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Photovoltaic Generation Penetration in Radial Distribution System for Improving Voltage Profile and Power Losses

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Abstract: The objectives of this research are to minimize power losses and improve voltage profile in the radial distribution system by the optimal placement and sizing of Photovoltaic Distributed Generator (PVDG). The multiobjective function based on system performance indices of ILP and ILQ, related to real and reactive power losses and IVD, related to voltage profile improvement are utilized in the present research. The Particle Swarm Optimization (PSO) has been employed to minimize the multiobjective function. Two scenarios have been studded in this research. In the first scenario, the constraint for PVDG unit size has not been considered and problem has been solved for different number of PVDGs (one, two and three). In the second scenario, the constraint for PVDG unit size has been considered and problem has been solved with one PVDG. The studies have been carried out on IEEE 33-bus test system and on a real 33-bus distribution system in Parsabad, Iran. The results show that PVDG penetration has decreased power loss and improved voltage profile. Comparison of the results obtained by the proposed method with those attained in other studies shows the effectiveness of the proposed method.

Key words: Photovoltaic Distributed Generator (PVDG), radial distribution system, the Particle Swarm Optimization (PSO), power losses, voltage profile

INTRODUCTION

World net electricity generation increases by 93%, from 20.2 trillion KWh in 2010 to 39.0 trillion KWh in 2040. In many parts of the world, concerns about security of energy supplies and the environmental consequences of greenhouse gas emissions have spurred government policies that support a projected increase in renewable energy sources. Among the renewable energy sources, Photovoltaic (PV) application has received a great attention in research because it appears to be one of the most efficient and effective solutions to this environmental problem. In addition to the above expression, another problem is with the existing electric power system. Most of the distribution networks were designed in order to operate in radial configuration with single source. With this kind of network, the power flows from the substation to the loads in every point of the grid (Singh and Verma, 2009). This unidirectional power flow results in power losses and voltage reduction along the distribution system.

Distributed generation units (also called decentralized generation, dispersed generation and embedded generation) are small generating plants connected directly to the distribution network or on the customer site of the meter. In the last decade, the penetration of renewable and nonrenewable Distributed Generation (DG) resources is increasing worldwide encouraged by national and international policies aiming to increase the share of renewable energy sources and highly efficient micro-combined heat and power units in order to reduce greenhouse gas emissions and alleviate global warming. Next to environmental advantages, DGs contribute to the technical benefits. Inappropriate DG placement may increase system losses and network capital and operating costs. On the contrary, Optimal DG Placement (ODGP) can improve network performance in terms of voltage profile, reduce flows and system losses and improve power quality and reliability of supply. The DG placement problem has therefore attracted the interest of many research efforts in the last 15 year (Georgilakis and Hatziargyriou, 2013). In order to maximize

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the benefits of using DGs in power systems, it is crucial to find the best location and size of DGs simultaneously (Rau and Wan, 1994). The typical ODGP problem deals with the determination of the optimum locations and sizes of DG units to be installed into existing distribution networks, subject to electrical network operating constraints, DG operation constraints. The objective function of the ODGP can be single or multiobjective. The main single-objective functions are: minimization of the total power loss of the system; minimization of energy losses; minimization of System Average Interruption Duration Index (SAIDI); minimization of cost; minimization of voltage deviations; maximization of DG capacity; maximization of profit; maximization of a benefit/cost ratio and maximization of voltage limit loadability (i.e., the maximum loading that can be supplied by the power distribution system while the voltages at all nodes are kept within the limits) (Georgilakis and Hatziargyriou, 2013).

The objectives of this research are to minimize power losses and improve voltage profile in the radial distribution system by the optimal placement and sizing of Photovoltaic Distributed Generator (PVDG).

