network constraints are checked. If network constraints are violated, the location and size are removed from the list of solutions; otherwise, CVD is calculated. After the initial generation and recording the fitness levels, or the g_best and the p_best, are calculated using Eqs. (5) and (6). Then if the iterations reach a specified number, g_best is selected and the location, type and size of DGs are presented. Otherwise, it is repeated until the maximum number of iterations is satisfied. Implementation process flowchart is depicted in Fig. 2.

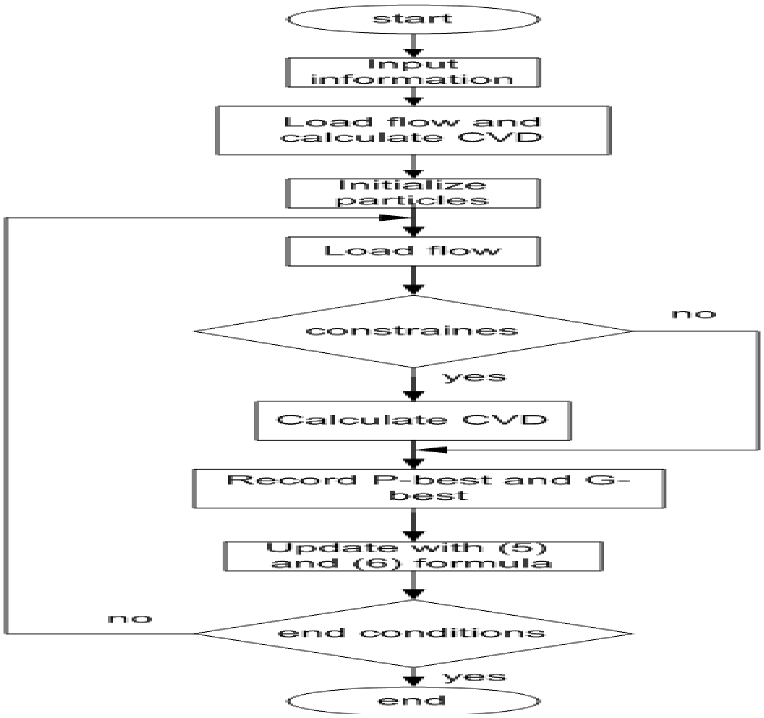

Figure 2. Flowchart of implementation method

Simulations are carried out using MATLAB software. The results are obtained after 20 times running. Results are presented in four different cases: 1) without faults and without DGs, 2) with faults and without DGs, 3) without faults and with DGs, and 4) with faults and with DGs. In each case, CVD and voltage of all nodes are obtained. Finally, the comparisons were done for these cases.

Case one: system without Faults and DGs

The first study was performed on the IEEE 36 bus system without faults and DGs placement. Based on the obtained results in this case, cumulative voltage deviation is 2.2356. Voltages of nodes in this case are given in Table 2. Fig. 2 illustrates the diagram of nodes' voltages.

It can be seen from the obtained results in Table 2 that the minimum voltage of nodes is for node 740 at the end of the feeder (see Fig. 1). It is observed that the lowest voltage for buses at the end of the feeder is even lower than the acceptable voltage value (-5%) indicating poor condition of buses voltage at the end of the feeder. So, in the case that there is no DGs in system, voltage of nodes decreases toward the end of the feeder, this can affect consumers feeding from these points. This situation is obvious in Table 2 and Fig. 2.

Case two: system with Faults and without DGs

In this case, it is assumed that a fault has been occurred in system in the line 704-720 and DGs not integrated into the system. The cumulative voltage deviation is 1.9130. By comparing this value with the value obtained in case one, it is clear that CVD is decreased by 1.17. This is because a part of system load is interrupted due to the fault. By occurring faults, changes are created in nodes' voltages. Bus voltages, in this case, are given in Table 3. Fig. 3 depicts nodes' voltages. According to the Table 3, the minimum node voltage is for node 740 which is same as to the case one; however, its value is decreased from 0.9397 to 0.94.

