Palestine Technical University Research Journal, 2023, 11(01), 01-15

IEEE-69 Distribution Network Performance Improvement by Simultaneously Optimal Distributed Generation Sizing and Location Using PSO Algorithm

عن طريق تحديد الحل الامثل لحجم وموقع مولد التوزيع IEEE-69تحسين أداء شبكة التوزيع باستخدام خوارزمية حركة الجزيئات

Ola Subhi Waheed Badran[1*]

علا صبحي وحيد بدران[1*]

[1]Department of Electrical Engineering-industrial automation, Palestine Technical University – Kadoorie (PTUK), Tulkarm, Palestine

[1]قسم الهندسة الكهربائية-الاتمته الصناعية، جامعة فلسطين التقنية - خضوري، طولكرم، فلسطين

Received: 06/03/2022 **Accepted: 18/07/2022** **Published: 30/03/2023**

Abstract: Integrated distributed generation (DG) to the network is the most popular technique to improve the network performance since DG sizing and location could reduce the power loss. However, using a non-optimal DG sizing and location could cause voltage fluctuation and power loss increase. Therefore, it is very important to develop a suitable optimization method that determines the optimal DG sizing and location. This research proposes a new strategy that leads to finding the simultaneous optimal solution involving both the optimal DG sizing and location. The proposed method aims to reduce the overall fitness function that taking into account both the voltage profile index and the power loss reduction. The particle swarm optimization (PSO) technique is the method that is used in this work. MATLAB simulations carried out on IEEE 69-bus radial distribution networks were used to prove the ability of the suggested method. The results obtained demonstrate the effectiveness of the presented method to determine the simultaneously optimal sizing and location of the DG units that minimize the overall power loss and improve the overall voltage profile.

Keywords: Distribution Network, Distributed Generation location and sizing, Optimal Solution, Voltage Profile, Power Loss.

المستخلص: يعد دمج مولدات التوزيع مع شبكة التوزيع هو الأسلوب الأكثر شيوعًا لتحسين أداء الشبكة لأن تحديد حجم وموقع مولدات التوزيع يمكن أن يقلل من فقد الطاقة. ومع ذلك ، فإن الحصول على قيمة غير مثالية لحجم وموقع مولدات التوزيع يمكن أن يتسبب في تذبذب الجهد وزيادة فقدان الطاقة. لذلك ، من المهم جدًا تطوير طريقة تحسين مناسبة تحدد حجم وموقع مولدات التوزيع الأمثل. يقترح هذا البحث إستراتيجية جديدة تؤدي إلى إيجاد الحل الأمثل المتزامن الذي يتضمن الحجم والموقع الأمثل لمولدات التوزيع. الهدف من الطريقة المقترحة هو تقليل دالة الاقتران التي تتضمن كلاً من مؤشر معامل الجهد ومؤشرتقليل فقد الطاقة. التقنية المستخدمة في هذا العمل هي خوارزمية حركة الجزيئات. لاثبات فعالية الطريقة المقترحة، تم استخدام عمليات محاكاة لبرنامج الماتلاب على شبكة التوزيع الشعاعي 69 ناقل. توضح النتائج التي تم الحصول عليها فعالية الطريقة المقدمة لتحديد الحجم والموقع الأمثل المتزامن لوحدات مولدات التوزيع التي تقلل من فقد الطاقة الكلي وتحسن ملف الجهد الكلي.

* Corresponding Author E-mail: o.badran@ptuk.edu.ps

الكلمات المفتاحية: شبكة التوزيع، موقع وحجم مولدات التوزيع، الحل الأمثل، معامل الجهد، فقدان الطاقة.

INTRODUCTION:

Employment of DG is one of the innovative technological opportunities create due to electric utility infrastructure recently that achieved a variety of benefits. Among the benefits of DG related to both customers and utility, there are some ways to solve DG problems to achieve the optimality of the power system operation and development. One of the ways is to integrate DG into the network system improving the network performance. In (Ayodele et al., 2015), the power system operation as well as the optimal location and sizing of the DGs were selected to minimize the power loss based on GA. Asynchronous, induction, and synchronous generators were the classes considered as the optimization problem variables. In order to test the algorithm applicability, the IEEE-14 network was used. The results improved the effectiveness of the proposed method in finding both the sizing and location of the DGs that reduce power loss in the network. While in (Emiroğlu et al.), a multi-objective methodology was proposed to find the optimal DGs sizing and placement in a network system. The aim was to reduce power loss and improve the voltage profile of the network. A mixed-integer nonlinear genetic algorithm based on both continuous and discrete variables were used to solve the optimization problem. IEEE-69 network was used and the results show that both power loss and voltage profile were improved. Moreover in (Syahputra et al., 2015), a new method was proposed in order to modify the network performance by integrating DGs into the system using the PSO algorithm. The objectives were to minimize the power losses and modified the loading balance in addition to voltage profile improvement. The method was tested in a different IEEE test system and the results obtained were encouraging. Furthermore, the authors in (Avchat & Mhetre, 2020), proposed a method that aims to minimize the total power loss by modifying the PSO algorithm. The simulation results show that the modified PSO obtained the minimum power loss and the best voltage profile compared to other heuristic search techniques. While the author in (Karuppiah, 2021), evaluated the active and reactive power loss, voltage stability enhancement in addition to power system reliability and security after integrated DGs into the network. Different types of DGs were placed based on the Voltage Stability Index (VSI) using the Differential Evolution (DE) algorithm. The simulation results showed that integrated DGs into the system obtained better results compared to the system without DGs.