Modeling

Distribution system modeling: Usually, the load of electrical appliances and devices vary with supply voltage. Their demand varies as a function of voltage. Loads can be categorized into constant power load, constant current load and constant impedance load. The load at a particular point may be a combination of some proportion of all these. In general, these models can be written as:

$$P = P_0\left(V/V_0\right)^n \tag{1}$$

$$Q = Q_0\left(V/V_0\right)^n \tag{2}$$

where, P_0, Q_0 and V_0 are nominal real power, reactive power and voltages on a per-unit basis, respectively. For a constant power model, we have n = 0, for a constant current model, we have n = 1 and for a constant impedance model, we have n = 2 (Davda *et al*., 2014). In this study, the load has been modelled as constantan power.

PVDG System Modeling: The IEEE 1547 rules that the distributed recourses shall not actively regulate the voltage at the point of common coupling. The most commonly used operational mode is simply unity PF. The inverter will output active power based on the insolation levels captured by the PV arrays. This mode complies with IEEE 1547 and is most common.

Inverter designs for both small-and large-scale applications typically size the inverter to match the dc rating of the PV cells after applying derating factors. This is because the inverter does not need to be controlled to manage the reactive power export. For power flow analysis, this means that the inverters are to be modeled as current source inverters operating at unity PF or simply negative active load. In this study, the PVDG has been modeled as negative active load. Another reason to operate the PVDG at unity PF is that it is normally considered that maximum benefit can be extracted when DG's are operated on unity power factor because the cost of real power is higher (Singh and Verma, 2009).

Problem formulation: The objective of this study is to minimize the power losses and improve voltage profile by injecting PVDG in optimal site and size. The PVDG site and its corresponding size in the distribution feeders can be optimally determined using the following function:

$$\min f\left(P_{loss}, Q_{loss}, V_{level}\right) \tag{3}$$

In this research, several indices will be computed in order to describe the effect of PVDG in the power losses and voltage improvement. These indices are defined as follows.

Real Power Loss Index (ILP): The real power loss indices are defined as:

$$ILP = \frac{P_{loss}^{with\ PVDG}}{P_{loss}^{without\ PVDG}} \tag{4}$$

Where:

$P_{loss}^{with\ PVDG}$ = The total real power loss of the distribution system after inclusion of PVDG

$P_{loss}^{without\ PVDG}$ = The total real system loss without PVDG in the distribution system

Reactive Power Loss Index (ILQ): The reactive power loss indices are defined as:

$$ILQ = \frac{Q_{loss}^{with\ PVDG}}{Q_{loss}^{without\ PVDG}} \tag{5}$$

Where:

$Q_{loss}^{with\ PVDG}$ = The total reactive power loss of the distribution system after inclusion of PVDG

$Q_{loss}^{without\ PVDG}$ = The total reactive system loss without PVDG in the distribution system

Table 1: Indices weights

Indices	Weights
ILP	0.55
ILQ	0.25
IVD	0.20

Voltage Profile Index (IVD): One of the advantages of proper site and size of the PVDG is the improvement in voltage profile. This index penalizes a size-location pair which gives higher voltage deviations from the nominal Value (V_{nom}). In this way, the closer the index is to zero better is the network performance. The IVD can be defined as:

$$IVD = {}_{i=2}^{n}\max\left[\frac{|V_{nom}|-|V_i|}{|V_{nom}|}\right] \tag{6}$$

where, n is the number of buses. The Multiobjective performance Index (IMO) was produced from the gather of these indices by the weighting factor assigned to that impact:

$$\min f\left(P_{loss}, Q_{loss}, V_{level}\right) = w_1 \times ILP + w_2 \times ILQ + w_3 \times IVD \tag{7}$$

The sum of the absolute values of the weights assigned to all indices should add up to one as shown in the following Eq. 8:

$$w_1 + w_2 + w_3 = 1 \tag{8}$$

This weighting factor is chosen by the planner to reflect the relative importance of each parameter in the decision making of sitting and sizing the PVDG. Table 1 shows the values for the weights used in present research and they are selected guided by the weights in (Singh and Verma, 2009). However, these values may vary according to engineer concerns.