Table 2. Bus voltages in case without faults and DGs

No.	bus	V_a	V_b	V_c
1	799	1.0000	1.0000	1.0000
2	701	0.9964	0.9984	0.9955
3	702	0.9915	0.9964	0.9909
4	713	0.9897	0.9917	0.9868
5	704	0.9879	0.9872	0.9843
6	714	0.9865	0.9862	0.9842
7	718	0.9858	0.9861	0.9841
8	720	0.9871	0.9832	0.9820
9	706	0.9870	0.9824	0.9819
10	725	0.9870	0.9811	0.9819
11	707	0.9863	0.9786	0.9812
12	724	0.9863	0.9782	0.9812
13	722	0.9856	0.9743	0.9804
14	705	0.9911	0.9957	0.9883
15	742	0.9908	0.9951	0.9883
16	712	0.9910	0.9957	0.9857
17	703	0.9872	0.9960	0.9881
18	727	0.9830	0.9945	0.9854
19	744	0.9804	0.9935	0.9844
20	729	0.9790	0.9934	0.9843
21	728	0.9790	0.9922	0.9831
22	733	0.9776	0.9944	0.9815
23	709	0.9697	0.9928	0.9750
24	731	0.9697	0.9923	0.9749
25	708	0.9620	0.9917	0.9685
26	732	0.9619	0.9917	0.9672
27	733	0.9543	0.9907	0.9629
28	734	0.9484	0.9897	0.9574
29	710	0.9482	0.9894	0.9547
30	736	0.9482	0.9890	0.9547
31	735	0.9481	0.9894	0.9521
32	737	0.9426	0.9892	0.9545
33	738	0.9399	0.9889	0.9517
34	711	0.9398	0.9887	0.9491
35	741	0.9397	0.9887	0.9477
36	740	0.9397	0.9886	0.9473