A new technique was proposed by (Anwar & Pota, 2012) based on a heuristic method that uses quadratic curve fitting and sensitivity analysis to determine the DGs sizing and location. In addition, a heuristic method based on the power loss index has been presented for multiple DGs unit locations. A multi-phase and unbalanced in nature IEEE test distribution systems were carried out. The deep analysis approved that obtaining the optimal size and location of the DGs improves the steady-state bus voltage and reduces the power loss resulting in improving the efficiency and stability of the system. Moreover in (Pisica et al., 2009), a comparison between GA and nonlinear optimization was proposed for finding the optimal location and sizing of the DG in the network. The fitness function includes the investment cost and the power loss. The method was tested on the IEEE-69 network. The study shows the importance of finding the best suited location and the optimal size of DGs. While in (Singh et al., 2015), effective technique and various indices were tested to find the best placement and size of the DGs units in order to minimize both voltage deviation and power loss. IEEE-33 bus is the test system that was used. The method was equipped to work in the real-time operation and aimed to execute the program in a fast way. The results show the feasibility of finding the DG placement according to the proposed techniques. In addition, in (Khoa et al., 2006) a new algorithm based on primal-dual interior point was presented for solving nonlinear optimal power flow problems. This aimed to minimize the line loss by optimizing the DGs sizing and location. A nonlinear manner was used to solve the inequality and equality constraints based on the Karush-Kuhn-Tucker statuses. Both 10-bus and 42-bus systems were simulated by MATLAB to present the line loss index. The results were encouraging.

A new methodology by (Yang et al., 2021) was presented to solve the energy consumption and environmental pollution problems through the development of renewable energy DGs. A multi objective function based on PSO was presented to handle with pollution emissions, power loss, DG costs, and voltage profile. IEEE 33-bus and 69-bus were used to test the effectiveness of the proposed methodology. the results proved the feasibility of the work. While in (Ha et al., 2020) a new method based on a hybrid algorithm between GA and PSO was presented to find the optimal sitting of DGs that aims to minimize both active and reactive power loss and voltage regulations improvement. The study was performed on different networks. A multi objectives optimization with weight factors was proposed to avoid human decision-making interference in the optimization procedure. The proposed method shown a better result in compare with other works. An effective methodology to find the best sitting and sizing of the DGs in the network was proposed by (Karunarathne et al., 2021) to minimize the power losses and improve the voltage profile in an active network with several soft open points. The method was carried out on an IEEE 33 bus test system with 3 DGs and 5 soft open points. The findings results proved that using DGs with soft open points obtained better results than without using them.

This work leads to find the optimal simultaneous solution that combines the DG sizing and location. The main objectives of this paper are to reduce the total power loss and improve the voltage profile index. The results of other related works were compared to the results of our proposed approach.

OBJECTIVE FITNESS AND CONSTRAINTS:

The proposed methodology aims to simultaneous optimizing the DG sizing and location to minimize distribution network power loss and voltage profile index.

The fitness function is as the following:

$$F_R = (P_{loss}^R + IVD) \quad (1)$$

The power loss is given by:

$$P_{loss} = \sum_{N=1}^{M} (R_N \times |I_N|^2) \quad (2)$$

where, P_{loss}: is the distribution power loss power; M: is number of branches; R_N: is the resistance of branch; I_N: is the current in branch.

The definition of the Voltage Profile Index is as follows:

$$IVD = max_{i=2}^{n} \frac{(|V_1|-|V_i|)}{|V_1|} \quad (3)$$

where, V_1: is the nominal voltage; V_i: is the voltage at bus i ; $i = 2, 3, \cdots, nbus.$

The proposed optimization method must fulfill the following constraints:

The Distributed Generator Capacity:

$$P_i^{min} \leq P_{DG,i} \leq P_i^{max} \quad (4)$$

where, P_i^{max} and P_i^{min}: are the limitations of the DG size.

Injection Power:

$$\sum_{i=1}^{k} P_{DG,i} < (P_{Load} + P_{loss}) \quad (5)$$

where, k: is the number of the DG; P_{loss}: is the total active power losses of the network; P_{Load}: is the network active power load.

