Journal of Information Systems Engineering and Management
2025, 10(27s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Optimal Placement and Sizing of or Power Loss Reduction in Distributed Generation System by using Hybrid Optimization

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ARTICLE INFO

Received: 22 Dec 2024

Revised: 20 Feb 2025

Accepted:27 Feb 2025

ABSTRACT

The implementation of distributed generation (DG) units presents several advantages, such as decreased power loss, ecological sustainability, enhanced voltage, postponed system improvements, and heightened reliability. With the help of the Discrete Black Window Algorithm (DBWA) and Ant Lion Optimization (ALO), a novel hybrid methodology called Optimal DG-DBWALO is presented in this work. Here, the suggested method is used to determine the best location for the DG unit in terms of power loss, line power flow, and voltage profile. The recommended method increases the dynamic execution by directing the limit of DG concerning the least amount of power loss, voltage profile, and generation cost as well as maximum reliability with optimal DG. To determine the ideal DG location and size that corresponds to the greatest loss reduction, a single DG deployment is employed. The effectiveness of the suggested methodology is evaluated by analysing a total of four different operational scenarios. Because it can increase voltage profiles and enhance overall power loss at the same time, the penalty factor is a crucial component in the analysis of real power system scenarios. To validate the DBWALO-ODG approach, an investigation was carried out using the IEEE 33, IEEE 69, IEEE 119, and Indian 52 Bus systems. By executing various system load scenarios, the stability of the distribution system through loss reduction is examined. The suggested system's functionality is examined and contrasted with a wide range of current methods.

Keywords: Distribution generation, Power loss, bus system, Optimization, optimal placement and Bio-inspired algorithm.

INTRODUCTION

Producing power from a source that is directly connected to the distribution network or the meter's consumer site is known as distributed generation. Small-scale electricity production is incorporated into the current distribution network [1]. This article provides a method for assessing the impact of DG on distribution network dependability, power loss, and voltage profile. In a reorganized environment, electric utilities are currently searching for innovative, new ways to give their consumers improved dependability and acceptable power quality [2]. The electric power system is entering a new era marked by advantages for the environment, increased system efficiency, and improved control over transmission congestion [3].

The initial design of electric power systems was based on unidirectional power flow; however, additional considerations for distribution networks have been brought about by the notion of distributed generation (DG) [4]. To optimize benefits and avoid challenges, technical limitations on DG unit interconnection and penetration levels are being implemented worldwide [5]. discovered that the total losses in the distribution network would drop by almost 85% if DGs were positioned at the optimal locations and sizes. As a result, an algorithm was proposed to determine the best location and size of DGs to reduce losses at each bus in the distribution system [6].

The optimization technique, a useful tool for system design and scaling, is applied in this work for an actual feeder given the increase in dispersed generation systems that occur nowadays [7]. There are several difficult problems facing the current distribution network. Because high-quality voltage-controlled electrical equipment requires high-quality electricity to be provided, a voltage profile is crucial for consumers [8]. The financial benefits include lower transmission and distribution costs, cheaper electricity, and fuel savings. Benefits to the environment include lower greenhouse gas emissions and sound pollution [9]. However, the installation of DGs in a distribution system can generate reactive power, which can lower distribution power losses and enhance load-bus voltage [10]. It is suggested that DG units be placed and sized optimally to reduce predetermined loss. Sequential quadratic programming was utilized to do this [11].

The coexistence of PV-distributed generators and the grid presents numerous challenges. In particular, to improve voltage support in distribution networks, such systems' placement and sizing must be adjusted [12]. Additionally, the increase in the degree of short circuit failure as a result of the DGs' inappropriate placement and size has been demonstrated [13], which further highlights the detrimental effects of non-optimal DG allocation on overall cost, power quality, and reliability. Determining the ideal DG sizes and placements is therefore urgently needed to reduce the system's power loss [14]. Various optimization techniques, including Differential Evolution (DE), Evolutionary Programming (EP), Particle Swarm Optimization (PSO), Genetic Algorithm (GA), Mixed Integer Non-Linear Programming (MINLP), and Evolutionary Programming (EP), are employed to address the issues arising from the multiple DG allocations in the distribution network [15]. To lower the overall real power loss and enhance the voltage profile in the radial distribution system, we suggest a method that determines the best multi-DG sites and sizes while adhering to security regulations.