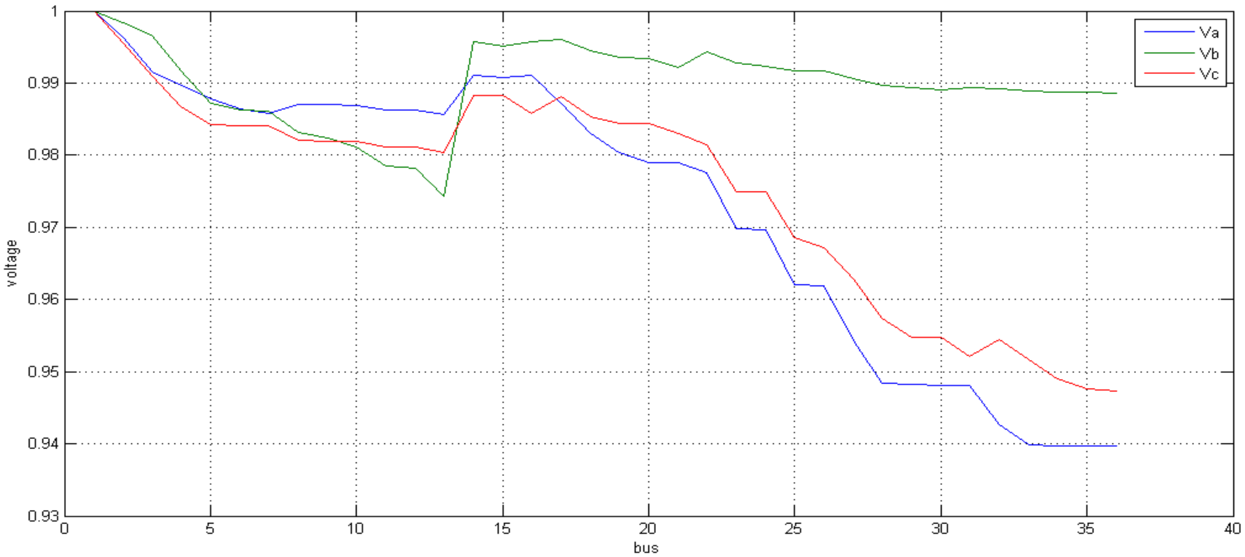

Figure 2. Bus voltages diagram in case without faults and DGs

Table 3. Bus voltages with a fault in line 720-704 and without DGs

No.	bus	V_a	V_b	V_c
1	799	1.0000	1.0000	1.0000
2	701	0.9966	0.9991	0.9960
3	702	0.9919	0.9984	0.9920
4	713	0.9908	0.9976	0.9902
5	704	0.9898	0.9970	0.9900
6	714	0.9884	0.9960	0.9899
7	718	0.9877	0.9959	0.9898
8	720	F	F	F
9	706	F	F	F
10	725	F	F	F
11	707	F	F	F
12	724	F	F	F
13	722	F	F	F
14	705	0.9914	0.9977	0.9894
15	742	0.9911	0.9970	0.9894
16	712	0.9913	0.9977	0.9869
17	703	0.9875	0.9980	0.9893
18	727	0.9834	0.9965	0.9866
19	744	0.9807	0.9955	0.9855
20	729	0.9793	0.9954	0.9855
21	728	0.9793	0.9941	0.9842
22	733	0.9779	0.9963	0.9827
23	709	0.9701	0.9948	0.9761
24	731	0.9700	0.9943	0.9760
25	708	0.9623	0.9937	0.9697
26	732	0.9623	0.9937	0.9684
27	733	0.9546	0.9926	0.9641
28	734	0.9487	0.9917	0.9585
29	710	0.9486	0.9913	0.9559
30	736	0.9485	0.9910	0.9559
31	735	0.9485	0.9913	0.9532
32	737	0.9430	0.9912	0.9557
33	738	0.9402	0.9909	0.9529
34	711	0.9401	0.9907	0.9502
35	741	0.9401	0.9907	0.9489
36	740	0.9400	0.9906	0.9485

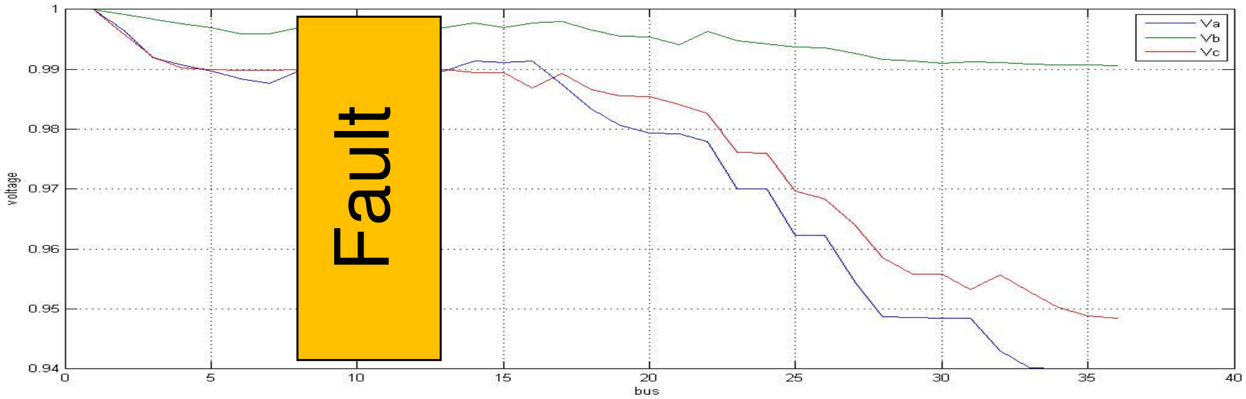

Figure 3. Bus voltages with a fault in line 720-704 and without DGs

Case three: system without Faults and with DGs

In this case, DGs placement is done. Table 4 presents the location, size and type of DG obtained by the proposed method. In this case, it is assumed that there is no fault in the system. The cumulative voltage deviation is 0.9866.

Table 4. location, size and type of DG in the case three

DG size	20% of total load size
DG place	709
DG type	PV

Table 5. Bus voltages in third case

No.	bus	V_a	V_b	V_c
1	799	1.0000	1.0000	1.0000
2	701	0.9985	1.0003	0.9977
3	702	0.9971	1.0016	0.9965
4	713	0.9952	0.9969	0.9924
5	704	0.9934	0.9923	0.9899
6	714	0.9920	0.9914	0.9898
7	718	0.9913	0.9913	0.9897
8	720	0.9926	0.9884	0.9876
9	706	0.9926	0.9876	0.9876
10	725	0.9925	0.9863	0.9876
11	707	0.9919	0.9838	0.9869
12	724	0.9918	0.9834	0.9869
13	722	0.9911	0.9794	0.9861
14	705	0.9967	1.0009	0.9939
15	742	0.9963	1.0002	0.9939
16	712	0.9965	1.0009	0.9914
17	703	0.9962	1.0045	0.9972
18	727	0.9921	1.0030	0.9945
19	744	0.9894	1.0020	0.9935
20	729	0.9880	1.0019	0.9935
21	728	0.9880	1.0006	0.9922
22	733	0.9973	1.0136	1.0014
23	709	1.0000	1.0000	1.0000
24	731	0.9999	0.9995	0.9999
25	708	0.9923	0.9989	0.9937
26	732	0.9923	0.9989	0.9924
27	733	0.9847	0.9979	0.9882
28	734	0.9789	0.9970	0.9828
29	710	0.9787	0.9966	0.9802
30	736	0.9787	0.9962	0.9802
31	735	0.9786	0.9966	0.9776
32	737	0.9732	0.9965	0.9799
33	738	0.9706	0.9962	0.9772
34	711	0.9705	0.9960	0.9746
35	741	0.9704	0.9960	0.9732
36	740	0.9704	0.9959	0.9729

