Journal of Engineering and Computer Sciences
Qassim University, Vol. 12, No. 1, pp. 73-90 (January 2019 /Rabi II 1440H)

Reduction of Active and Reactive Power Losses of Three-Phase Distribution Networks Using Adaptive Particle Swarm Optimization

Ahmad Eid
Electrical Engineering Department
College of Engineering in Unaizah
Qassim University
Qassim 51452, Kingdom of Saudi Arabia

(Received 22/7/2019, accepted for publication 8/12/2019)

Abstract. This paper uses adaptive particle swarm optimization (APSO) to minimize the power losses of radial balanced and unbalanced three-phase distribution systems. A Matlab program is used to solve two distribution systems using backward/forward sweep (BFS) method. The first is the balanced three-phase 12-bus system and the second is the unbalanced three-phase IEEE 37-bus system. Three scenarios are adopted for adding a distribution generation (DG) at specified nodes. In the first scenario, the DG is assumed to generate only reactive power representing capacitor banks or kVar compensators, while in the second scenario the DG generates active power and in the third scenario the DG generates both active and reactive power representing cogenerations. The APSO algorithm determines the required amount of reactive and/or active power to minimize the total losses of the radial distribution systems. The obtained results prove the effectiveness of the APSO for DG allocation and enhancing the distribution power system performance in terms of reducing the losses, regulating the bus voltages and increasing the system stability.
Keywords: PSO, Backward/forward load flow, DG allocation, Distribution systems

1. Introduction

Due to the continuous increase of electrical energy consumption and limitations on contaminant emissions, distributed generation (DG) units are widely added to distribution systems (DSs). In general, the DG units have a positive impact on distribution systems if they are correctly connected at specific locations with specific type or magnitude [1]–[3]. The DG can reduce the system loss, improve the voltage stability, increase the system reliability and quality. These DG units can supply reactive power and/or active power depending on their type and connection control [4]. The DG units can be wind generators, fuel cell stacks, micro turbines, photovoltaic arrays or similar.

The issue of DG siting and sizing is critical. Introducing DG units at non-ideal system nodes may result in an expansion in network troubles, expenses, and subsequently, having a contrary impact to what is wanted. Accordingly, utilizing an enhancement optimization strategy equipped for demonstrating the best result for a given distribution system can be helpful for planning or operating engineers. Choosing the best places for introducing DG units and their best sizes in enormous power distribution systems is a compound optimization issue.

For proper planning of DG connection with distribution systems (DSs), optimization algorithms are important and supporting tools for their placement. Several approaches are used in literature to determine the optimal size and location of a DG unit. These approaches can be analytical tools or an optimization technique. The analytical solution are proposed by several authors [3], [5], [6]. The authors in [5] proposed a non-iterative analytical strategy for DG allocations (location and size) that involves no convergence matters even for distribution systems with high r/x ratios. The authors in [6] used analytical expressions based on change of current components in the system branches in both active and reactive directions due to the connection of DG. In [3] the authors developed an analytical expressions to reduce the power loss by placing DG at different locations after calculating the branch currents in both active and reactive directions.

Recently, many authors utilize metaheuristic population based techniques for finding the optimal location and size of DG units. These techniques may include genetic algorithm (GA) [7-9]. In [7] the authors proposed PSO combined with GA for optimal allocations of DG in distribution system. They defined the problem as a multi-objective optimization with several indices. The authors of [8] combined the analytical and GA for DG allocations to minimize the power losses, while, the authors of [9] used an adaptive GA to find the optimal size and location of DG in distribution networks to reduce energy loss, enhance voltage quality and line loadability.

Another authors used PSO for DG allocation problem such as in [10] where they addressed a multi-objective PSO function to boost annual savings and to reduce power losses and maintain a good voltage profile. The authors in [11] used PSO technique to get the near-optimal solution for capacitor allocation in distribution network with wind energy generators to reduce the power loss and enhance the voltage profile. In [14, 15] PSO algorithm is used for battery sizing in distribution systems with renewable energy sources such as PV, wind and diesel generators. The authors in [2,

14] used different modified PSO algorithms for reactive power planning in distribution networks. Another group of authors used gravitational search algorithm (GSA) such as in [15, 17]. Another authors used ant colony optimization (ACO), artificial bee colony (ABC) and hybrid or modified versions of them [18].
In this paper, an adaptive PSO based algorithm is used to determine the size and location of a DG to minimize the power loss of both balanced distribution system of the 12-bus [19] and the unbalanced distribution system of the IEEE 37-bus [20]. The candidate nodes of DG are determined using analytical form of the line stability index. The DG is assumed either supplying reactive power only using a one-dimensional APSO algorithm or both active and reactive powers using two-dimensional APSO algorithm.

2. Backward/Forward Sweep Load Flow

The backward/forward sweep load flow is usually used for solving radial distribution systems [21, 22] and it mainly depends on the fact that the voltage at the swing bus is known as well as the loads at the lateral terminals. To solve any distribution system, all branches should be numbered in a logic sequence. In addition to branch currents and their starting and ending nodes must be outlined. The BFS method can be summarized in the following steps:

1. Load current calculations

The voltage is assumed equal to 1.0 pu at all load buses and the load current is calculated as:

$$I_j^{\emptyset} = \left[\left(\frac{S_j^{\emptyset}}{V_j^{\emptyset}}\right)^*\right] + \frac{1}{2}\, Y_j^{\emptyset}\, V_j^{\emptyset} \tag{1}$$

Where ϕ is the phase (a, b or c), S is the apparent power of each phase, V is the phase voltage at node j and I is the corresponding load current. The second term represents the capacitor current per phase.