Balance power:

$$\sum_{i=1}^{k} P_{DG,i} + P_{Substation} = P_{Load} + P_{loss} \quad (6)$$

Both the supplied power and the load power should be equal.

Magnitude Voltage:

$$V_{min} \leq V_{bus} \leq V_{max} \quad (7)$$

The 0.95 and 1.05 are the limitation ranges that each bus voltage should be within (Rahim et al., 2019).

Radial Configuration:

The distribution network must be in radial configuration any time and so a MATLAB function called graph theory is used:

$$TF = graphissap\_ntree(G) \quad (8)$$

$$TF = \begin{Bmatrix} 1 & radial \\ 0 & not\_radial \end{Bmatrix} \quad (9)$$

where, G: is the network.

Isolation load:

All nodes must be energized in order to sure that power connected to each node.

PROPOSED STRATEGY:

Simultaneous DG sizing and location:

This section discusses the main goal of this paper that to minimize the total power loss and improve the voltage profile index. PSO is the meta-heuristic approach used in this work. The description details of the PSO algorithm were presented in (Badran et al., 2018).

The steps of the proposed approach for DG sizing and location using PSO are as follows:

Step 1: The input data are determined, encompassing the bus load and voltage, and line impedance, alongside the PSO parameters.

Step 2: Generate an array of random particles with random positions and velocities. Each particle represents DG location L_{DG} and DG size P_{DG} that fulfill the set limitations and constraints $(L\&E)$ as follows:

$$x = \begin{bmatrix} L_{DG11}, L_{DG12}, \cdots, L_{DG1\mathrm{n}}, P_{DG11}, P_{DG12}, \cdots, P_{DG1K} \\ L_{DG21}, L_{DG22}, \cdots, L_{DG2\mathrm{n}}, P_{DG21}, P_{DG22}, \cdots, P_{DG2K} \\ \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \\ L_{DG\mathrm{m}1}, L_{DG\mathrm{m}2}, \cdots, L_{DG\mathrm{mn}}, P_{DGm1}, P_{DGm2}, \cdots, P_{DGmK} \end{bmatrix} \quad (10)$$

where, m = indicates the population size.

n = is the number of the switches.

K = number of DG.

Step 3: Evaluate the fitness value in equation (1) for each particle using distributed load flow based on Newton – Raphson method.

Step 4: Each particle updates its position (DG sizing and location) and velocity based on its own searching experience called P_{best} and on the experience from the other particle called G_{best}. The update of the particles' position and velocity is done using the following equations:

$$x_a^{b+1} = x_a^b + x_a^{b+1} \quad (11)$$

$$v_a^{b+1} = W v_a^b + c_1 r_1 \times \left(P_{best,a} - x_a^b\right) + c_2 r_2 \left(G_{best,a} - x_a^b\right) \quad (12)$$

$$W = w_{max} - \frac{w_{max} - w_{min}}{iter_{max}} \times iter \quad (13)$$

where, x_a^b and x_a^{b+1} = the current position of the particle i at iteration b and $b+1$, respectively.

v_a^b and v_a^{b+1} = the current velocity of the particle a at iteration b and $b+1$, respectively.

c_1 and c_2 = the weighting factors and equal to 0.7.

r_1 and r_2 = a random number between 0 and 1.

w_{max} and w_{min} = the maximum and the minimum weight of the inertia that equal to 0.9 and 0.4, respectively.

$iter$ and $iter_{max}$ = the current iteration number and the maximum iteration number, respectively.

Step 5: The process is repeated until the optimal or near optimal solution is found based on the minimum power loss and the best voltage profile index.

Step 6: Print out the best solution that represents the DGs sizing and locations, the power loss for this process, the voltage at each bus, and its fitness.

The simultaneous DG sizing and location are illustrated in Figure (1) using PSO algorithms. The proposed approach is programmed in MATLAB on a PC with 8-GB RAM and a 3.07 GHz CPU. For the application of the PSO algorithm, 100 populations and 300 iterations were set.