By DG placement, changes created in the voltage of nodes as given in Table 4. Nodes' voltages are shown in Table 5. Fig. 4 depicts the nodes' voltages diagram. According to the obtained results, it is obvious that installing DG on bus 709 with 20% of total load size and of PV type leads to reduction of CVD from initial value of 2.2356 to 0.9866. This amount is reduced by 2.66 and 1.96 in comparison to the first and second cases, respectively. This clearly shows that with appropriate DG integration into the system, cumulative voltage deviation is decreased and voltage profile is improved. Comparing Tables 2 and 5 results reveals that by the DG integration, nodes' voltages are improved. In addition, the minimum voltage at node 740 has increased from 0.9393 in first case to 0.9704 in the third one. Also, according to Fig. 4 and Table 5, it is found that, by DG integration, in spite of increasing nodes' voltages, none of them not exceed the acceptable limit. It illustrates the positive effect of DGs placement.

Case four: System with Fault and with DGs

In this case, it is assumed that a fault is occurred in system. Here, size and location of DGs should be determined such that the voltages of nodes not violate acceptable range, since by fault occurrence a part of system load is interrupted resulting in increase of some nodes' voltages. Inappropriate DGs placement may worsen such condition and increase the voltages in turn damage system and consumers.

Fault location in network and DG's size and location to have best CVD and proper values for remaining nodes' voltages after fault are determined using PSO. The obtained results for location, size and type of DG to have minimum CVD and voltage profile are given in Table 6. According to the results, the best state is when a fault occurred in line 704-720. When a fault is happened in line 720-704, buses 707, 725, 706, 720, 724 and 722 are interrupted. By DG installation as presented in Table 6, with expected faults, all nodes' voltages are kept in acceptable range. The minimum CVD is realized if the fault is in a distinguished line in Table 6.

