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A new approach for optimal sizing and allocation of distributed generation in power grids

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ABSTRACT

This paper presents a methodology for optimizing the allocation and sizing of distributed generators (DG) in electrical systems, aiming to minimize active power losses on transmission lines and maintain bus voltages within permissible limits. The approach consists of two stages. First, a sensitivity-based analysis is used to identify the optimal candidate bus or buses for DG placement. In the second stage, a new random number generation method is applied to determine the optimal DG sizing. Moreover, a ranking for the optimal locations and sizes is given in case the optimal location is unavailable in real-world scenarios. The proposed methodology is demonstrated through a straightforward algorithm and tested on the IEEE 14-bus and IEEE 30-bus networks. Numerical simulations in MATLAB illustrate the effectiveness of the proposed approach in finding the optimal allocation of DG and the amount of active power to be allocated at the candidate buses, considering the inequality constraints regarding voltage limits and DG allowable power. The paper concludes with results, discussions, and recommendations derived from the proposed approach.

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1. INTRODUCTION

A distributed generator (DG) is a power source connected to an electrical system that generates electricity in quantities of kilowatts or more. These generators primarily rely on renewable energy sources, such as wind, water, geothermal, solar irradiance, and biomass [1], [2]. Due to the depletion of fossil fuel reserves and the need to reduce CO2 emissions, the use of renewable energy sources has significantly increased over the past two decades. Optimistic projections suggest that renewable energy could contribute up to 85% of the total energy production by 2050 [3]. Distributed generators (DGs) are typically integrated into existing power systems, rather than being part of the original design. As a result, several technical and economic challenges may arise when determining the optimal allocation and sizing of DGs in the electrical grid. These challenges may include technical factors such as changes in active power flow, power losses, bus voltage levels, reliability, and stability, as well as non-technical factors like right-of-way issues and social concerns, among others [4].

Various methodologies have been proposed to investigate this problem. Moravej *et al.* [5] employed the Pareto strength optimization technique to determine the optimal DG size. At the same time, a genetic algorithm was used to determine the optimal location of DGs in radial distribution systems. Similarly, [6] employed a sensitivity analysis of the Jacobian matrix to determine the optimal DG placement. However, Dulău *et al.* [7] used the Newton-Raphson power flow method to calculate the active power losses at each bus while determining the best DG allocation in the electrical system. Shrivastava *et al*. [8] employed load flow analysis to determine the optimal size and location of DG; the proposed approach was applied to an IEEE 12-bus radial power system. The primary objective of the work was to enhance the voltage profile and reduce overall active power losses. Further improvements in overall system stability and reductions in system losses were discussed in [9]. Ghosh *et al.* [10] employed the cuckoo search algorithm (CSA) to identify the optimal locations and sizes for DG units in a radial distribution system. The IEEE 33-bus system has been studied to minimize active power losses, enhance quality and reliability, and improve the voltage profile due to the allocation of DG. A similar approach was implemented in [11], where a multi-leader particle swarm optimization technique was used to evaluate the reduction in power losses and minimize emission pollution due to the allocation of DG in the electrical system. The same methodology was also tested on the IEEE 33-bus radial distribution system, as detailed in [12]. Yang *et al.* [13] applied multi-objective particle swarm optimization (MOPSO) to the IEEE 33-bus and IEEE 69-bus systems to determine the optimal allocation and sizing of DG units.