Constrain formulation: Voltage limits: the voltage drop limits depend on the voltage regulation limits provided by the disco:

$$V_{min} \le V_i \le V_{max} \tag{9}$$

Line thermal limits: power flow through any distribution feeder must comply with the thermal capacity of the line:

$$S_i \le S_{i,max} \tag{10}$$

PVDG capacity: this study defines the boundary of power generation by PVDG:

$$P_{min}^{PVDG} \le P_i^{PVDG} \le P_{max}^{PVDG} \tag{11}$$

MATERIALS AND METHODS

Backward Forward Sweep Load Flow method: Traditional load flow methods, which incorporate the Gauss-Seidel method, the Newton-Raphson method and fast decoupled techniques, were primarily developed for transmission system analysis. Additionally, a Backward Forward Sweep method for radial distribution systems using basic circuit theories and laws is another well-known method. Distribution systems usually fall into the category of ill-conditioned power systems having high R/X ratios due to which the methods like Newton Raphson and fast decoupled may provide inaccurate results and may not converge. Therefore, traditional load flow methods cannot be directly applied to distribution systems since the assumptions made for transmission systems are not valid for the unique characteristics of distribution systems (Davda *et al*., 2014). On the other hand, Backward Forward Sweep methods are quite suitable for radial networks with high R/X ratio (Medina *et al*., 2003).

Particle Swarm Optimization (PSO): Kennedy and Eberhart developed PSO through simulation of bird flocking in a two-dimensional space. The position of each agent is represented by its x, y axis position and also its velocity is expressed by v_x (the velocity of x axis) and v_y (the velocity of y axis). Modification of the agent position is realized by the position and velocity information. Bird flocking optimizes a certain objective function. Each agent knows its best value so far (pbest) and its x, y position. This information is an analogy of the personal experiences of each agent. Moreover, each agent knows the best value so far in the group (gbest) among pbests.

This modification can be represented by the concept of velocity (modified value for the current positions). Velocity of each agent can be modified by the following Eq. 12:

$$v_i^{k+1} = wv_i^k + c_1 rand_1 \times \left(pbest_i - s_i^k\right) + c_2 rand_2 \times \left(gbest - s_i^k\right) \tag{12}$$

Where:

- v_i^k = The velocity of agent i at iteration k
- w = The weighting function
- c_j = The weighting coefficients
- rand = The random number between 0 and 1
- s_i^k = The current position of agent i at iteration k
- $pbest_i$ = The pbest of agent I
- gbest = The gbest of the group

The following weighting function is usually utilized in Eq. 12:

$$w = w_{max} - \frac{w_{max} - w_{min}}{iter_{max}} \times iter \tag{13}$$

Where:
w_{max} = Initial weight
w_{min} = Final weight iterm axis maximum iteration number
iter = Current iteration number

Shi and Eberhart (1998a, b) tried to examine the parameter selection of the above parameters. According to their examination, the following parameters are appropriate and the values do not depend on problems: $c_1 = 2$, $c_2 = 2$, $w_{max} = 0.9$ and $w_{min} = 0.4$ (Lee and El-Sharkawi, 2008). The current position (searching point in the solution space) can be modified by the following Eq. 14:

$$s_i^{k+1} = s_i^k + v_i^{k+1} \quad (14)$$

Algorithm to find the PVDG size and site: The PSO-based approach for solving the optimal placement of PVDG problem to minimize the loss and voltage improvement takes the following steps:

- Step 1: Input line and bus data
- Step 2: Calculate the loss using distribution load flow based on backward sweep-forward sweep method
- Step 3: Randomly generates an initial population (array) of particles with random positions and velocities on dimensions (size of PVDG and location of PVDG) in the solution space. Set the iteration counter k = 0
- Step 4: For each particle, compare its objective value with the individual best. If the objective value is lower than pbest, set this value as the current pbest and record the corresponding particle position
- Step 5: Choose the particle associated with the minimum individual best pbest of all particles and set the value of this pbest as the current overall best gbest
- Step 6: Update the velocity and position of particle using Eq. 12 and 14, respectively
- Step 7: If the iteration number reaches the maximum limit, go to Step 9. Otherwise, set iteration index k = k+1 and go back to step 4
- Step 8: Print out the optimal solution to the target problem. The best position includes the optimal locations and sizes of DG and the corresponding fitness value representing the minimum total real power loss