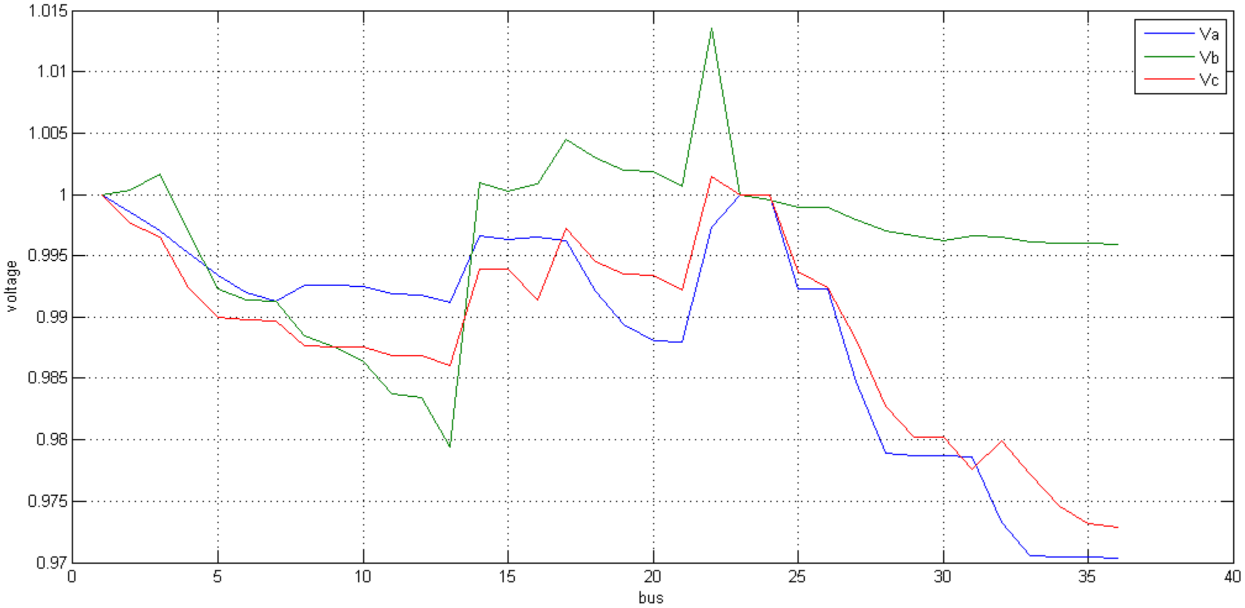

Figure 4. Bus voltages in third case

Table 6. Location, size and type of DGs, and fault location in fourth case

DG size	20% of total load size
DG place	734
DG type	PV
fault	704-720

According to the obtained results, CVD is 0.5916 which is less than other cases. This amount is reduced by 3.77, 3.23 and 1.66 in comparison to the first, second and third cases, respectively. This indicates voltage profile improvement. Results obtained for nodes' voltages and diagram of voltage profile after fault are shown in Table 7 and Fig. 5, respectively. The least voltage value is for nodes 744 and 729 at 0.9884 which is more than corresponding values in other cases.

By comparison nodes' voltages in this case with the previous ones, it is obtained that remaining nodes' voltages are increased due to fault occurrence and integration of a DGs with appropriate size, type and location. Another important issue is that DGs integration should not cause nodes' voltages to violate acceptable range. DGs integration with characteristics in Table 6 causes nodes' voltages to change. These are given in Table 7 and Fig. 5. Despite that a part of system load is interrupted, with a proper DG placement, voltage of all remaining nodes will be in acceptable range. It was likely that inappropriate DG allocation with load outage cause nodes' voltages to be increased unfavorably.

By comparing results given in Table 4 and 6, it was observed that DG location in the case with fault is different from the case without fault. Based on this fact, it can be claimed that DG placement should be performed considering network faults to avoid serious damage to the network and customers.

Table 7. Bus voltages in case four

No.	bus	V_a	V_b	V_c
1	799	1.0000	1.0000	1.0000
2	701	0.9987	1.0011	0.9981
3	702	0.9975	1.0036	0.9977
4	713	0.9964	1.0028	0.9959
5	704	0.9954	1.0021	0.9957
6	714	0.9939	1.0012	0.9956
7	718	0.9933	1.0010	0.9955
8	720	F	F	F
9	706	F	F	F
10	725	F	F	F
11	707	F	F	F
12	724	F	F	F
13	722	F	F	F
14	705	0.9970	1.0029	0.9951
15	742	0.9967	1.0022	0.9951
16	712	0.9969	1.0029	0.9926
17	703	0.9966	1.0064	0.9984
18	727	0.9925	1.0049	0.9957
19	744	0.9898	1.0039	0.9947
20	729	0.9884	1.0038	0.9947
21	728	0.9884	1.0026	0.9934
22	733	0.9978	1.0156	1.0027
23	709	1.0008	1.0248	1.0071
24	731	1.0007	1.0243	1.0070
25	708	1.0039	1.0345	1.0116
26	732	1.0039	1.0345	1.0103
27	733	1.0071	1.0443	1.0169
28	734	1.0000	1.0000	1.0000
29	710	0.9998	0.9996	0.9975
30	736	0.9998	0.9993	0.9975
31	735	0.9997	0.9996	0.9949
32	737	0.9944	0.9995	0.9972
33	738	0.9918	0.9992	0.9945
34	711	0.9917	0.9990	0.9919
35	741	0.9916	0.9990	0.9905
36	740	0.9916	0.9989	0.9903

To understand the importance of DG placement considering fault, it is assumed that DG placement is done with Table 4 characteristic and a fault in line 720-704. Therefore, voltage in bus 22 is violated which is obvious in Fig. 6.

As it is shown in Fig. 6, in bus-22 the maximum voltage not exceeds +5% acceptable ranges indicating improper DGs placement.

Comparison of CVD among four cases

Comparisons of CVD among four cases are given in Table 8. According to the results, when there is no fault and no DGs, CVD is the most. However, CVD is decreased for case two in comparison to the case one. In case three, reduction is more than case two. This fact indicates that DG improves the system condition, reduce

CVD and improve voltage profile. According to the Table 8, CVD is better when a fault is occurred and DGs allocation is performed. However, improper placement of DGs may result in bus voltages increase. In addition, fault occurrence worsens this situation.