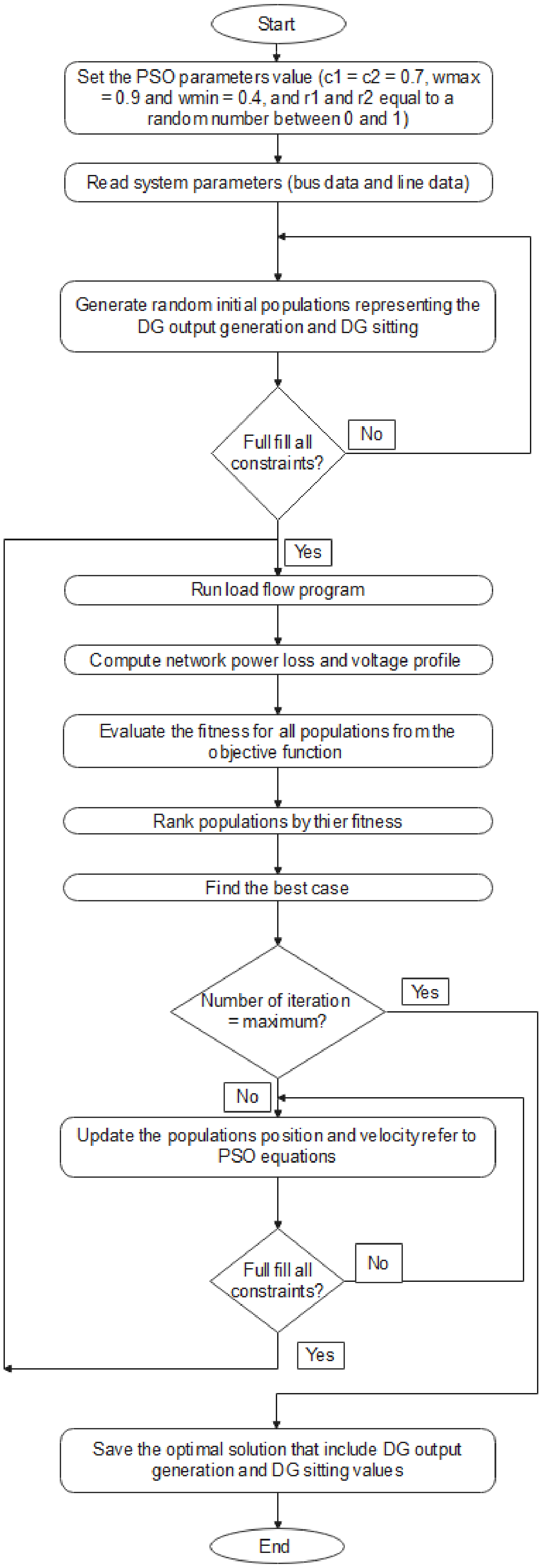

Figure (1). Simultaneous DG Sizing and Location Flowchart

SIMULATION RESULTS AND DISCUSSION:

This section presented the performance of the proposed methodology to solve DG sizing and location problems simultaneously. The proposed method was tested on an IEEE-69 bus distribution network as shown in Figure (2). The features of the test system are presented in Table (1). The complete bus and line data are included in (Baran & Wu, 1989). A mini-hydro generation was used as a DG in this test system with a 2 MW maximum capacity (Badran et al., 2020). Three mini-hydro DGs are used as the best case as it presented in (Aman et al., 2012; Rao et al., 2012). Optimal solutions were simultaneously obtained for the DG size and DG location.

Test system 1: IEEE 69-Bus:

The parameters of the IEEE 69-bus network are shown in Figure (2) and summarized in Table (1). All parameters are presented in details in (Aman et al., 2014).

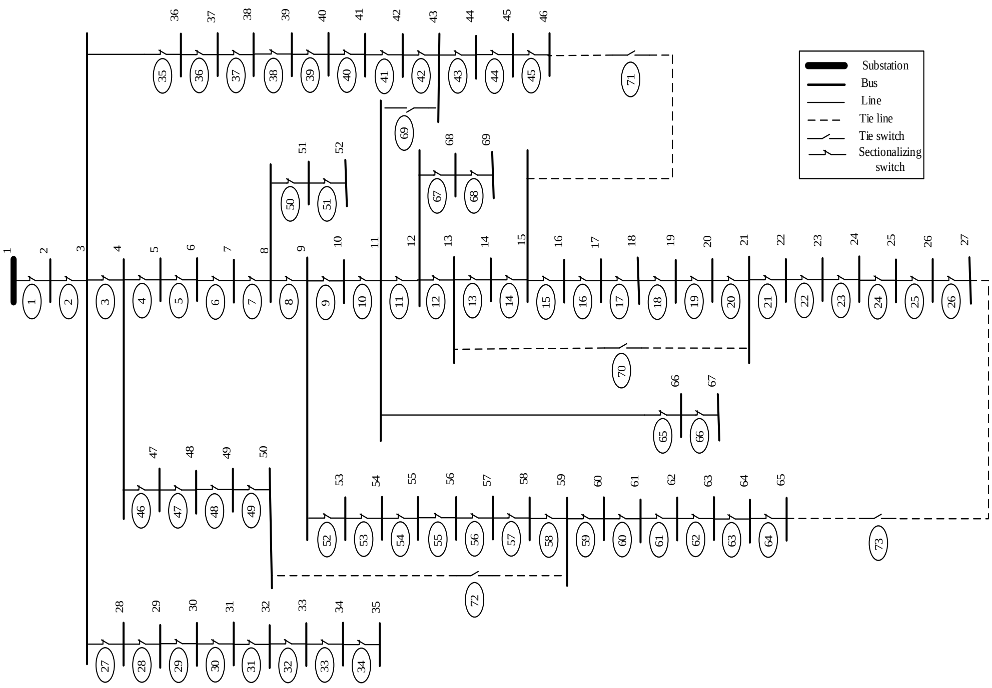

Figure (2). IEEE 69-Bus Distribution Network System

Table (1). IEEE 69-Bus Distribution Network System Features

Item	Value
Network switches number	73
Number of sectionalizing switches	68
Number of tie switches	5
Normally open switches	69, 70, 71, 72, and 73
Normally closed switches	1, 2, 3, ... , 68
Total real load demand	3801.89 kW