RESULTS AND DISCUSSION

The studies have been carried out on an IEEE 33-bus test system and on a real 33-bus distribution system in Parsabad, Iran. We studied two load scenarios, scenario I and scenario II. For the first scenario, the constraint for PVDG unit size has not been considered and problem has been solved for different number of PVDGs (one, two and three). Scenario II, on the other hand represents the situation where the constraint for PVDG unit size has been considered and problem has been solved with one PVDG. 10, 15 and 25% of total active of distribution system represent the constraint for PVDG unit size in the second scenario. The substation voltage in both scenarios was considered as 1 pu. the PVDG can be connected to any buses except the first bus which is considered to be the slack bus.

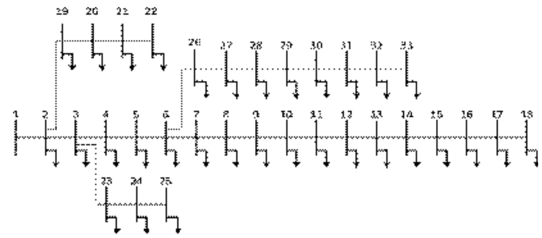

Fig. 1: Single line diagram of the IEEE 33-bus test system

Table 2: Results for IEEE 33-bus Test System for Scenario I

Parameters	Impact index 1	2	Site	Size (KW)	P_{loss} (KW)	Q_{loss} (Kvar)
One PVDG	ILP	0.509130	6	2594.829	102.7901	74.1464
	ILQ	0.550640				
	IVD	0.047579				
	IMO	0.427200				
Two PVDG	ILP	0.410620	13	853.7076	82.9005	56.8199
	ILQ	0.421960				
	IVD	0.026575	30	1196.677		
	IMO	0.336640				
Three PVDG	ILP	0.343720	14	759.0987	69.3939	48.0883
	ILQ	0.357120	24	1059.4370		
	IVD	0.026505	30	1118.1400		
	IMO	0.283620				

Case 1; IEEE 33-bus test system: The proposed PSO-based algorithm was applied to the IEEE 33-bus test system to determine the optimal size and site of DG units such that the multi-objective function given in Eq. 7 is minimized. For this test system, three DG units were optimally sized and placed. The IEEE 33-bus test system operates at 12.66 KV is shown in Fig. 1. The network data can be found in (Kashem *et al*., 2000). This test network has loads connected to all buses except bus 1. The total demand of the network is 3.715 MW and 2.3 Mvar. The power losses for base case (without DG) of the IEEE 33-bus test system are 201.7897KW and 74.1422 Kvar.

Scenario I: As discussed above, there isn't the constraint for PVDG unit size in this scenario. The proposed PSO algorithm results were obtained after carrying out 10 independent runs. In other words, the initial population was randomly generated in each run. Table 1 shows the best results. Table 2 also shows

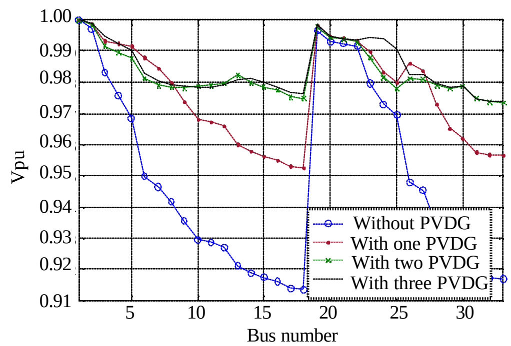

Fig. 2: Voltage profiles of the IEEE 33-bus test system for scenario I; Voltage prefile with PVDG