Prakash and Lakshminarayana [14] employed particle swarm optimization (PSO) to determine the optimal sizing and location of DG units, aiming to minimize active power losses. The work in [15] focused on using PSO to enhance voltage stability and reduce power losses, which was tested in an IEEE 14-bus system. El-Ela *et al.* [16] employed both PSO and parallel cat swarm optimization (PCSO) to determine DGs' optimal sizing and placement. Karunarathne *et al.* [17] conducted a study aimed at reducing active power losses, improving voltage profiles, minimizing generation costs, and decreasing CO2 emissions associated with DGs. Elattar and Elsayed [18] used voltage source inverters (VSI) and PSO as optimization techniques to achieve optimal sizing and allocation of DGs. The modified moth flame optimization (MMFO) technique was applied in [19], while the ant colony algorithm (ACA) was used in [20]. Various indices, including the voltage deviation index (VDI), voltage stability index (VSI), and index vector method (IVM), were considered to minimize total active power losses and enhance the voltage profile, as introduced in [21]. Similar objectives using the dragonfly algorithm were presented in [22]. Azad *et al.* [23] addressed DGs' irregular and unstable output. The optimal sizing of DGs was achieved through Differential Evolution (DE), as introduced in [24], where the VSI was utilized to identify the optimal locations for DGs. Finally, the optimal location and sizing of DGs with minimum active power losses were determined using the bat algorithm (BA) based on the weighted sum method (WSM) in [25].

This paper uses sensitivity analysis to identify optimal candidate buses for the placement of DG. This analysis focuses on buses where the impact of real power losses, attributed to active power flow, has a maximum value. The optimal sizing of the DG is then determined using a new approach based on random number generation, facilitating rapid and effective convergence. This method accounts for both the voltage profile and the reduction of power losses in the electrical distribution system. The contribution of this paper is as follows: i) A Jacobian matrix-based formulation to analyze DG size impact on power flow in transmission lines; ii) A systematic framework is developed to find both optimal location and optimal size of DG in the power grid; iii) A descending order ranking of the best fit of optimal size of DG and location of the optimal bus from the power losses on transmission lines point of view is presented, i.e. from higher reduction achieved of power losses to the lowest reduction. To our knowledge, no other paper in the literature has provided this ranking system. This ranking system of buses is essential considering the possibility of unavailability of the optimal bus in real-world scenarios; other options may need to be further explored.

The rest of this paper is structured as follows: Section 2 presents the problem formulation, supported by mathematical equations. Section 3 presents the solution for optimal location and sizing, along with the associated algorithm. In section 4, numerical examples are provided to demonstrate the effectiveness of the proposed approach. Section 5 includes an analysis and discussion of the results. Eventually, the conclusion is presented in section 6.

2. PROBLEM FORMULATION

Integrating DG into an existing power system influences power flow and impacts factors such as overall power losses, voltage profiles, and system stability [26]. Minimizing active power losses plays a crucial role in enhancing the power system's efficiency, stability, reliability, and economic viability. As a result, lower active power losses directly correlate with reduced per-kilowatt-hour production costs. This study aims to minimize total active power losses while ensuring that voltage levels at system buses remain within acceptable limits. Mathematically, this objective can be formulated as (1).

$$Min.\{P_{l(total)}\} \quad (1)$$

Where P_l is the total active power losses [MW].

Subject to equality constraints as defined in (2) and (3).

$$P_i(V,\theta) = 0 \quad (2)$$

$$Q_i(V,\theta) = 0 \quad (3)$$

Where P_i is the active power value at bus i [MW], Q_i is the reactive power value at bus i [MVAr] and the inequality constraints as in (4) and (5).

$$|V|_i^{min} < |V|_i < |V|_i^{max} \quad (4)$$

$$P_{DG} \leq P_{DG(allowed)} \quad (5)$$

Where $|V|_i$ is the voltage magnitude at bus i [V], $|V|_i^{min}$ is the minimum limit of the voltage magnitude at bus i [V], $|V|_i^{max}$ is the maximum limit of the voltage magnitude at bus i [V], $P_{DG(allowed)}$ is allowed active power value of DG can be installed at a specific bus [MW].