Network voltage	12.66 kV
Apparent power base value	100 MVA
Initial configuration power loss	224.56 kW
Lowest bus voltage	0.90929 p.u

Simultaneously DG sizing and location for IEEE 69 Bus System:

This section concentrates on improvement of the voltage profile and reduction of the power loss via Simultaneously DG sizing and location. Table (2) summarizes the test results obtained using a 69 bus network and compared to standard scenario (initial form). The locations of the DGs were set to be on buses number 66, 19, and 61 with DGs size of 0.51016 kW, 0.45159 kW, and 1.72778 kW respectively. The active power loss was reduced to 69.949 kW compared with initial case were it is 224.56 kW. That means the active power reduction equal to 68.84 %. The minimum bus voltage is improved to 0.97960 p.u compare to the initial form were the minimum bus voltage is 0.90929 p.u which violates the voltage constraints. It can be observed that the proposed scenario provides better results in comparison with the standard scenario.

Table (2). Proposed Method Results

Scenario	DG size (MW)	DG sitting	Fitness	Power loss (kW)	Loss reduction (%)	Bus voltage (p.u) min-max
Initial form	---	---	1.117200	224.56	---	0.90929–1
Simultaneous DG output generation and sittings	0.51016 0.45159 1.72778	66 19 61	0.347371	69.949	68.84	0.97960-1

The voltage profile for the proposed method using PSO is shown in Figure (3). The voltage magnitudes of all busses are improved in comparison with the standard scenario.

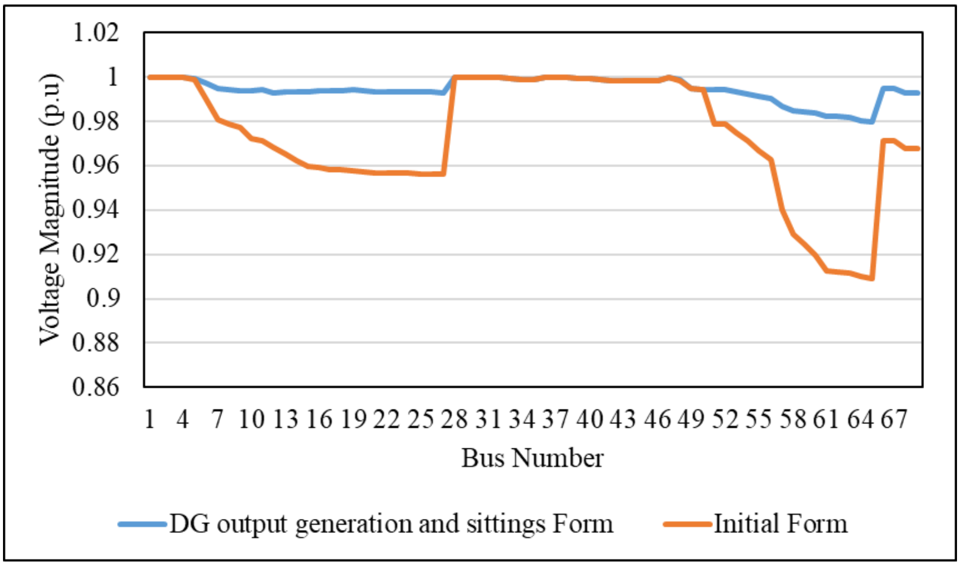

Figure (3). IEEE 69-Bus Radial Distribution Voltage Profile

For the purpose of verification of the robustness of our proposed approach, it was run for 100 times. It is evident that the PSO algorithm reported results that are almost equal in each run as shown in Figure (4). This means that PSO is strongly robust in finding the optimal solution for a complex problem such as simultaneously DG sizing and location.