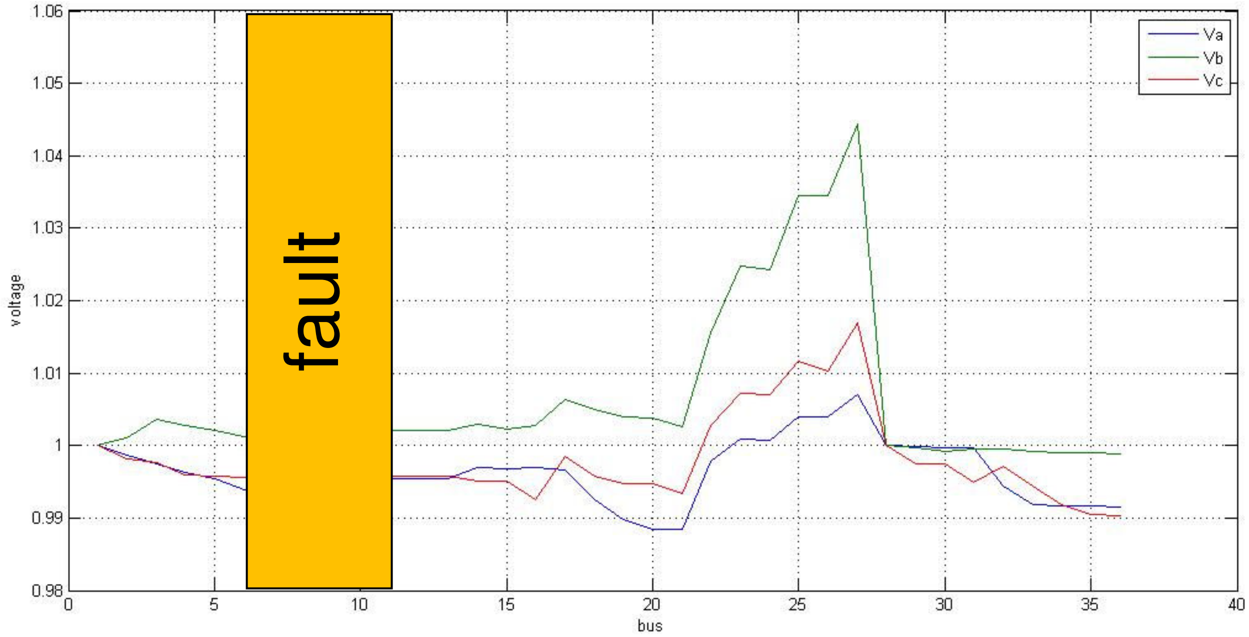

Figure 5. Bus voltages in case four

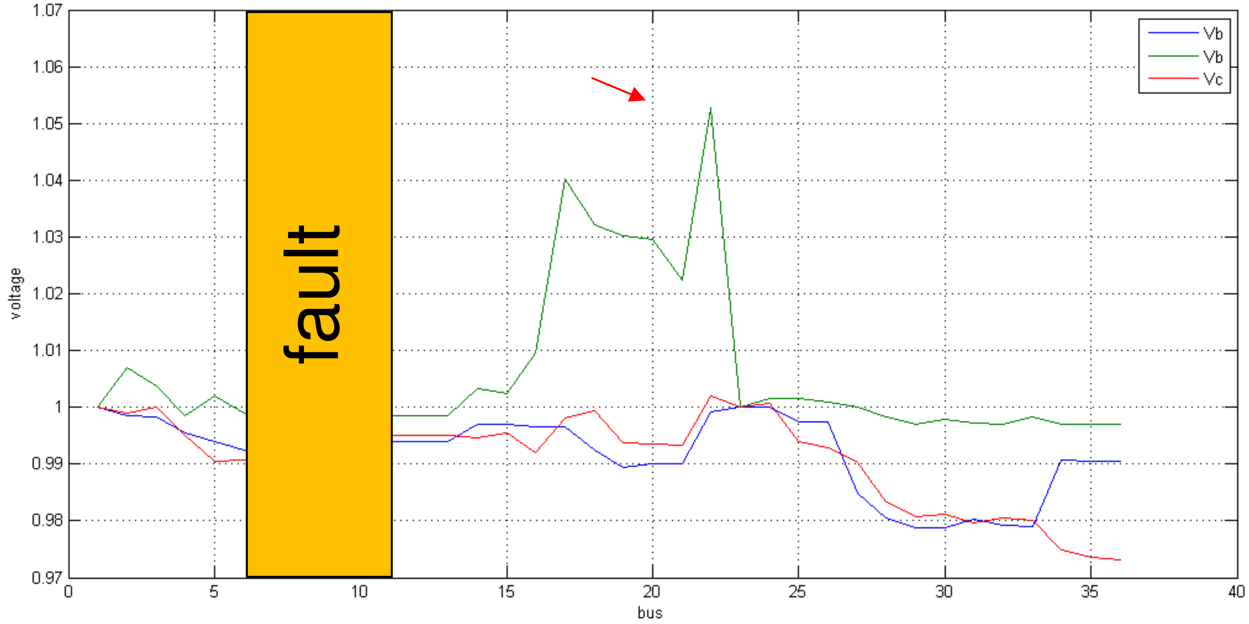

Figure 6. Inappropriate DG placement effect

Therefore, proper DG placement has a significant impact on system, thus fault effect on DG placement in network should be evaluated such that it can have a destructive effect on system if placed inappropriately. In Fig. 7, comparison of CVD among four cases are shown.

Table 8. CVD comparisons for four cases

case	CVD	Reduce CVD
first	2.2356	---------
two	1.9130	Fault
three	0.9866	DGs allocation (Table IV)