The total active power losses and the permissible DG power at a given bus can be calculated using (6) and (7), respectively.

$$P_{l(total)} = \sum_{i=1}^{n} P_{li} \quad (6)$$

$$P_{DG(allowed)} \leq k_f . P_{Max} . Cap \quad (7)$$

Where P_{li} is the active power losses at the bus i [MW], k_f is a factor that varies between 0 and 1, determining the allowable capacity of distributed generation relative to the maximum designed capacity at bus i, subject to the local regulations in each country $P_{Max}.Cap.$ is the maximum power designed capacity of the power system [MW]. For any power system, the total active power loss can be determined as the algebraic sum of the losses at each bus, formulated in (8).

$$P_{li} = \sum_{i=1}^{n} \Delta V_{ik}^2 . G_{ik} \quad (8)$$

The voltage drops between any two buses, denoted as i and k, for any inductive load is illustrated in Figure 1 [27]-[29] and can be mathematically formulated using the cosine theorem as shown in (9).

$$\Delta V^2 = V_i^2 + V_k^2 - (2. V_i . V_k . cos(\theta_i - \theta_k)) \quad (9)$$

Substituting (9) into (8) yields the active power losses at the bus i as in (10).

$$P_{li} = \sum_{i=1}^{n} G_{ik} . (V_i^2 + V_k^2 - (2. V_i . V_k . \cos(\theta_i - \theta_k))) \quad (10)$$

Where ΔV is the voltage drop vector between buses i and k, $\Delta\overline{V} = \Delta\overline{V_r} + \Delta\overline{V_x}$, [V], ΔV_r is the voltage vector across the resistance between buses i and k [V], ΔV_x is the voltage vector across the inductance between buses i and k [V], G_{ik} is the conductance between buses i and k, [1/Ω], θ_i, θ_k are voltage phase angle at buses i and k, respectively, [V], n is the number of buses in the power system.

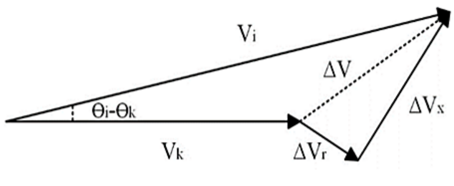


Figure 1. Phasor diagram of the voltage drop between two buses

3. PROBLEM SOLUTION

The solution to the problem comprises two main components. The first component involves identifying the optimal candidate bus for DG allocation. The second component focuses on determining the optimal sizing of DG at that bus while considering local regulations that dictate the allowable percentage of DG power that can be installed in any area, substation, or region relative to their maximum designed capacity. This factor is referred to as k_f. The mathematical calculations assume that the admittances, voltage magnitudes, and loads of the three-phase lines are identical and that the equality constraints [30] specified in (2) and (3) are satisfied. Consequently, the calculations are conducted for a single phase, as the calculations for the remaining phases will be the same.

3.1. Sensitivity-based for optimal DG location

Sensitivity analysis [31] is used to identify the optimal location for DG. This systematic procedure identifies the nodes with the most significant impact on real power losses resulting from active power flow. This has been mathematically proven in references [6], [7], [18] and is presented in (11).

$$\begin{bmatrix} \frac{\partial P_l}{\partial P} \\ \frac{\partial P_l}{\partial Q} \end{bmatrix} = \begin{bmatrix} \frac{\partial P}{\partial \theta} & \frac{\partial P}{\partial |V|} \\ \frac{\partial Q}{\partial \theta} & \frac{\partial Q}{\partial |V|} \end{bmatrix}^{-1} \cdot \begin{bmatrix} \frac{\partial P_l}{\partial \theta} \\ \frac{\partial P_l}{\partial |V|} \end{bmatrix} = [J]^{-1} \cdot \begin{bmatrix} \frac{\partial P_l}{\partial \theta} \\ \frac{\partial P_l}{\partial |V|} \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix}^{-1} \cdot \begin{bmatrix} \frac{\partial P_l}{\partial \theta} \\ \frac{\partial P_l}{\partial |V|} \end{bmatrix} \tag{11}$$

Where J, J^{-1} are Jacobian matrix and the Jacobian matrix inverse of the Newton–Raphson power flow are matrices with $((n-1)\times(n-1))$ elements, $\left[\frac{\partial P_l}{\partial P}\right], \left[\frac{\partial P_l}{\partial Q}\right]$ are partial derivatives of the real power losses; for the active and reactive power flow, they are vectors with $((n-1)\times 1)$ elements, $\left[\frac{\partial P}{\partial \theta}\right], \left[\frac{\partial P}{\partial |V|}\right]$ are partial derivatives of the real power for bus voltage angle and magnitude, they are matrices with $((n-1)\times(n-1))$ elements, $\left[\frac{\partial Q}{\partial \theta}\right], \left[\frac{\partial Q}{\partial |V|}\right]$ are partial derivatives of the reactive power to bus voltage angle and magnitude; they are matrices with $((n-1)\times(n-1))$ elements.