The format of this paper is as follows. Section 2 is an overview of the literature on distributed generation with ideal location. The issue formulation is found in Part 3. The hybrid (DBWALO) computing method for the ODG problem is presented in Section 4. The simulation results on the test systems are displayed in Section 5. The conclusion is then given in Section 6.

Novelty of Work

- To determine the ideal DG placement and sizing in distribution networks, this study suggests using the DBWO and ALO. The following goals are to be achieved by the suggested approach.

- To ascertain the ideal placement and DG size that can significantly lower power loss (PL), and generation costs (GC), and enhance voltage stability. The voltage regulation, PL reduction, and penalty cost fitness functions are derived from the suggested DBWALOODG technique. Furthermore, the standard ALO algorithm's global optimization capabilities are enhanced by the BWO algorithm, which integrates the concept of chaos theory.

- The IEEE 33, IEEE 119, IEEE 69, and Indian 69 Bus systems were used to experimentally validate the DBWALO-ODG algorithm. The results were analyzed in terms of PL and voltage deviation reduction as well as system voltage profile enhancement.

LITERATURE REVIEW

Anil Kumar Bhargava et al. presented a comprehensive review of the capacitor placement issues in IEEE-14, 30, 33 bus systems in 2023 [16]. The optimization work became more difficult to discover the optimal location and size for capacitors due to many restrictions. The ever-increasing loads of both residential and commercial applications are making power loss and voltage deviation a daily problem in distribution systems. Optimization problems are addressed by heuristic algorithms such as the genetic algorithm. The optimization process becomes more challenging while deciding on the optimal location and size of capacitors due to the numerous constraints. The Pareto front is then obtained using the multi-objective optimization approach by the different risk-based leakage functions, as stated by Zukang Hu et al. in 2020 [17]. Ultimately, the Pareto fronts are ranked and clustered using the multi-criteria decision analysis method. The best solution for each cluster is then found, compared, and examined. In situations when there is a shortage of sensors, taking into account the various risk-based leakage functions of the nodes can yield a more rational optimal sensor placement scheme that will have less of an effect on the water distribution network in the event of a leak. Molla Addisu et al. presented a fuzzy logic optimization method in 2021 [18] for the effective location of voltage regulators and capacitors in distribution systems (DS). The VR and capacitor placement appropriateness index were calculated using a fuzzy expert system (FES) that included a collection of heuristic criteria. The usefulness of the outcomes from the suggested method's voltage regulator and capacitor placement optimality's are demonstrated and contrasted. As a result, the recommended approach was assessed by Mohammad Zaher Ghorbani Jouybari et al. using the most widely used multi-objective algorithms in 2023 [19]. As a result, a comparison is presented between the most widely used multi-objective algorithms and the proposed method. Furthermore, a real-world case study analysing the optimal switch placement—which includes reclosers and disconnectors—when DG sources are present is examined using the proposed technique. Previous research has shown interest in the optimal distribution network planning. Several obstacles related to this subject include a significant number of linear and non-linear restrictions, multiple goal consideration, and numerous decision variables in big networks. Vempalle Rafi et al. in 2023 [20] found that the electric generators, which use non-conventional energy sources, are directly connected to distribution grids with lower ratings than conventional source-driven generators. To improve performance in terms of optimal reorganization and superlative location of distribution generation, a combination of optimization techniques, such as the black widow and crow search techniques, is used. Several situations in a normal 69-bus grid, as well as in larger-scale 119-bus and 135-bus systems, with and without the availability of dispersed generation resources, are taken into consideration when examining and analysing the reorganization problem. A hybrid technique was developed in 2020 [21] by M.C.V. Suresh and J. Belwin Edward to minimize distribution system losses by optimizing the size and placement of DG units. The combined use of the Cuckoo Search (CS) and Grasshopper Optimization Algorithm (GOA) approaches is known as the hybrid approach. In this instance, applying the CS approach improves the GOA optimization behaviour. Here, the suggested method is used to determine the best location for the DG unit in terms of power loss, line power flow, and voltage profile. The DG limit guided by the suggested technique about the cost task is necessary to improve the dynamic execution.