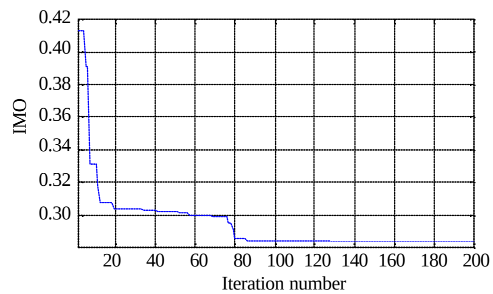

Fig. 3: The convergence of the PSO for PVDG Placement on IEEE 33-bus test system; PSO corege

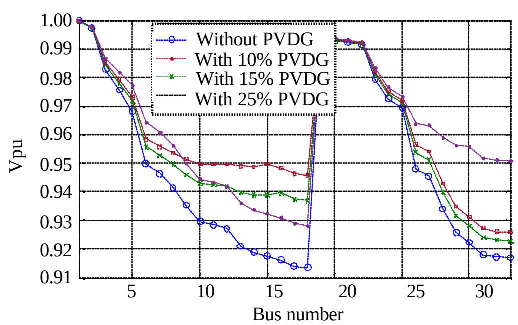

Fig. 4: Voltage profiles of the IEEE 33-bus test system for scenario II; Voltage profile

voltage and power losses for IEEE 33-bus test system for Scenario I. Figure 2 and 3 illustrate voltage profiles and PSO convergence for PVDG placement, respectively. Table 3 and Fig. 2 and 3 show how PVDG cases power loss reduction and voltage improvement on IEEE 33-bus test system for the first scenario. In the case we penetrated three PVDG's the power loss reduction was 65.61% and minimum voltage improved from 0.9134-0.973495 pu.

Scenario II: Constraint for PVDG unit size has been defined for this scenario. Table 4 shows the best results.

Table 3: Voltage and power losses for IEEE 33-bus test system for scenario I

Cases	Power loss as (%) of total active load	Power loss reduction (%)	Minimum voltage (pu)
No PVDG	5.430	-	0.913400
One PVDG	2.766	49.06	0.952421
Two PVDG	2.231	58.91	0.973425
Three PVDG	1.867	65.61	0.973495

Table 4: Results for IEEE 33-bus test system for scenario II

Power generation of PVDG	Impact index 1	2	Site	Size (KW)	P_{loss} (KW)	Q_{loss} (Kvar)
370 KW (10%)	ILP	0.79504	16	370	160.5123	106.115
	ILQ	0.78805				
	IVD	0.07711				
	IMO	0.6497				
555 KW (15%)	ILP	0.72712	15	555	146.8012	97.0985
	ILQ	0.72109				
	IVD	0.07415				
	IMO	0.59502				
930 KW (25%)	ILP	0.62978	30	930	127.149	86.4207
	ILQ	0.64179				
	IVD	0.071684				
	IMO	0.52116				

Table 5: Voltage and power losses for IEEE 33-bus test system for scenario II

Cases	Power loss as (%) of total active load	Power loss reduction (%)	Minimum voltage (pu)
No PVDG	5.4300	-	0.9134
370 KW (10%)	4.3206	20.43	0.92289
555 KW (15%)	3.9515	27.22	0.92585
930 KW (25%)	3.4225	36.97	0.928316

Table 5 also shows voltage and power losses for IEEE 33-bus test system for scenario II. Figure 4 illustrates voltage profile.

Results on IEEE 33-bus test system for the second scenario revealed that in the case the PVDG unit size was 25% of total active load, the power loss reduced by 36.98% and minimum voltage improved to 0.928316 pu.

Case 2: Real 33-bus distribution system in Parsabad: An actual 20 KV distribution system in Parsabad is employed as a second test case. The parameters of this system have been calculated by getting necessary data from the electrical distribution company for the first time in this study. All system parameters are given in Appendix A. The test system has 33 buses with a total load of 4.9829 MW and 1.9189 Mvar as shown in Fig. 5 and 6.

Scenario I: Results of the real 33-bus distribution system in Parsabad for the scenario I are shown in Table 6 and 7. Figure 7 and 8 illustrate Voltage profiles and PSO convergence for PVDG placement, respectively.