The partial derivative $\frac{\partial P_l}{\partial |V|}$ *and* $\frac{\partial P_l}{\partial \theta}$ in (11) can be obtained by differentiating (10) with respect to the voltage magnitude and voltage angle, respectively. The resulting products are expressed in (12) and (13).

$$\frac{\partial P_{li}}{\partial |V_i|} = \sum_{i=1}^{n} G_{ik} \ .[\ 2\big(|V_i| - (|V_k|.cos(\ \theta_i - \theta_k)\big)] \tag{12}$$

$$\frac{\partial P_{li}}{\partial \theta_i} = \sum_{i=1}^{n} G_{ik} \,.[2.\,|V_i|.\,|V_k|.\sin(\theta_i - \theta_k)] \tag{13}$$

After some mathematical arrangement of (11), a vector with $((n-1)\times 1)$ elements are obtained, representing the real power losses due to active power flow, as in (14).

$$\left[\frac{\partial P_l}{\partial P}\right] = \left[\frac{\partial \theta}{\partial P}\right].\left[\frac{\partial P_l}{\partial \theta}\right] + \left[\frac{\partial |V|}{\partial P}\right].\left[\frac{\partial P_l}{\partial |V|}\right] \tag{14}$$

The elements with the maximum value in (14) indicate the bus number with the highest impact on active power losses from active power flow. In other words, installing DG on this bus will significantly reduce active power losses. Consequently, this vector can be rearranged in descending order to identify the buses with the highest substantial effect on active power loss reduction. The procedure for determining the optimal buses for P_{DG} allocation [30], [32] can be summarized as follows: i) Input the system data and execute the power flow program; ii) Calculate the Jacobian matrices $[J_1, J_2, J_3, J_4]$; iii) Determine $\left[\frac{\partial P_l}{\partial |V|}\right]$ and $\left[\frac{\partial P_l}{\partial \theta}\right]$ using (10) and (11); iv) Compute $\left[\frac{\partial P_l}{\partial P}\right]$ based on (14), excluding candidate buses where DG installation is impractical for various reasons (e.g., proximity to buildings and roads); and v) Select the bus with the highest value of $\left[\frac{\partial P_l}{\partial P}\right]$ as the first candidate for DG allocation [33], [34], followed by the bus with the second-highest value, and so on.

3.2. Optimal sizing of DG

The amount of power from the DG injected at any candidate bus (i) is the standardized size of (7), denoted as (P_{DGSi}), and can be determined using a new algorithm based on random number generation with rapid convergence, as (15).

$$P_{DGi} = \ 2^{\alpha} + (P_{DGSi})_{intial\ value} \tag{15}$$

Where α is a set of 100 distinct real numbers randomly chosen from the interval $[-10, log_2(P_{DG(allowed)})]$. The value 2^{-10} denotes the minimum number necessary to meet the specified tolerance requirement, $(\mathrm{P_{DGSi}})_{intial\ value}$ is the initial DG capacity at the onset of the optimization process, measured in megawatts (MW).