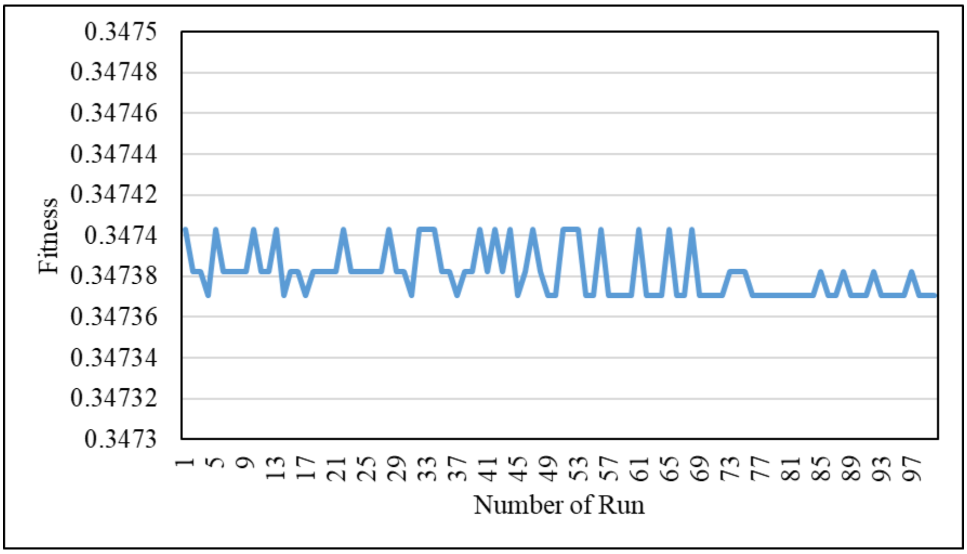

Figure (4). Robustness Test of IEEE 69-Bus Network

Based on the global cases for the proposed method (the best solution after running the program 100 times is called global solution), the global value convergence performance was also illustrated in Figure (5).

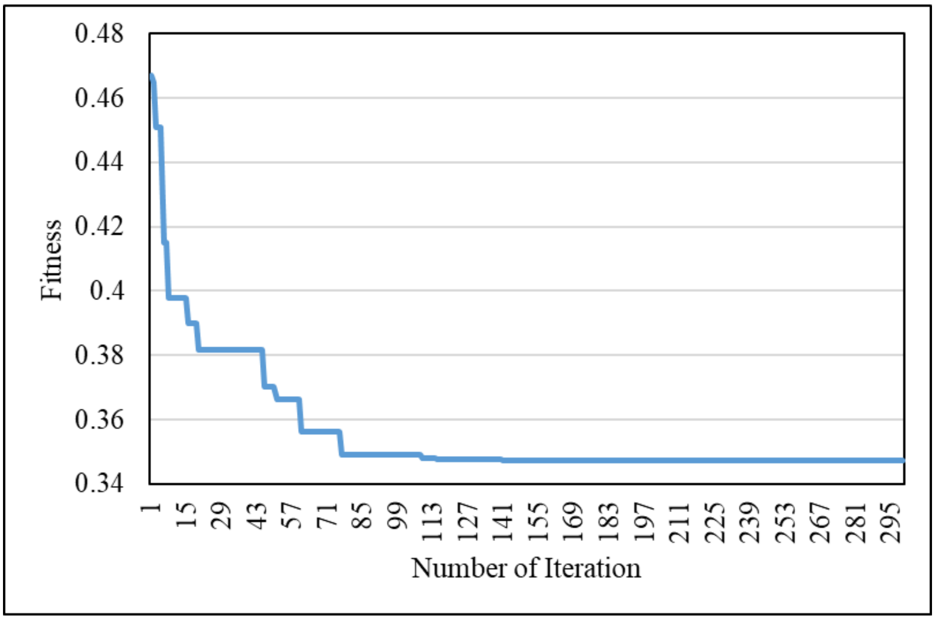

Figure (5). Convergence Performance of IEEE 69-Bus Network

The features of the proposed method were also compared to other previously published results are included in Table (3). It is clear that the presented method based on PSO shows better results in comparison with other algorithms.

Table (3). Comparison of Simulation Results of IEEE 69-Bus Network

Scenario	DG size (MW)	DG sitting	Power loss (kW)	Loss reduction (%)	Lowest bus voltage (p.u)
(Pisica et al., 2009)	0.736	62	73.76	67.15	0.9659
Using GA	0.519	18			
	0.809	61			
(Emiroğlu et al.)	0.6392	17			0.981
Using GA	0.1109	57	72.1	67.9%	
	1.7679	61			
(Duong et al.,	0.5239	18	70.1	68.78	0.9790
2019)	0.9365	49			
Using GA	1.7856	61			
(Duong et al.,	0.4290	18	70	68.82	0.9790
2019)	1.7405	61			
Using APC	0.3320	69			
	0.3435	60	97.3	56.6	0.958
(Elattar & Elsayed,	0.6100	63			
2020)	0.2742	65			
ALO					
(Elattar & Elsayed,	0.6500	61	72.6	67.67	0.967
2020)	0.1824	62			
SSA	0.2836	60			
(Al-Ammar et al.,	1.000	61	86.8	61.34	0.96
2021)	0.200	51			
ABC	0.3382	62			

DG output generation and sittings using PSO	0.51016	66	69.949	68.84	0.9796
	0.45159	19			
	1.72778	61			

CONCLUSION:

This work proposed a new methodology to determine the optimal solution of the DG sizing and location. The presented strategy aimed to minimize the power loss and find the best voltage profile index of the distribution network system. PSO is the heuristic method that was used in order to achieve the minimum value of the total fitness. The effectiveness of the proposed method has been verified on a 69-bus distribution system. The proposed method is effective and perfect to find the simultaneous optimal solution that combines the optimal DG sizing and location. The obtained were compared with other literature work and the proposed method get better results. Also the computational results showed that the performance of PSO exceeds that of other algorithms presented in the other literature work.