In the case, we penetrated three PVDG's the power loss reduction was 86.60% and minimum voltage improved

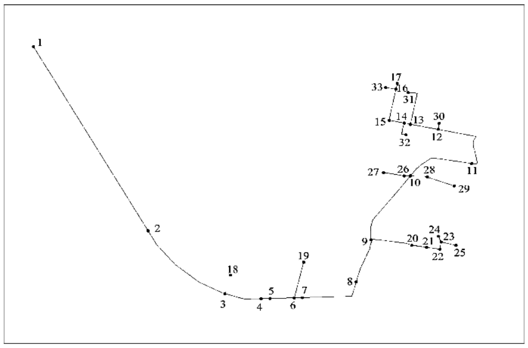

Fig. 5: A Real 33-bus distribution system in Parsabad

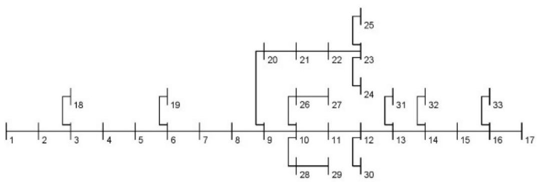

Fig. 6: Single line diagram of the real 33-bus distribution system in Parsabad

Table 6: Results for real 33-bus distribution system in Parsabad for Scenario I

Parameters	Impact index 1	Impact index 2	Site	Size (KW)	P_{loss} (KW)	Q_{loss} (Kvar)
One PVDG	ILP	0.169980	10	4482.322	27.6369	38.5148
	ILQ	0.164530				
	IVD	0.018817				
	IMO	0.138390				
Two PVDG	ILP	0.144390	9	3023.327	23.4762	32.5862
	ILQ	0.139210				
	IVD	0.016579	13	1682.948		
	IMO	0.117530				
Three PVDG	ILP	0.133870	6	1540.069	21.7654	30.3072
	ILQ	0.129470	10	2184.76		
	IVD	0.016556	14	1225.413		
	IMO	0.109310				

Table 7: Voltage and power losses of the real 33-bus distribution system in parsabad for Scenario I

Cases	Power loss as (%) of total active load	Power loss reduction (%)	Minimum voltage (pu)
No PVDG	3.2600	-	0.952900
One PVDG	0.5546	82.98	0.981183
Two PVDG	0.4711	85.54	0.983421
Three PVDG	0.4368	86.6	0.983444

from 0.9529-0.983444 pu. As it is shown in Table 6 the PVDG size is very high. The reason comes from the special structure and topology of the real distribution system. As it is clear from Fig. 5, most of the loads have been concentrated at the end of the feeder and this structure makes tendency to use distributed generation instead of grid.

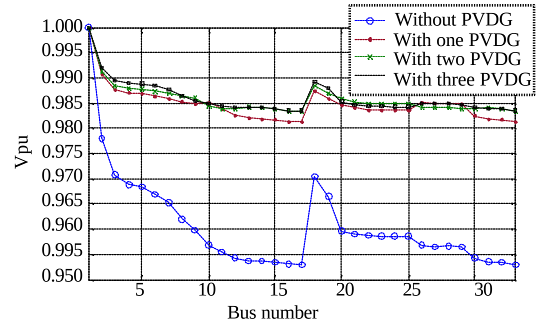

Fig. 7: Voltage profiles of the real 33-bus distribution system in parsabad for Scenario I; Voltage profile with PVDG

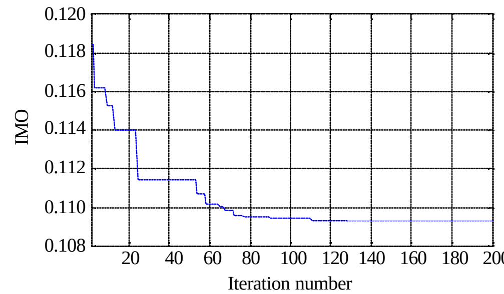

Fig. 8: The convergence of the PSO for PVDG placement on the real 33-bus distribution system in Parsabad; PSO converge