Steps for determining optimal sizing using a random number generation-based algorithm:

i) Generate a set of random numbers represented by α.

ii) For each α, add the active power, as defined in (15), to a selected bus (optimal location) identified in section 3.1.

iii) Update the Jacobian matrix for each α using the N.R method.

iv) Calculate the $\left[\frac{\partial P_l}{\partial P}\right]$ for all generated α and for every bus in the system to find the sensitivity of DG at the selected. This is formulated in the following matrix:

$$\begin{bmatrix} \frac{\partial P_{l11}}{\partial P} & \cdots & \cdots & \frac{\partial P_{l1r}}{\partial P} \\ \vdots & \ddots & \ddots & \vdots \\ \frac{\partial P_{ln1}}{\partial P} & \cdots & \cdots & \frac{\partial P_{lnr}}{\partial P} \end{bmatrix}^{(*)}$$

v) Find the max value of $\left[\frac{\partial P_l}{\partial P}\right]$ in the above matrix, denoted (*) and denote it as α_{min}.

vi) Update the (*) matrix after adding the new injected power from DG at the optimal location from step 5. If the new (*) matrix has a different row index from the min value of $\left[\frac{\partial P_l}{\partial P}\right]$ (α_{max}) than in step 5, i.e., pointing to a different optimal location (optimal bus), then update the optimal location info based on the new α_{max}.

vii) The values of α_{min} and α_{max} are taken as a reference to regenerate a new random value, as shown in (16).

$$\alpha = \alpha_{min} + (\alpha_{min} - \alpha_{max}) \quad (16)$$

viii) Repeat the calculation as in (15) until the tolerance between α_{min} and α_{max} has the same value ($\alpha_{min} \cong \alpha_{max}$) or until the calculation obtains the required tolerance, i.e. $\Delta(P_{DGSi}) = 1 \times 10^{-4}\ kW$.

ix) The algorithm is stopped if the allowed active power is achieved, as in (7). Otherwise, proceed to step 2 in section 3.1 (new optimal location for the updated system after adding the DG, as outlined in the previous steps).

The proposed approach's solution algorithm is illustrated in a flowchart shown in Figure 2.

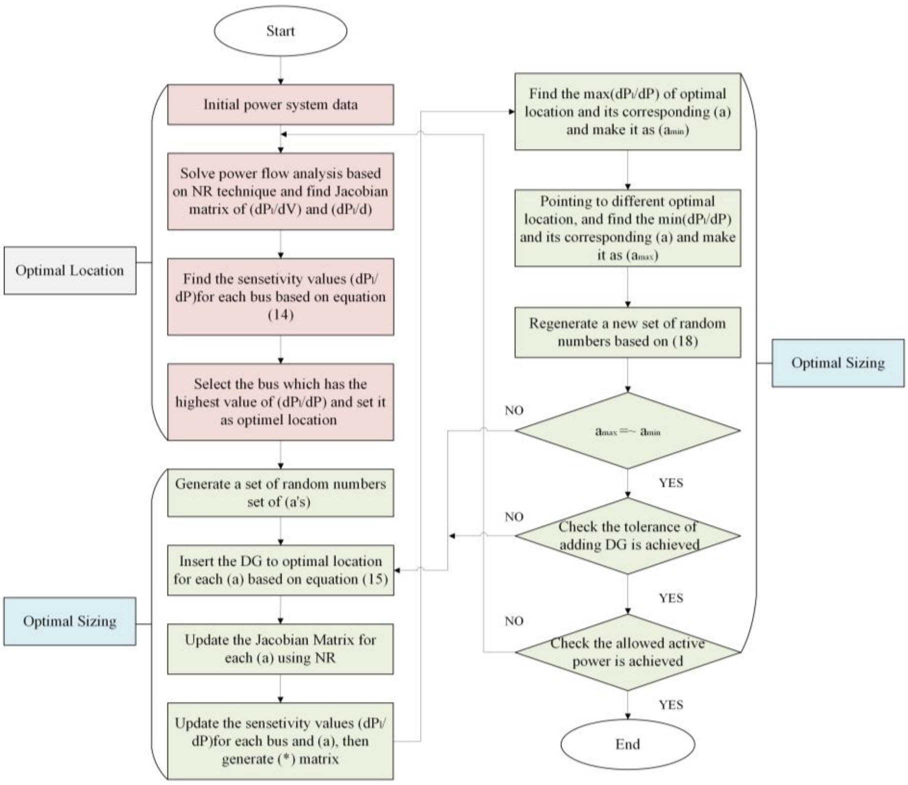
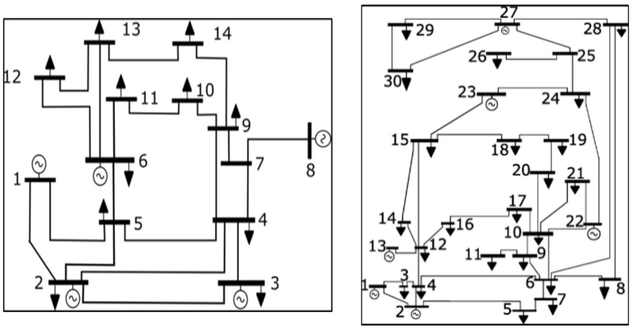