2. Backward sweep

The branch currents are calculated based on the initial known voltages and load power as:

$$I_{br}^{\emptyset} = -I_j^{\emptyset} + \sum_{k\epsilon M} I_k^{\emptyset} \tag{2}$$

Where $I_{br}^{\emptyset}$ is branch phase current flowing in branch br, M is total number of branches connected downstream to node j. starting from the most faraway branch, the total current at the supply can be calculated.

3. Forward sweep

After the calculations of all branch currents and with the known swing voltage, the downstream node voltages are calculated as:

$$V_r^{\emptyset} = V_s^{\emptyset} - I_{br}^{\emptyset}\, Z_{br}^{\emptyset} \tag{3}$$

Where $V_r^{\emptyset}$, $V_s^{\emptyset}$ are the receiving and sending voltages of each branch, and $Z_{br}^{\emptyset}$ is its impedance.

4. Stopping criteria

The above steps are repeated until the power/voltage mismatch is reached. The mismatch is calculated as the difference between the current and previous values.

3. PSO/APSO Mathematical Formulations

A. Basic PSO Model

PSO is developed to simulate bird flocking or fish schooling for optimizing a certain objective function under certain constraints. PSO uses swarm of particles, each particle position xi is represented by n-dimensional vector xi=[x1, x2,… xn] where n is the number of control variables. The total number of particles represent the population. Each particle moves (searches) to find the best solution (minimum position) of its own, pbest, at iteration k which is defined as:

$$pbest(i,k) = \min_{k=1,2,\dots n} fit\big(x_i(k)\big) \quad (4)$$

The global best solution gbest of all particle is defined as:

$$gbest(k) = \min_{i=1,2,\dots N} pbest(i,k) \quad (5)$$

where N is the total number of population and fit is the fitness (objective) function.

After each iteration, each particle updates it position according to its velocity component, v(k) as:

$$v_i(k+1) = \omega\, v_i(k) + C_1\, r_1\, [pbest(i,k) - x_i(k)] + C_2\, r_2\, [gbest(k) - x_i(k)] \quad (6)$$

The updated or new position of each particle is:

$$x_i(k+1) = x_i(k) + v_i(k+1) \quad (7)$$

Where ω is the inertia weight, C1 and C2 are positive numbers and represent acceleration coefficients, r1 and r2 are positive random numbers in [0,1] range. These constants are normally taken as: ω = 1.0, C1 = C2 = 2 for basic PSO operation.

B. APSO formulations

For better and faster operation, the constant ω can be decreased linearly with the iteration number from 0.9 to 0.4 as:

$$\omega = 0.4 + \frac{0.5\,(k_{max} - k)}{k_{max} - 1} \quad (8)$$

where kmax is the maximum number of iteration and k is the current iteration.

The constant C1 and C2 can be changed linearly with the iteration as:

$$C_1 = C_{max} - C_d\, \frac{k}{k_{max}} \quad (9)$$

$$C_2 = C_{min} + C_d \frac{k}{k_{max}} \quad (10)$$

where Cmin and Cmax are the minimum and maximum of C1 or C2 values and Cd is the positive difference between them. The value of Cmin can be taken from 0.5 to 1.0 while the value of Cmax can be taken from 2.0 to 2.5 [23]. In this case, using (8) - (10) the cognitive component of (6) is reduced while the social component is increased as search operation proceeds. Thus the optimization allows the search agents or particles to converge to the global optimum by the end of iterations.