Inductive loads on distribution feeders are provided using a process based on an on-site study. Power factor (PF), line capacity, and monthly power loss as a percentage have all been examined in this study by Koondhar, M. A. et al. in 2020 [26].To examine the power loss caused by Koondhar, M. A. et al. in 2021 [27] load factor, the calculated peak power & minimum load data loss sources at different load times, and to analyze the load impact on the distribution losses of the 07 feeders on the 132/11 kV gird station during collection.

It has been demonstrated through analysis that Koondhar, M. A. et al. in [28] have reduced peak load to minimize peak demand and minimum load during peak period, increased b/w average load during bed period, and stabilized the power distribution system to improve load factor and increase unit load factor savings.The enhancement in their energy conversion capabilities and the simplification of their related electronic control circuitry are the reasons, according to Channa, I. A. et al. in 2021 [29]. the outcome of their use at the level of localized distributed generation. In 2024, Chandio, S., et al. made an effort to comprehend and illustrate the effects of wind and solar power generation on power quality at the localized system of distribution voltage level [30].

PROBLEM FORMULATION OF DG SYSTEM

Each distribution system operated by the power company gets electricity from a site remote from the user and distributes it among broadcast lines. In order to fulfill the service level agreement, power is typically received by the distribution network system and sent to the client [22]. The challenge lies in satisfying all specifications for a particular total capacity and number of distributed generators (DGs) within a given radial distribution system. This is done by arranging and sizing the DGs in a way that minimizes distribution power losses and enhances voltage stability. As seen in Figure 1, a single sending node supplies all receiving nodes in a radial distribution strategy.

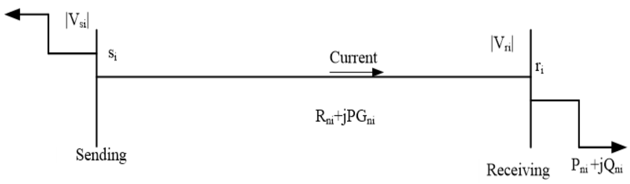


Fig. 1: Equivalent circuit of a radial distribution system

$$I_{PGi} = \frac{V_{si} - V_{ri}}{R_{ni} + jPG_{ni}} \quad (1)$$

$$P_{ni} - jQ_{ni} = V_{si} * V_{ri} \quad (2)$$

Where P_{ni} *and* Q_{ni} the net real and reactive power injection in the bus R_{ni} and PG_{ni} is represented by the line resistance between V_{si} *and* V_{ri} the bus, the voltage, and the angle at the bus, respectively. branch of the radial system. In a radial distribution system, all of the receiving nodes are supplied by a single sending node. The main criteria for choosing the ideal location and dimensions of GD units are thought to be the decrease of power loss, the stability of the bus voltage, and the maximizing of voltage stabilities.

MATHEMATICAL MODELLING OF DISTRIBUTION GENERATION (DG) UNIT

The proper positioning of the DGs within the network is a significant contributing factor. By using the engagement factor, optimal DG sizing and placement in such a network can minimize total power losses and allow for full power profile modifications. There are a lot of new ideas on display for utilizing hybrid optimization (BWO and ALO) separation networks to size and allocate distributed generation (DG) in power systems as efficiently as possible. Through the reduction of line loss, voltage variation, and separation network expenses, the proposed method presented an optimal technique capability for the separation scheme.