Figure 2. Allocation and sizing of DG

4. NUMERICAL EXAMPLE

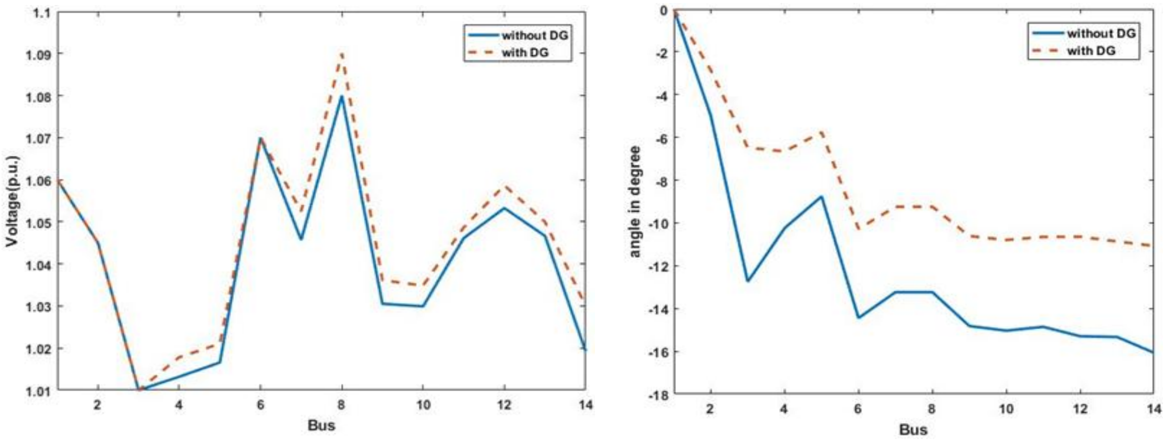
The proposed method is tested on two standard power systems: the IEEE 14-bus and IEEE 30-bus systems [35], for which data were obtained from [36], [37], respectively. The single-line diagram of the IEEE 14-bus system is shown in Figure 3(a), while Figure 3(b) illustrates the single-line diagram of the IEEE 30-bus system. The calculations presented below are specific to the IEEE 14-bus system; however, the same calculations are also conducted for the IEEE 30-bus system. The test analyses of the IEEE 14-bus system are presented as follows.

A test is conducted based on sensitivity analyses (section 3.1), the buses with max. $\left[\frac{\partial P_l}{\partial P}\right]$ is arranged in descending order and is presented in Table 1. As shown in Table 1, bus number 3 is the best candidate for DG allocation, followed by bus number 14 as the second highest, and so on. The addition of more DG power is affecting the voltage magnitude and the voltage angle, as presented in Figure 4. This improvement in the voltage magnitude and the decreased voltage angle will affect the inequality constraints in (3) and (4). Table 2 summarizes the determination of the optimal location and sizing of DG for the tested IEEE 14-bus system, following the flowchart in Figure 2. Conditions (5) and (7) were maintained during the optimization procedure.