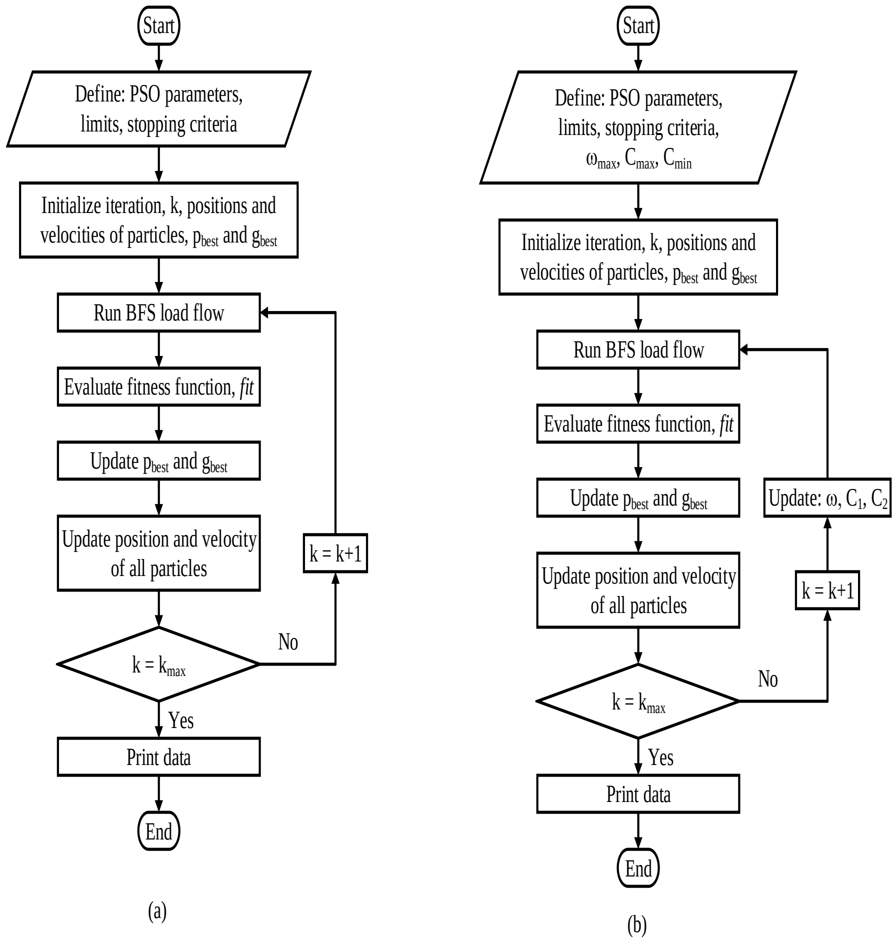

Fig. (1). Flow charts of (a) basic PSO and (b) adaptive PSO algorithms.

4. Results and Discussions

Two test systems are used in this paper to verify the explained concepts of PSO effects on the performance of the distribution systems. These systems include the balanced three-phase IEEE 12- bus DS, shown in Fig. 2 and the unbalanced three-phase IEEE 37-bus DS, shown in Fig. 3. The performance of the distribution systems is measured by the amount of total power losses, voltage profile enhancement and the system stability. A Matlab program is built to model and simulate the distribution systems under different case studies which appear in the following subsections. The distributed generations can be of different types and generally are divided to:

1- Type 1: DG generates only reactive power representing a capacitor bank effect.
2- Type 2: DG generates only active power representing PV or battery systems.
3- Type 3: DG generates both active and reactive powers representing a synchronous generator.
4- Type 4: DG generates active power but consumes reactive power representing an induction generator such as in wind energy systems.

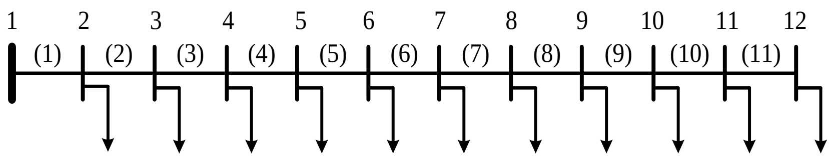

Fig. (2). Single line diagram of the 12-bus distribution system.

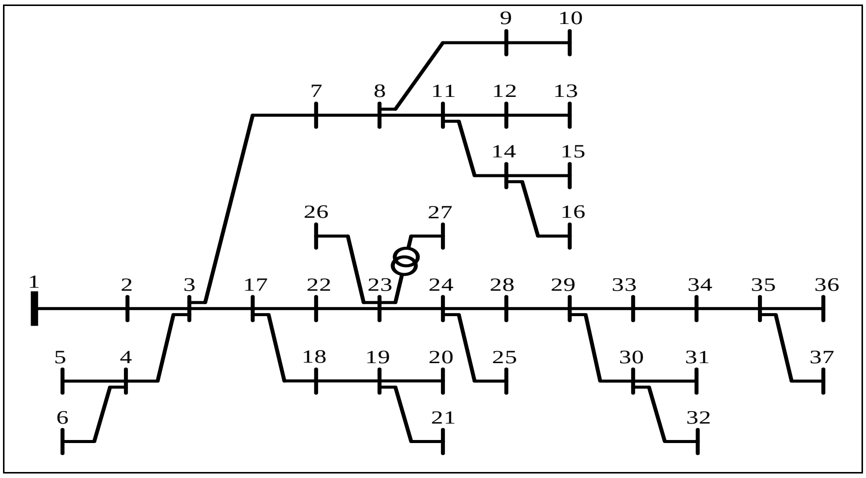

Fig. (3). Single line diagram of IEEE 37-bus distribution system.

In this study, types 1, 2 and 3 are considered to reflect the different used types. The line and load data [19] of the 12-bus DS are listed in Table I and Table II, respectively.

Table (I). Line data of the 12-bus system

Branch No.	Start	End	R (Ω)	X (Ω)
1	1	2	1.093	0.455
2	2	3	1.184	0.494
3	3	4	2.095	0.873
4	4	5	3.188	1.329
5	5	6	1.093	0.455
6	6	7	1.002	0.417
7	7	8	4.403	1.215
8	8	9	5.642	1.597
9	9	10	2.890	0.818
10	10	11	1.514	0.428
11	11	12	1.238	0.351

Table (II). Load data of the 12-bus system

Bus No.	P_L (kW)	Q_L (kVAR)
1	0	0
2	60	60
3	40	30
4	55	55
5	30	30
6	20	15
7	55	55
8	45	45
9	40	40
10	35	30
11	40	30
12	15	15

A. Base Case

In the base case, the distributed systems are solved without DG installation. The 11kV 12-bus system is solved using the BFS load flow. The biggest voltage mismatch is 0.05991 V compared to the available solution [19]. The power losses are compared to the original solution and listed in Table III. The active power mismatch is 3.77 W while the reactive power mismatch is 1.13 VAR.

Table (III). Comparison of losses for the 12-bus system

Losses	Solution [19]	Proposed	mismatch
Active loss	20.71 kW	20.71377 kW	3.77 W
Reactive loss	8.04 kVAR	8.04113	1.13 VAR

The second solved system is the IEEE 37-bus DS which is unbalanced three phase system. The voltage mismatch between the BFS and the published solution of the three phases are listed in Table IV. The maximum voltage mismatch or error is recorded for the line voltage VBC and is equal to 0.2693 V. The power loss mismatches for the system are listed in Table V. The recoded maximum mismatches are 2W for phase A and 1.2 VAR for phase B. These small mismatches verify the accuracy of the current solution of BFS method with the Matlab coding.