four	0.5916	Fault occurred and DGs allocation(Table VI)

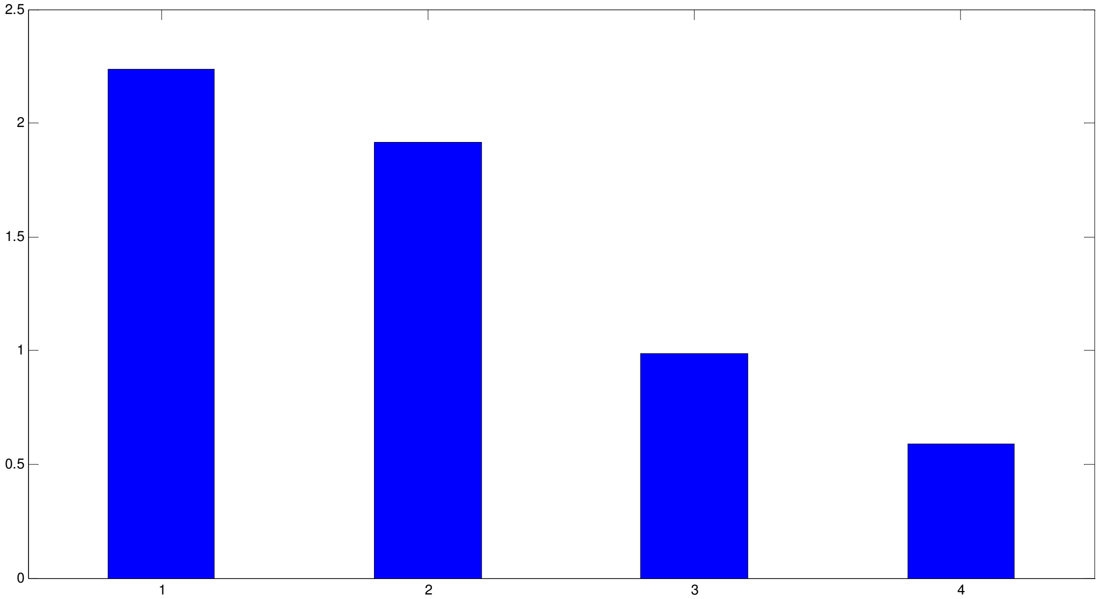

Figure 7. Comparison of CVD among four cases

From Fig. 7, it is clear that the minimum CVD is for fourth case while the maximum value is for case one. In Table 9, a comparison has been done for minimum and maximum voltages of nodes in unbalanced 36 bus system. The minimum voltage is for phase a in case 1. By occurring fault and interrupting a part of system load, bus voltages are increased. In addition, it is found that by proper integration of DGs, bus voltages are effectively improved.