(a) (b)

Figure 3. Single-line diagram for (a) IEEE 14-bus and (b) IEEE 30-bus systems



(a) (b)

Figure 4. For IEEE 14-bus: (a) voltage magnitude and (b) voltage angle for each bus

Table 1. Values of voltage magnitude and voltage angle for IEEE 14-bus

Bus	3	14	12	4	7	8	13	10	9	11	6	5	2
$\frac{\partial P_l}{\partial P}$	0.1338	0.1140	0.1086	0.1066	0.1057	0.1057	0.1056	0.1056	0.1052	0.1029	0.0998	0.0906	0.0595

Table 2. The number of distribution generators added to the IEEE 14-bus

Bus number	DG [MW]	Bus number	DG [MW]
3	58.2832	4	2.4629
14	8.0923	10	1.0049
12	5.1334		

5. RESULTS ANALYSIS

The paper presents a technique for determining distributed generation's optimal sizing and allocation DG. Sensitivity analyses based on the Newton-Raphson method are employed. The proposed technique was tested on the IEEE 14-bus and IEEE 30-bus systems. Local regulations determining the allowable amount of DG to be installed in these areas are considered, represented by the k_f factor, which is equal to 0.3 in Jordan. This factor has been taken into consideration while conducting the calculations using MATLAB software. The introduced method shows that the active power loss for the IEEE 14-bus system is reduced from 13.593 MW to 5.554 MW, representing a reduction of approximately 59.14%. Additionally, the reactive power losses are reduced from 56.910 MVAr to 26.803 MVAr, corresponding to a reduction of about 52.9% as shown in Figure 5(a). The same procedure applies to the IEEE 14-bus system as to the IEEE 30-bus system. The reduction of power losses due to the allocation of DG in the IEEE 30-bus system is presented in Figure 5(b). Allocating DGs reduces the total active power losses from 17.528 MW to 7.260 MW, representing a reduction of approximately 58.58%. Additionally, the reactive power losses are reduced from 68.888 MVAr to 32.421 MVAr, corresponding to a reduction of about 52.94%. Figures 6(a) and 6(b) present the effect of DG allocation on voltage magnitude and angle, respectively.

The priority ranking for each iteration is significant in achieving this work's objective. For each iteration, the selected bus is chosen based on the highest priority and inserts the appropriate amount of active power into the network. Table 3 lists the priority ranking for each iteration of the IEEE 14-Bus system. The buses in the first column are ordered to represent the optimal location of the DG from active power losses on transmission lines point of view, from lower active power losses to the highest. The size of the DG installed on a given bus is represented in the third column, If the chosen optimal bus is introduced for the first time, then it will start from zero to its optimal size x, i.e. 0→x, if the same bus is chosen in a following rank, then the optimal DG size on that bus for that rank will start from its previous optimal size x to the new optimal size y, i.e. y→x. Moreover, the priority ranking can be utilized with different values of k_f without rerunning the algorithm to find the optimal sizing and location. Also, priority ranking helps create a decision-making model for prioritizing DG technologies and their costs. Finally, the theoretical components along with the developed software serve as effective tools in determining where to allocate distributed generation (DG) and what size to install.

(a)
(b)

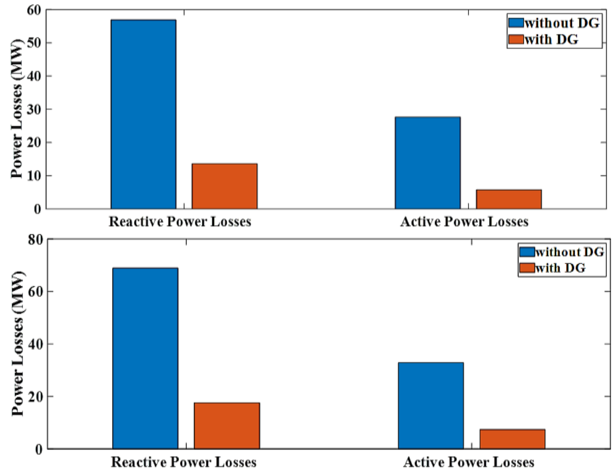


Figure 5. Active and reactive power losses before and after the installed DG, for (a) IEEE 14 and (b) IEEE 30