Table (IV). Maximum voltage errors of the 37-bus system

Line voltage	V_{AB}	V_{BC}	V_{CA}
Max voltage error (V)	0.2386	0.2693	0.2389
Max voltage error (pu)	4.97×10^{-5}	5.61×10^{-5}	4.98×10^{-5}

Table (V). Power loss comparisons of the IEEE 37-bus system

Losses	Phase A	Phase B	Phase C	Total	Unit
Power loss (IEEE solution)	26.671	13.804	20.088	60.563	kW
Power loss (Calculation)	26.669	13.804	20.087	60.560	kW
Power mismatch	2.000	0.300	0.900	3.200	W
VAR loss (IEEE solution)	18.769	9.953	17.733	46.455	kVar
VAR loss (Calculation)	18.768	9.952	17.734	46.454	kVar
VAR mismatch	1.200	1.300	-1.200	1.200	Var

A stability index is calculated as [24]:

$$SI = \frac{4\, r_b\, P_r}{|V_s \cos(\theta_b - \theta_s + \theta_r)|^2} \tag{11}$$

where rb is the branch resistance, Pr is the receiving end power of the branch, Vs is the sending end voltage magnitude, θb, θs, and θr are the phase angles of the branch impedance, sending end voltage , and receiving end voltage, respectively.

B. Performance of the 12-Bus System with DG Support

The 12-bus DS is solved with different DG types, including types 1, 2 and 3. The PSO determines the optimal place and size of the DG for each types. For DG type 1 where the DG is assumed to supply only reactive power, the APSO algorithm determines the optimal DG location at bus number 9 and the optimal size is 210.2077 kVAR. The system power loss in this case is 12.584 kW. The reactive power support reduces the power loss by 39.24% compared with losses of the base case. Moreover, the voltage profile and stability index are enhanced at all nodes (except the slack) as shown in Fig. 4 and Fig. 5, respectively. The minimum voltage at bus 12 with a value of 0.9563 pu.

With DG type 2 where only active power is injected to the system, the optimal location and size of the DG are bus number 9 with a capacity of 235.5021 kW with a corresponding system loss of 10.7744 kW. The losses are reduced by 47.97% compared to the base case losses. The voltage profile and the stability index are improved as shown in Fig. 6 and Fig. 7, respectively. The minimum voltage 0.9835 pu at bus 7.

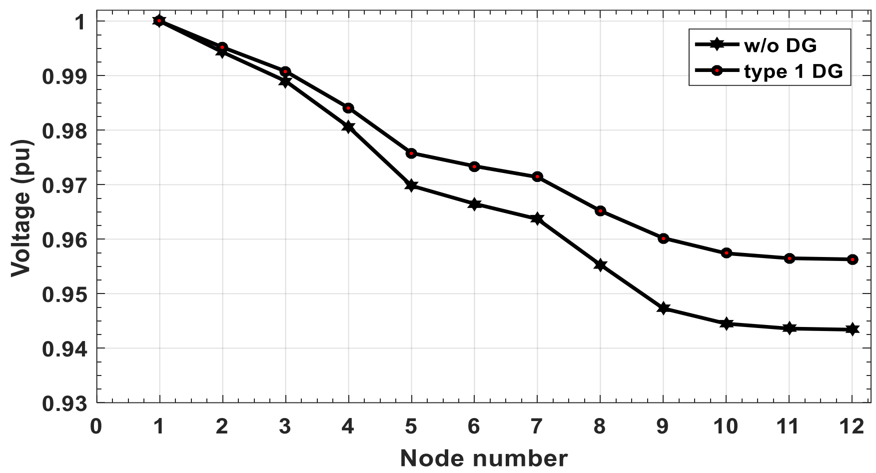

Fig. (4). Voltage profile of the 12-bus DS with DG type 1.

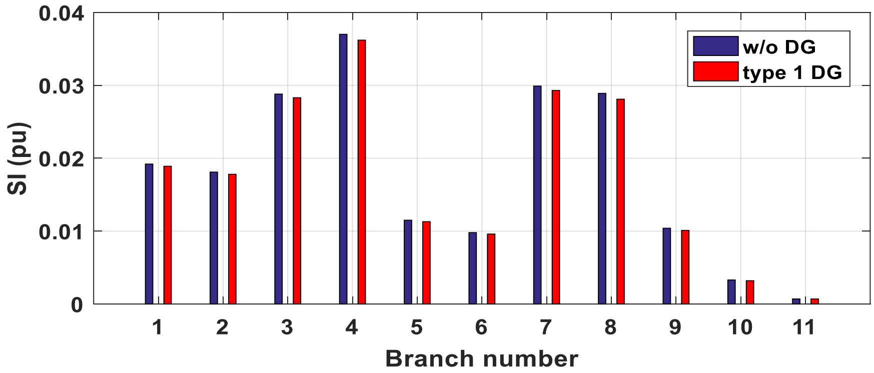

Fig. (5). Stability index of the 12-bus DS with DG type 1.

When the DG is of type 3 where both active and reactive power can be supplied to the DS, the power losses are much reduced compared to the previous DG types. In this case, the total losses are 3.1561 kW with a reduction of 84.76%. The optimal location is at bus number 9 with an optimal size of 232.4853 kW and 212.191 kVAR. The enhanced voltage profile is shown in Fig. 8, and the minimum voltage becomes 0.9908 pu at bus number 7. The corresponding stability index is shown in Fig. 9.