1.1. The objective functions of the Proposed DG model

Reducing power loss, optimizing voltage profile, boosting dependability, and lowering the cost of various Bus systems in DG radial systems are the recommended strategies.

(a) Power Loss minimization

The initial goal function is to minimize line losses after the distribution network has been injected with DG [6]. The following methods can be used to carry out this function: The true PL in distribution systems under preset operating conditions is found using equation (3).

$$PL_{\min} = \sum_{i=1}^{n} I^2 R_i \tag{3}$$

Circuit branch I is represented by I *and* R_i the current magnitude and resistance, whereas the branch count is shown by n.

(b) Generation cost of DG

To reduce the cost of producing electricity, which can be computed using a generator installed in each power generation unit's bus [1].

$$GC_{\min} = \min \sum_{i=1}^{N_{DG}} (C_{DGi} + C_{sub} + C_{cb}) \tag{4}$$

Based on the highest complex power that the DG can generate, the cost of the reactive power can be computed as follows.

Where

$$C_{DGi} = capital\ \cos t + fuel\ \cos t * PG_i \tag{5}$$

$$C_{sub} = G_{P\,grid} * G_{\Pr grid}\ ,$$

$$C_{DGi} = capital\ \cos t + fuel\ \cos t * PG_i \tag{6}$$

The N_{DG}=number of dispersed generations is shown here. The expenses associated with C_{DG}=distributed generation, C_{sub}=substation, and $\boldsymbol{C_{cb}}$ capacitor banks. PG = Unit of power generation: G_P *and* $G_{pg\ grid}$real and reactive grid power.

(c) Optimal Placement of DG

The ideal positioning and size of DG units have a significant role in the distribution networks. The following statement explains the DBWALO model's answer for the best location and size of DG in the radial distribution system. The best location for the reactive and real components of the DG

$$P_{ra} = \sum_{i=1}^{n} I^2 ac_i\ R_i \qquad P_{re} = \sum_{i=1}^{n} I^2 rc_i\ R_i \tag{7}$$

P_{re} *and* P_{ra} current that is both real and reactive in terms of power. Voltage Profile to enhance Iac_i *and* Irc_i the voltage profile in the radial distribution system while adhering to security restrictions and the system's operating framework [8]. One of the most important metrics is the voltage stability. This is how the voltage stability index (VSI) is explained.

$$V_{index} = \sum (V_{Ni} - V_{rated}) \tag{8}$$

$$VP = \min(1/V_{index(m2)}) \tag{9}$$

Here $m2$ Slack bus, voltage profile inside the system's operational framework, and security restrictions in the radial distribution system are all present here. However, the installation of DG in a distribution system can generate reactive power, which can lower distribution power loss and enhance load-bus voltage.

(d) Reliability Indices

Distribution system reliability indexes, which are frequently divided into load point and system reliability index levels, are a crucial criterion and the foundation for assessing system dependability. The island's DG continues to provide its load, which enhances the island's load's power supply reliability [23].

1.2. Constraints of Distribution system

Three primary categories of limits are present in the distribution network: DG capacity, power flow equality, and power flow inequity. To reduce system losses, power, voltage, and current limitations are taken into account.

Equality Constraints: The outputs of the active and reactive generation are represented as,

$$\sum_{i=1}^{NPG} PG_i - P_L = D_p \tag{10}$$

$$\sum_{i=1}^{N_{PG}} QG_i - Q_L = D_q \tag{11}$$

Numerous references are made to the node's active and reactive loads $QG\, and\ \ PG$. These are the power flow equation's $D_p\ D_q$ equality requirements.

Inequality Constraints: Due to inequality constraints, the maximum allowed generated power from DGs cannot exceed the distribution system allowable limitations.

Generation operating limits

$$PG_i^{\min} \le PG_i \le PG_i^{\max} \tag{12}$$

PG are the maximum permissible value and absolute power that flow between the nodes over the distribution line.