(a)
(b)

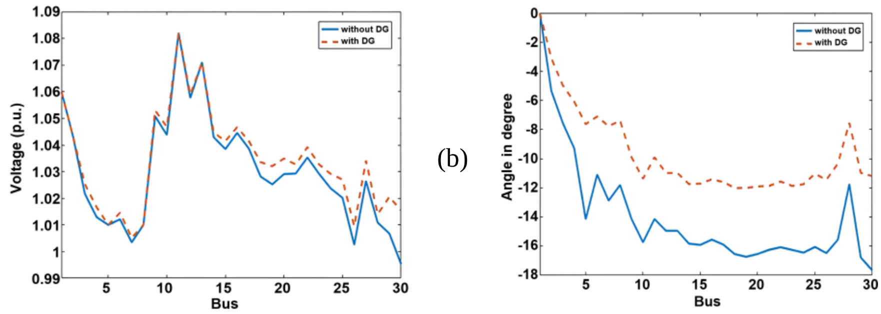


Figure 6. For IEEE 30-bus: (a) voltage magnitude and (b) voltage angle for each bus

Table 3. Priority ranking for IEEE 14-bus

Bus	Priority rank	Size of DG (MW)	Bus	Priority rank	Size of DG (MW)
3	1	0→40.0346	14	16	5.0728→6.0748
14	2	0→1.0164	3	17	50.7823→52.0289
3	3	40.0346→41.4819	12	18	2.0327→3.0365
14	4	1.0164→2.0370	3	19	52.0289→53.0600
3	5	41.4819→44.6364	14	20	6.0748→7.0879
14	6	2.0370→3.0395	3	21	53.0600→54.1525
3	7	44.6364→45.6736	12	22	3.0365→4.1120
14	8	3.0395→4.0424	3	23	54.1525→55.2012
3	9	45.6736→47.2308	14	24	7.0879→8.0923
14	10	4.0424→5.0728	3	25	55.2012→56.2638
3	11	47.2308→48.2746	12	26	4.1120→5.1334
12	12	0→1.0014	3	27	56.2638→57.2643
3	13	48.2746→49.7733	10	28	0→1.0049
12	14	1.0014→2.0327	4	29	0→2.4629
3	15	49.7733→50.7823	3	30	57.2643→58.2832

6. CONCLUSION

The approach presented in this study aims to determine the optimal location and size of DG to minimize total active power losses in the system. A sensitivity analysis is proposed to identify the optimal DG location to achieve this objective. At the same time, a novel approach based on random number generation is employed to determine the optimal DG size. The proposed method and the implemented algorithm ensure rapid and effective convergence to the final solution. The proposed approach is tested on IEEE 14 and IEEE 30 bus systems to evaluate its effectiveness. The numerical results demonstrate the robustness and efficiency of this methodology. Specifically, the approach reduces total active power losses in IEEE 14 and IEEE 30 buses by approximately 59.14% and 58.58%, respectively, while total reactive power losses are reduced by about 52.9% and 52.94%, respectively. However, unlike the current work, which focuses solely on minimizing active power losses, this approach can be extended to minimize both active and reactive power losses. This expansion, however, presents a significant challenge and suggests a direction for future research.

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AUTHOR CONTRIBUTIONS STATEMENT

The Contributor Roles Taxonomy (CRediT) has been applied in this work, and each author's contributions are detailed in the table below and as follows:

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Huthaifa Alkhashaneh	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Ayman Agha	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Mohammed Baniyounis		✓	✓	✓	✓					✓			✓	✓
Wasseem Al-Rousan				✓		✓	✓	✓		✓				

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest.

INFORMED CONSENT

The authors confirm that informed consent was obtained from all individuals included in this work.

DATA AVAILABILITY

The authors confirm that the data supporting this study's findings are available within the article and/or its supplementary materials.

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