Table 9. Comparison of nodes' voltages

Case	min			max		
	V_a	V_b	V_c	V_a	V_b	V_c
First	0.9397	0.9743	0.9473	1.0000	1.0000	1.0000
two	0.9400	0.9906	0.9485	1.0000	1.0000	1.0000
three	0.9704	0.9794	0.9729	1.0000	1.0136	1.0014
four	0.9884	0.9989	0.9903	1.0071	1.0443	1.0169

CONCLUSION

In this paper, finding appropriate location, size and type of DGs to have adequate voltage profile and having suitable voltage in three-phase unbalanced systems in the presence of fault was evaluated using PSO algorithm. To evaluate fault effect and DGs placement on voltage profile, CVD is utilized. According to the obtained results,

1. Fault occurrence causes nodes' voltages to be increased due to the interruption of a part of network load.
2. DGs integration in network with optimal size and location leads to CVD decrease and voltage profile improvement as well as nodes' voltage rise.
3. DGs location, when a fault is occurred in system, is different from its location in a case without any faults. Thus, faults occurrence should be considered in DGs placement to avoid nodes' voltage increase. Because, by fault

occurrence, a part of system load is interrupted resulting in nodes' voltage increase. In addition, improper DG placement worsens this condition and damages system.

4. In most studies, DG is considered as PQ (a negative load) in the network. In this paper, both PV and PQ types of DG were investigated, and according to the obtained results it was found that PV suggests better solutions than PQ for voltage profile.
5. According to the obtained results, it was observed that voltage drops at nodes in the end of network, when there is no DG, is higher, and farther locations from the main bus is better location for DG placement. In other words, locating DG at the end of feeder leads to a positive impact on voltage profile improvement, and nodes' voltages are improved especially at the end of line.
6. Proposed method for large systems has better maneuver capability while DG placement in these systems is a complicated task. Used algorithm in this paper can appropriately calculate location and size of DG in large systems and reduces calculation time.

REFERENCES

Abdelaziz AY, Mohammed FM, Mekhamer SF, Badr MAL. 2009. Distribution systems reconfiguration using a modified particle swarm optimization algorithm. Electric Power Systems Research. 79(11): 1521-1530.

Acharya N, Mahat P, Mithulananthan N. 2006. An analytical approach for DGs allocation in primary distribution network. International Journal of Electrical Power & Energy Systems. 28(10): 669-678.

Ackerman T, Anderson G, Soder L. 2000. Distributed generation: a definition. Electric Power Systems Research. 57(3): 195–204.

Amraee T, Ranjbar AM, Mozafari B, Sadati N. 2007. An enhanced under-voltage load-shedding scheme to provide voltage stability. Electric Power Systems Research. 77(8): 1038-1046.

Atanasovski M, Taleski R. 2011. Energy summation method for loss allocation in radial distribution networks with DGs. IEEE Transactions On Power Systems. 27(3): 1433-1440.

Borges C, Falcao D. 2006. Optimal distributed generation allocation for reliability, losses,and voltage improvement. Electrical Power and Energy Systems. 28(6): 413-420.

Borges C. 2012. An overview of reliability models and methods for distribution systems with renewable energy distributed generation. Renewable and Sustainable Energy Reviews. 16(6): 4008-4015.

El-Zonkoly AM. 2011. Optimal placement of multi-distributed generation units including different load models using particle swarm optimization. Swarm and Evolutionary Computation. 1(1): 50-59.

Ghosh S, Ghoshal S, Ghosh S. 2010. Optimal sizing and placement of distributed generation in a network system. Electrical Power and Energy Systems. 32(8): 849-856.

IEEE PES Test Feeders, IEEE PES Distribution System Analysis Subcommittee, http://www.ewh.ieee.org/soc/pes/dsacom/testfeeders.html.

Kennedy J, Eberhart R. 1995. Particle swarm optimization. in: Proc. IEEE Int. Conf. Neural Networks. Perth. Australia. 4: 1942-1948.

Kotamarty S, Khushalani S, Schulz N. 2008. Impact of distributed generation on distribution contingency analysis. Electric Power Systems Research. 78(9): pp 1537-1545.

Moradi MH, Abedini M. 2012. A combination of genetic algorithm and particle swarm optimization for optimal DGs location and sizing in distribution systems. Electrical Power and Energy Systems. 34(1): 66-74.

Singh D, Misra R, Singh D. 2007. Effect of load models in distributed generation planning. IEEE Transactions On Power Systems. 22(4): 2204-2212

Srivastava A, Kumar A, Schulz N. 2012. Impact of distributed generations with energy storage devices on the electric grid. IEEE Systems Journal. 6(1): 110-117.

Zangiabadi M , Feuillet R, Lesani H, Hadj-Said N, Kvaløy J. 2011. Assessing the performance and benefits of customer distributed generation developers under uncertainties. Energy. 36(3): 1703-1712.