ACKNOWLEDGEMENTS:

The author would like to thank the Palestine Technical University-Kadoorie for their financial support to conduct this research.

Appendix:

Table (4). IEEE 69-Bus Test System Data

From bus	To bus	R (p.u)	X (p.u)	P (MW)	Q (MVAR)
1	2	0.000312	0.000749	0	0
2	3	0.000312	0.000749	0	0
3	4	0.000936	0.002246	0	0
4	5	0.015661	0.018343	0	0
5	6	0.228357	0.1163	0	0
6	7	0.237716	0.121104	0.0026	0.0022
7	8	0.057526	0.029324	0.0404	0.03
8	9	0.03076	0.015661	0.075	0.054
9	10	0.510995	0.168897	0.03	0.022
10	11	0.116799	0.038621	0.028	0.019
11	12	0.44386	0.146685	0.145	0.104
12	13	0.642643	0.212135	0.145	0.104
13	14	0.651378	0.215254	0.008	0.005
14	15	0.660113	0.218124	0.008	0.0055
15	16	0.122664	0.040555	0	0
16	17	0.233598	0.077242	0.0455	0.03
17	18	0.002932	0.000998	0.06	0.035
18	19	0.204398	0.067571	0.06	0.035
19	20	0.131399	0.043051	0	0
20	21	0.213133	0.070441	0.001	0.0006
21	22	0.008735	0.00287	0.114	0.081
22	23	0.099267	0.032818	0.005	0.0035
23	24	0.216065	0.071439	0	0
24	25	0.467195	0.154422	0.028	0.02
25	26	0.192731	0.063703	0	0
26	27	0.108064	0.035689	0.014	0.01
3	28	0.002745	0.006738	0.014	0.01
28	29	0.039931	0.097644	0.026	0.0186
29	30	0.248197	0.082046	0.026	0.0186
30	31	0.0438	0.014475	0	0

31	32	0.218998	0.072375	0	0
32	33	0.523473	0.175697	0	0
33	34	1.065664	0.352268	0.014	0.01
34	35	0.919666	0.304039	0.0195	0.014
3	36	0.002745	0.006738	0.006	0.004
36	37	0.039931	0.097644	0.026	0.01855
37	38	0.065699	0.076743	0.026	0.01855
38	39	0.018967	0.022149	0	0
39	40	0.001123	0.00131	0.024	0.017
40	41	0.454405	0.530898	0.024	0.017
41	42	0.193417	0.226048	0.0012	0.001
42	43	0.025581	0.029824	0	0
43	44	0.00574	0.007238	0.006	0.0043
44	45	0.067945	0.085665	0	0
45	46	0.000562	0.000749	0.03922	0.0263
4	47	0.002121	0.005241	0.03922	0.0263
47	48	0.053096	0.129964	0	0
48	49	0.180814	0.442425	0.079	0.0564
49	50	0.051287	0.125471	0.3847	0.2745
8	51	0.0579	0.029512	0.3847	0.2745
51	52	0.206519	0.069505	0.0405	0.0283
9	53	0.108563	0.05528	0.0036	0.0027
53	54	0.126657	0.064514	0.00435	0.0035
54	55	0.17732	0.090282	0.0264	0.019
55	56	0.17551	0.089408	0.024	0.0172
56	57	0.992041	0.332989	0	0
57	58	0.48897	0.164092	0	0
58	59	0.189798	0.062767	0	0
59	60	0.240898	0.073124	0.1	0.072
60	61	0.316642	0.161285	0	0
61	62	0.06077	0.030947	1.244	0.888
62	63	0.090469	0.046046	0.032	0.023
63	64	0.443299	0.225799	0	0
64	65	0.649506	0.330805	0.227	0.162
11	66	0.125534	0.038122	0.059	0.042
66	67	0.002932	0.000873	0.018	0.013
12	68	0.46133	0.152487	0.018	0.013
68	69	0.002932	0.000998	0.028	0.02
11	43	0.311963	0.311963	0.028	0.02
13	21	0.311963	0.311963		
15	46	0.623925	0.311963		
50	59	1.247851	0.623925		
27	65	0.623925	0.311963		

REFERENCES:

Al-Ammar, E. A., Farzana, K., Waqar, A., Aamir, M., Haq, A. U., Zahid, M., & Batool, M. (2021). ABC algorithm based optimal sizing and placement of DGs in distribution networks considering multiple objectives. *Ain Shams Engineering Journal, 12*(1), 697-708.