Table 8: Results for the real 33-bus distribution system in Parsabad for Scenario II

Power generation of PVDG	Impact index 1	Impact index 2	Site	Size (KW)	P_{loss} (KW)	Q_{loss} (Kvar)
500 KW (10%)	ILP	0.806400	33	500	131.1126	188.9259
	ILQ	0.807080				
	IVD	0.042805				
	IMO	0.653850				
750 KW (15%)	ILP	0.721780	16	750	117.354	169.0086
	ILQ	0.722000				
	IVD	0.040837				
	IMO	0.585650				
1250 KW (25%)	ILP	0.575010	14	1250	93.4911	134.2381
	ILQ	0.573460				
	IVD	0.037351				
	IMO	0.467090				

Table 9: Voltage and power losses the real 33-bus distribution system in Parsabad for Scenario II

Cases	Power loss as (%) of total active load	Power loss reduction (%)	Minimum voltage (pu)
No PVDG	3.26000	-	0.952900
500 KW (10%)	2.63125	19.28	0.957195
750 KW (15%)	2.35513	27.75	0.959163
1250 KW (25%)	1.87623	42.44	0.962649

Scenario II: Results of the real 33-bus distribution system in Parsabad for the first scenario are shown in Table 8 and 9.

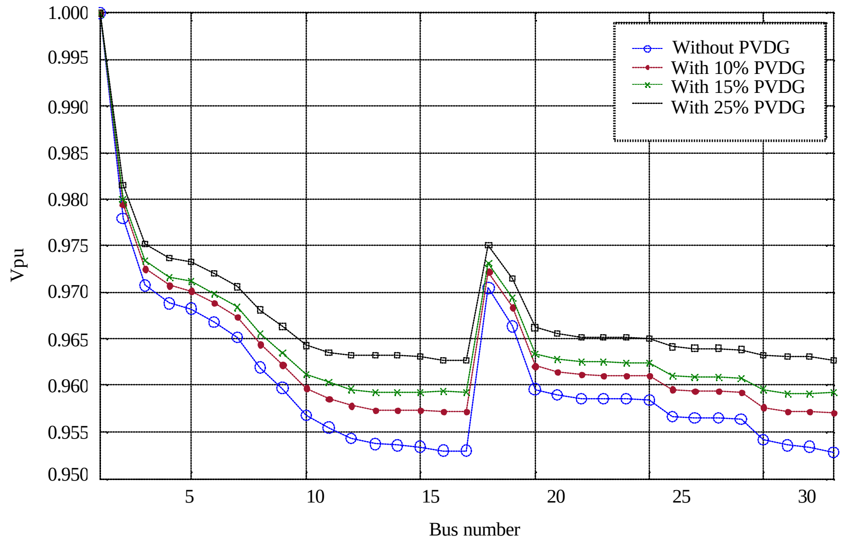

Fig. 9: Voltage profiles of the real 33-bus distribution system in Parsabad for Scenario II; voltage profile

Table 10: Comparative study for IEEE 33-bus test system

Cases	1	2	3	4	Proposed approach
One DG; site, size (KW)	6,2490	6,2380	6,2400	6,2590	6,2594
Loss reduction (%)	47.33	44.83	48.19	46.92	49.06
Two DG; site, size (KW)	-	-	-	6,1958.9	13,853
				14,606.3	30,1196
Loss reduction (%)	-	-	-	56.22	58.91
Three DG; site, size (KW)	-	-	-	6,1189.1	14,759
				14,646.9	24,1059
				31,686.3	30,1118
Loss reduction (%)	-	-	-	65.01	65.61

Acharya *et al.* (2006), Shukla (2010), Abu-Mouti and El-Hawary (2011) and Hussain and Roy (2012)

Figure 9 and illustrates voltage profile of the real 33-bus distribution system in Parsabad for the second scenario.