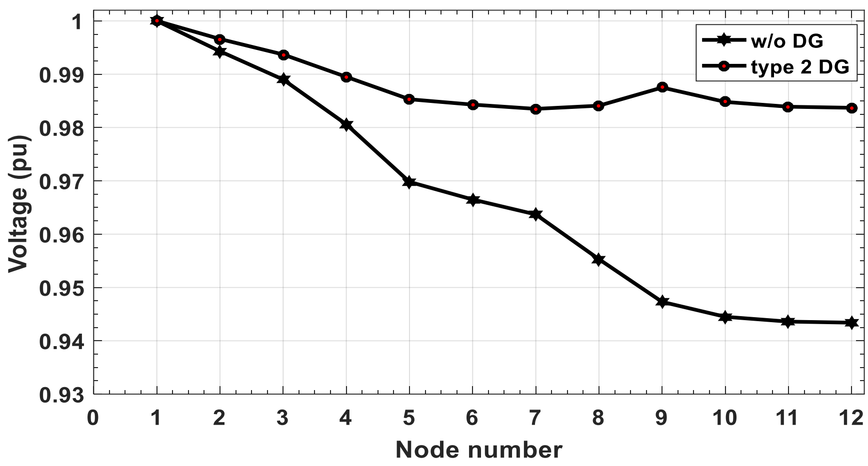

Fig. (6). Voltage profile of the 12-bus DS with DG type 2.

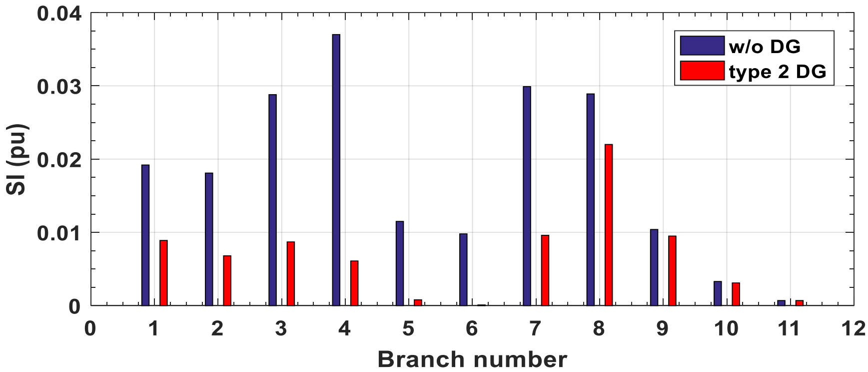

Fig. (7). Stability index of the 12-bus DS with DG type 2.

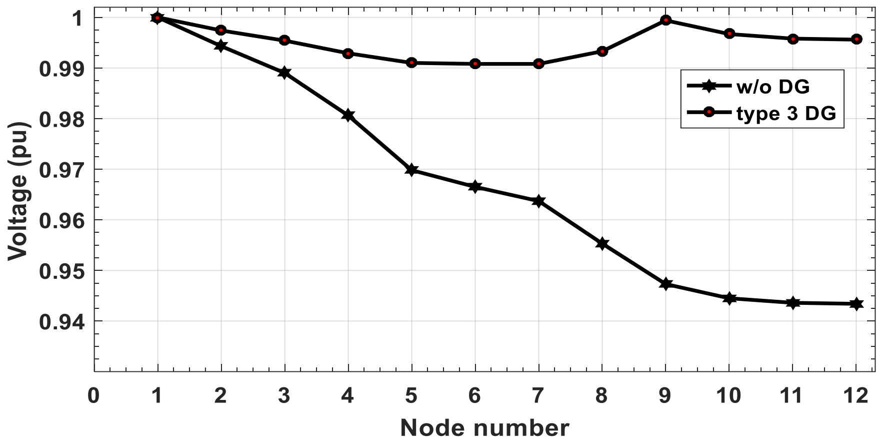

Fig. (8). Voltage profile of the 12-bus DS with DG type 3.

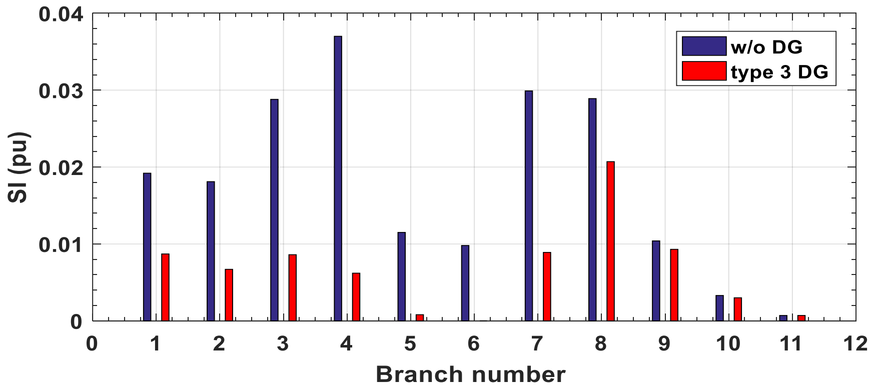

Fig. (9). Stability index of the 12-bus DS with DG type 3.