Aman, M., Jasmon, G., Bakar, A., & Mokhlis, H. (2014). Optimum network reconfiguration based on maximization of system loadability using continuation power flow theorem. *International Journal of Electrical Power & Energy Systems, 54*, 123-133.

Aman, M., Jasmon, G., Mokhlis, H., & Bakar, A. (2012). Optimal placement and sizing of a DG based on a new power stability index and line losses. International Journal of Electrical Power & Energy Systems, 43(1), 1296-1304.

Anwar, A., & Pota, H. (2012). Optimum allocation and sizing of DG unit for efficiency enhancement of distribution system. 2012 IEEE International Power Engineering and Optimization Conference Melaka, Malaysia.

Avchat, H. S., & Mhetre, S. (2020). Optimal placement of distributed generation in distribution network using particle swarm optimization. 2020 International Conference for Emerging Technology (INCET).

Ayodele, T., Ogunjuyigbe, A., & Akinola, O. (2015). Optimal location, sizing, and appropriate technology selection of distributed generators for minimizing power loss using genetic algorithm. Journal of Renewable Energy, 2015.

Badran, O., Jallad, J., Mokhlis, H., & Mekhilef, S. (2020). Network reconfiguration and DG output including real time optimal switching sequence for system improvement. Australian Journal of Electrical and Electronics Engineering, 17(3), 157-172.

Badran, O., Mokhlis, H., Mekhilef, S., & Dahalan, W. (2018). Multi-Objective network reconfiguration with optimal DG output using meta-heuristic search algorithms. Arabian Journal for Science and Engineering, 43(6), 2673-2686.

Baran, M. E., & Wu, F. F. (1989). Network reconfiguration in distribution systems for loss reduction and load balancing. IEEE Power Engineering Review, 9(4), 101-102.

Duong, M. Q., Pham, T. D., Nguyen, T. T., Doan, A. T., & Tran, H. V. (2019). Determination of optimal location and sizing of solar photovoltaic distribution generation units in radial distribution systems. Energies, 12(1), 174.

Elattar, E. E., & Elsayed, S. K. (2020). Optimal location and sizing of distributed generators based on renewable energy sources using modified moth flame optimization technique. IEEE Access, 8, 109625-109638.

Emiroğlu, S., Gümüş, T. E., & Yalçın, M. A. Optimal Dg Placement And Sizing In Distribution Systems By Using Mixed-Integer Genetic Algorithm.

Ha, M. P., Nazari-Heris, M., Mohammadi-Ivatloo, B., & Seyedi, H. (2020). A hybrid genetic particle swarm optimization for distributed generation allocation in power distribution networks. Energy, 209, 118218.

Karunarathne, E., Pasupuleti, J., Ekanayake, J., & Almeida, D. (2021). The optimal placement and sizing of distributed generation in an active distribution network with several soft open points. Energies, 14(4), 1084.

Karuppiah, N. (2021). Optimal siting and sizing of multiple type DGs for the performance enhancement of Distribution System using Differential Evolution Algorithm. Turkish Journal of Computer and Mathematics Education (TURCOMAT), 12(2), 1140-1146.

Khoa, T. Q. D., Binh, P., & Tran, H. (2006). Optimizing location and sizing of distributed generation in distribution systems. 2006 IEEE PES Power Systems Conference and Exposition.

Pisica, I., Bulac, C., & Eremia, M. (2009). Optimal distributed generation location and sizing using genetic algorithms. 2009 15th International Conference on Intelligent System Applications to Power Systems.

Rahim, M. N. A., Mokhlis, H., Bakar, A. H. A., Rahman, M. T., Badran, O., & Mansor, N. N. (2019). Protection coordination toward optimal network reconfiguration and DG sizing. IEEE Access, 7, 163700-163718.

Rao, R. S., Ravindra, K., Satish, K., & Narasimham, S. (2012). Power loss minimization in distribution system using network reconfiguration in the presence of distributed generation. IEEE transactions on power systems, 28(1), 317-325.

Singh, N., Ghosh, S., & Murari, K. (2015). Optimal Sizing and Placement of DG in a Radial Distribution Network using Sensitivity based methods. International Electrical Engineering Journal (IEEJ), 6(1), 1727-1734.

Syahputra, R., Robandi, I., & Ashari, M. (2015). Performance improvement of radial distribution network with distributed generation integration using extended particle swarm optimization algorithm. International Review of Electrical Engineering (IREE), 10(2), 293-304.

Yang, D., Jia, J., Wu, W., Cai, W., An, D., Luo, K., & Yang, B. (2021). Optimal Placement and Sizing of Distributed Generators Based on Multiobjective Particle Swarm Optimization. Frontiers in Energy Research, 9, 770342.