Comparative study: The comparative study has been done for validity of the results. As mentioned above the real distribution system was simulated for the first time in this study and there is no previous study for comparison. But, lots of study has been done for IEEE 33-bus test system and some of them have been considered for comparison in this study. The results of the PSO algorithm for IEEE 33-bus test system were compared with the solutions obtained based on the analytical method (Acharya *et al*., 2006), GA method (Shukla *et al*., 2010) and ABC (Abu-Mouti and El-Hawary, 2011; Hussain and Roy, 2012). The comparison shows that the methodology is more effective in determining the sizes and PVDG site for power loss reduction (Table 10).

CONCLUSION

In this study, the PSO algorithm has been used to find the optimal solution of PVDGs sizing and sitting problems. The goal of this optimization was minimizing the power loss and improving voltage profile by penetrating PVDG. Inverter is formulated in form of negative active load. The simulation result demonstrates that PVDG in optimum sizing and sitting can reduce power loss and improve voltage profile.

For IEEE 33-bus test system in the first scenario power loss reduced by 65.61% and minimum voltage improved from 0.9134-0.973495 pu. And in the second scenario power loss reduced by 36.98% and minimum voltage improved by 0.928316 pu.

For the real 33-bus distribution system in Parsabad in the first scenario power loss reduced by 86.60% and minimum voltage improved from 0.9529-0.983444 pu. And for the second scenario power loss reduced 42.44% and minimum voltage improved by 0.962649 pu.

Results for IEEE 33-bus test system in the first scenario were compared by results of other studies and the comparisons show that the methodology is more effective in determining the sizes and PVDG size for power loss reduction.

APPENDIX

Parameters For the real 33-bus distribution system in Parsabad, Iran

Parameters for the real 33-bus distribution system in Parsabad, Iran

Branch No.	Sending bus	Receiving bus	Resistance Ω	Reactance Ω	Nominal load at receiving bus P (KW)	Q (KW)	Line (KVA) capacity
1	1	2	1.1192	1.6227	8.6	18.0	10000
2	2	3	0.3765	0.5458	121.0	286.0	10000
3	3	4	0.1090	0.1581	2.7	6.5	10000
4	4	5	0.0312	0.0452	2.8	7.0	10000
5	5	6	0.0828	0.1200	0.0	0.0	10000
6	6	7	0.1104	0.1600	135.0	283.0	10000
7	7	8	0.2225	0.3226	7.8	18.4	10000
8	8	9	0.1624	0.2355	0.0	0.0	10000
9	9	10	0.2915	0.4226	0.0	0.0	10000
10	10	11	0.2461	0.3568	112.0	267.0	10000
11	11	12	0.2626	0.3807	0.0	0.0	10000
12	12	13	0.1929	0.1441	0.0	0.0	6000
13	13	14	0.0447	0.0334	0.0	0.0	6000
14	14	15	0.1072	0.0800	0.0	0.0	6000
15	15	16	0.2393	0.1788	0.0	0.0	6000
16	16	17	0.0447	0.0334	118.0	277.0	6000
17	3	18	0.2679	0.2001	106.0	250.0	6000
18	6	19	0.3572	0.2668	193.0	405.0	6000
19	9	20	0.0447	0.0334	78.0	250.0	6000
20	20	21	0.2143	0.1601	101.0	240.0	6000
21	21	22	0.1965	0.1467	107.0	252.0	6000
22	22	23	0.0625	0.0467	0	0.0	6000
23	23	24	0.0447	0.0334	17	36.0	6000
24	23	25	0.067	0.0500	78	294.0	6000
25	10	26	0.0447	0.0334	89	287.0	6000
26	26	27	0.1429	0.1067	156	368.0	6000
27	10	28	0.125	0.0934	77	291.0	6000
28	28	29	0.2009	0.1501	104	244.0	6000
29	12	30	0.0447	0.0334	80	255.0	6000
30	13	31	0.2679	0.2001	54	150.0	6000
31	14	32	0.1786	0.1334	112	264.0	6000
32	16	33	0.0893	0.0667	59	234.0	6000

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