C. Performance of the 37-Bus System with DG Support

The proposed APSO algorithm is applied to the IEEE 37-bus systems for optimum allocation of DG sources including types 1, 2 and 3. With DG type 1, the APSO determines the optimal location for the DG at bus number 22 with an optimum value of 484.4182 kVAR. The corresponding active and reactive power losses for each phase as well as the total system losses are listed in Table VI. The losses are reduced for each phase and as a result, the total losses are reduced from 60.5598 kW and 46.4538 kVAR for the base case to 27.9085 kW and 13.8245 kVAR after DG type 1 has been installed. A reduction loss of 53.92% and 70.24% for active and reactive power, respectively, is achieved. The voltage profile is shown in Fig. 10 with improvement for all three line voltages.

For the second type of DG, the optimal size and location are determined by APSO as 500.7921 kW at bus number 22. The phase losses as well as the total losses are reduced as listed in Table VI as compared to the base case and they are slightly bigger than that of the first case of the DG type 1. For the second case, a loss reduction of 53.30% and 69.63% has been achieved for active and reactive power loss, respectively. The voltage distribution of the system is shown in Fig. 11.

In the third type of DG, both active and reactive power have been optimized by APSO. After Applying APSO with DG type 3, the optimal size is determined as 496.2977 kW and 236.5494 kVAR with an optimal location at bus number 22. In this case the phase and total power losses are reduced remarkably. The total active power loss is reduced by 65.40% while the reactive power loss is reduced by 85.52%. The corresponding voltage distribution is shown in Fig. 12 with a bigger improvement compared to previous DG types.

The stability index for the three cases with the base case are listed in Table VII. As the IEEE 37-bus system is light loaded and some buses are not loaded at all, the SI is very small and the change due to the installation of different DG types is also small.

Table (VI). System losses of the IEEE 37-bus system with different DG types

DG type	Losses (kW, kVAR)				DG	
	Phase A	Phase B	Phase C	Total	Size	Location
No DG	26.6690 18.7678	13.8037 9.9517	20.0871 17.7342	60.5598 46.4538	--	--
Type 1	11.6682 6.0535	8.2494 3.4510	7.9909 4.3200	27.9085 13.8245	484.4182 kVAR	22
Type 2	12.0278 6.4165	8.4029 3.5345	7.8496 4.1581	28.2804 14.1090	500.7921 kW	22
Type 3	7.8008 2.6917	5.9231 0.9875	7.2314 3.0490	20.9553 6.7282	496.2977 kW 236.5494 kVAR	22

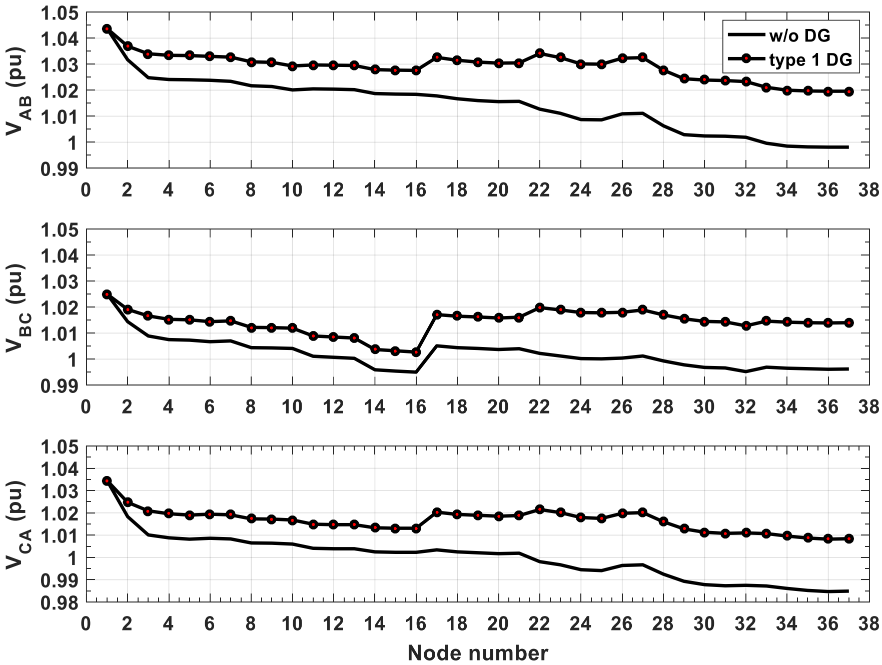

Fig. (10). Line voltages of the IEEE 37-bus system with DG type 1 installation.

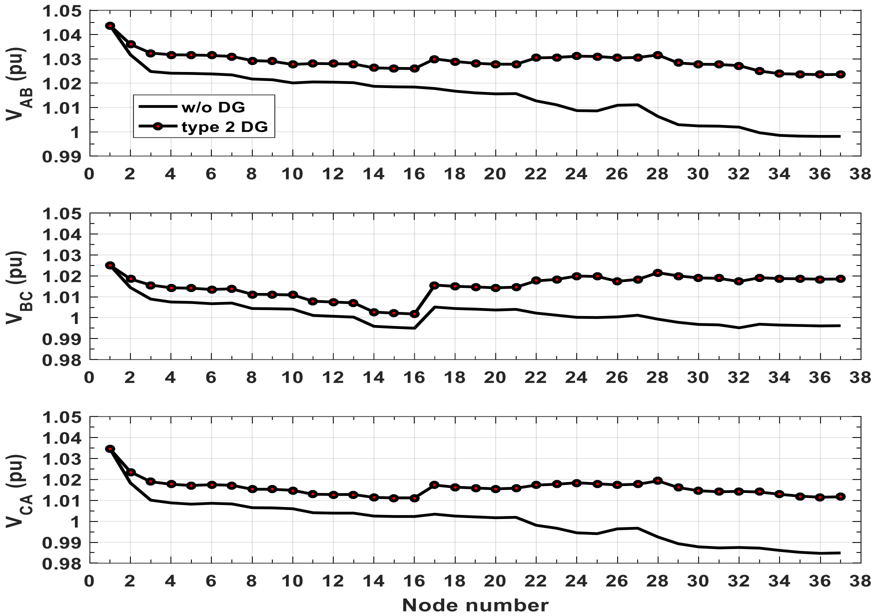

Fig. (11). Line voltages of the IEEE 37-bus system with DG type 2 installation.

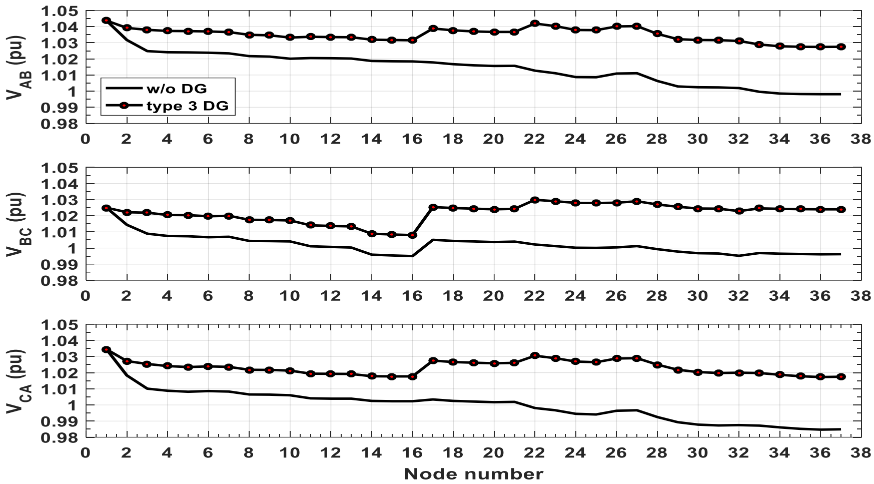

Fig. (12). Line voltages of the IEEE 37-bus system with DG type 3 installation.

Table (VII). Stability index of the IEEE 37-bus system with different DG types

DG type	SI_{max}		
	SI_A	SI_B	SI_C
No DG	0.0146	0.0125	0.0256
Type 1	0.0139	0.0120	0.0258
Type 2	0.0140	0.0120	0.0258
Type 3	0.0137	0.0118	0.0257

5. Conclusions

The paper discussed the integration of distribution generations to both balanced and unbalanced three-phase distribution systems to account for their benefits to the grid in terms of increasing load-ability, increasing system stability and reducing the power system losses. An adaptive particle swarm optimization technique is used to determine the best amount of the distributed generation at specific locations to reduce the system losses. Three types of distributed generations are adopted. The first distributed generation type supplies only reactive power while the second type supplies active power and the third type supplies both active and reactive power. For all types of distributed generations, the voltage profiles are enhanced and the total system losses are reduced. Using adaptive PSO decreases running time of the optimization compared to the ordinary PSO.

6. References

[1]M. Rahmani-Andebili, "Simultaneous placement of DG and capacitor in distribution network," Electr. Power Syst. Res., vol. 131, 2016.

[2]M. Mehdinejad, B. Mohammadi-Ivatloo, R. Dadashzadeh-Bonab, and K. Zare, "Solution of optimal reactive power dispatch of power systems using hybrid particle swarm optimization and imperialist competitive algorithms," Int. J. Electr. Power Energy Syst., vol. 83, pp. 104–116, 2016.

[3]R. Viral and D. K. Khatod, "An analytical approach for sizing and siting of DGs in balanced radial distribution networks for loss minimization," Electr. Power Energy Syst., vol. 67, pp. 191–201, 2015.

[4]A. Eid, "Utility integration of PV-wind-fuel cell hybrid distributed generation systems under variable load demands," Int. J. Electr. Power Energy Syst., vol. 62, pp. 689–699, Nov. 2014.

[5]S. Elsaiah, M. Benidris, and J. Mitra, "Analytical approach for placement and sizing of distributed generation on distribution systems," IET Gener. Transm. Distrib., vol. 8, no. 6, pp. 1039–1049, 2014.

[6]S. N. G. Naik, D. K. Khatod, and M. P. Sharma, "Analytical approach for optimal siting and sizing of distributed generation in radial distribution networks," IET Gener. Transm. Distrib., vol. 9, no. 3, pp. 209–220, 2015.

[7]A. K. Bohre, G. Agnihotri, and M. Dubey, “Optimal sizing and sitting of DG with load models using soft computing techniques in practical distribution system,” IET Gener. Transm. Distrib., vol. 10, no. 11, pp. 2606–2621, 2016.

[8]M. Vatani, D. S. Alkaran, M. J. Sanjari, and G. B. Gharehpetian, “Multiple distributed generation units allocation in distribution network for loss reduction based on a combination of analytical and genetic algorithm methods,” IET Gener. Transm. Distrib., vol. 10, no. 1, pp. 66–72, 2016.

[9]C. Wu, Y. Lou, P. Lou, and H. Xiao, “DG location and capacity optimization considering several objectives with cloud theory adapted GA,” Int. Trans. Electr. Energy Syst., vol. 24, pp. 1076–1088, 2014.

[10]N. Kanwar, N. Gupta, K. R. Niazi, A. Swarnkar, and R. C. Bansal, “Simultaneous allocation of distributed energy resource using improved particle swarm optimization,” Appl. Energy, vol. 185, pp. 1684–1693, 2017.

[11]H. S. Ramadan, A. F. Bendary, and S. Nagy, “Particle swarm optimization algorithm for capacitor allocation problem in distribution systems with wind turbine generators,” Int. J. Electr. Power Energy Syst., vol. 84, pp. 143–152, 2017.

[12]C. Shang, D. Srinivasan, and T. Reindl, “An improved particle swarm optimisation algorithm applied to battery sizing for stand-alone hybrid power systems,” Int. J. Electr. Power Energy Syst., vol. 74, pp. 104–117, 2016.

[13]T. Kerdphol, Y. Qudaih, and Y. Mitani, “Optimum battery energy storage system using PSO considering dynamic demand response for microgrids,” Int. J. Electr. Power Energy Syst., vol. 83, pp. 58–66, 2016.

[14]B. Bhattacharyya and S. Raj, “PSO based bio inspired algorithms for reactive power planning,” Int. J. Electr. Power Energy Syst., vol. 74, pp. 396–402, 2016.

[15]W. S. Tan, M. Y. Hassan, H. A. Rahman, P. Abdullah, and F. Hussin, “Multidistributed generation planning using hybrid particle swarm optimisationgravitational search algorithm including voltage rise issue,” IET Gener. Transm. Distrib., vol. 7, no. 9, pp. 929–942, 2013.

[16]A. F. A. Kadir, A. Mohamed, H. Shareef, A. A. Ibrahim, T. Khatib, and W. Elmenreich, “An improved gravitational search algorithm for optimal placement and sizing of renewable distributed generation units in a distribution system for power quality enhancement,” J. Renew. Sustain. Energy, vol. 6, no. 3, pp. 1–17, 2014.

[17]T. Niknam, M. Bornapour, and A. Gheisari, “Combined heat, power and hydrogen production optimal planning of fuel cell power plants in distribution networks,” Energy Convers. Manag., vol. 66, pp. 11–25, 2013.

[18]M. Kefayat, A. L. Ara, and S. A. N. Niaki, “A hybrid of ant colony optimization and artificial bee colony algorithm for probabilistic optimal placement and sizing of distributed energy resources,” Energy Convers. Manag., vol. 92, pp. 149–161, 2015.

[19]D. Das, H. S. Nagi, and D. P. Kothari, “Novel method for solving radial distribution networks,” IEE Proc. Gener. Transm. Distrib., vol. 141, no. 4, pp. 291–298, 1994.

[20]“Radial Distribution Test Feeders.” [Online]. Available: https://site.ieee.org/pes-testfeeders/resources/.

[21]M. Abdel-Akher and K. Mahmoud, “Implementation of three-phase transformer model in radial load-flow analysis,” Ain Shams Eng. J., vol. 4, no. 1, pp. 65–73, 2013.

[22]W. H. Kersting, Distribution System Modeling and Analysis, Third Edit. Boca Raton, FL: CRC Press, 2012.

[23]J. Radosavljevic, Metaheuristic optimization in power engineering, 1st Ed. London: IET, 2018.

[24]M. M. Aman, G. B. Jasmon, H. Mokhlis, and A. H. A. Bakar, “Optimal placement and sizing of a DG based on a new power stability index and line losses,” Electr. Power Energy Syst., vol. 43, pp. 1296–1304, 2012.

تخفيض الفقد القدرة الفاعلة وغير الفاعلة في شبكات التوزيع ثلاثية الطور باستخدام سرب الجزيئات المعدلة لتحقيق الأمثلية

أحمد محمد عيد

قسم الهندسة الكهربائية- كلية الهندسة في عنيزة- جامعة القصيم

A.MOHAMAD@qu.edu.sa

(قدم للنشر في ٢٢/٧/٢٠١٩؛ وقبل للنشر في ٨/١٢/٢٠١٩)

ملخص البحث. هذا البحث يستخدم طريقة سرب الجسيمات المعدلة ليقلل الفواقد الكهربائية فى انظمة التوزيع ثلاثية الطور الطولية المتزنة وغير المتزنة . لقد استخدم برنامج Matlab لحل نظام IEEE ذو الخمس اثنى عشرة عقدة والسبع والثلاثون عقدة باستخدام طريقة المسح الامامى/الخلفى. تم استخدام ثلاثة من السيناريوهات لاضافة مولد موزع عند العقد المناسبة للنظام. فى السيناريو الاول تم اعتبار ان المولد الموزع ينتج طاقة غير فعالة فقط ممثلا اضافة المكثفات او معوضات القدرة غير الفعالة، اما فى السيناريو الثانى فقد اعتبر ان المولد الموزع يضخ طاقة فعالة فقط. أما فى السيناريو الثالث فان المولد المزع يضخ كل من طاقة فعالة وغير فعالة فى نفس الوقت ممثلا بذلك التوليد المقترن. وهنا يقوم برنامج أمثلة سرب الجسيمات المعدل من تحديد مقدار الطاقة الفعالة او غير الفعالة لكل سيناريو ليقلل الفواقد الكهربائية لنظامى التوزيع. لقد اثبتت النتائج فعالية برنامج أمثلة سرب الجسيمات المعدل فى تحديد الكمية المطلوبة من طاقة المولد الموزع لتحسين اداء انظمة التوزيع وتقليل فواقدها الكهربائية وتحسين قيم الجهود فى الاماكن المختلفة وكذلك تحسين الاتزان للشبكة الكهربائية للنظامين.