The following is the expression for the load bus voltage constraint (13)

$$|V_i|^{\min} \le |V_i| \le |V_i|^{\max} \tag{13}$$

Where V_i are the bus voltage amplitudes' lowest and maximum values, respectively.

Capacity of DG constraints: To preserve system reliability, each DG's penetration into a distribution system is constrained. Given the 25% incursion factor and the maximum amount of DG that can be injected into the distribution network, the maximum DG of the total active electrical load should be less than 25%. Here's how this can be calculated.

$$\sum_{i=1}^{N_{DG}} P_{DGi} \le 0.25 \sum PL_i \tag{14}$$

1.3. Algorithmic Design of optimal DG in distribution: BWALO

The suggested method creates a hybrid technique—the combined execution of the ALO and BWO algorithms—by optimizing these two components. Installing DGs is required if the output is a bus number. The ALO algorithm is used to update the response that was received from the BWO. This can be accomplished by reducing overall power losses and enhancing the voltage profiles of the power distribution network by strategically placing and sizing distributed DGs. A novel metaheuristic improvement calculation called BWO mimics the unusual mating behaviors of dark widow beetles. The capacity of an ant lion to hunt is the primary component in ALO optimization [24]. the candidate in the best physical condition during the phase of trapping antlions. A random walk is used to model the ants, and the parameters of the objective functions are the ants' shifting positions. The BWALO technique, which maximizes the size and location of DG units in distribution networks, is described below.

Step 1: Initializing the population with a discrete solution

Establish and configure the associated generation constraints, bus values, line limitations, and DG power restrictions. These are going to be the input for the DBWO.

Step 2: Distributed Solution Generation

The initial step in the DBWO optimization process is to start the population of candidate solutions. This kind of restricted optimization helps reduce the number of solution iterations and computation durations. The collection of discrete and continuous conditions that represent the optimization-related parameters are shown below. Within the correspondingly feasible bounds, the initial candidate population is formed as follows:

feasible bounds, the initial candidate population is formed as follows:

$$PG_j^{(G=0)} = \{PG_{11}, PG_{12}, \ldots PG_{1n}; PG_{21}, PG_{22}, \ldots PG_{1n, \ldots} PG_{m1}, PG_{m2}, \ldots PG_{mn}\} \quad (15)$$
$$\therefore m = 1,2 \ldots\ldots N_p \;\&\; n = 1,2 \ldots\ldots N_p$$

First, the initial plants are used to generate the early population $N_p$indiscriminately, and the original plant position is represented as $PG_j^{(G=0)}$. One of the variables used to make a choice is the active power that DG injects. As the optimization's input, generate and initialize the bus values, line limitations, DG power limits, and associated generation constraints.

Step 3: Fitness function

With ***PL*** representing the line loss function, ***Vindex*** representing the voltage deviation function, and ***GC*** representing the cost function of DG, the multi-objective function is (16). The black window's position is used to calculate the population's fitness.

$$fitness = \min\{PL, GC, V_{index}\} \max\{\mathrm{Re}, ODG\} \quad (16)$$

Step 4: Procreate and Cannibalism Process

Alpha exhibits in BWO should be made comparable to that extent when a widow exhibits with irregular sums. Substitutions are then done using α with the eventual $b_1 and\ b_2$ guardianship scenarios (17) and (18), where the guardianship $g_1 and\ g_2$ could be any type of family.

$$g1 = \alpha \times b1 + (1-\alpha) \times b2 \quad (17)$$

$$g2 = \alpha \times b2 + (1-\alpha) \times b1 \quad (18)$$

The mother and kids are now included in a social gathering and arranged according on how well they are regarded; in other words, the best people are paired with those who are actually made, as indicated by the savagery grade. These techniques apply to any set. The number of survivors determines the cannibalism rating (CR). The third one is sometimes the one when the young bugs eat their mother [24].

Step 5: Mutation

While BWO has multiple ways to generate mutant vectors V_i, the most common and straightforward method is employed in this work. By varying a randomly selected vector $X_{r1}$by the difference of two additional randomly selected vectors, the mutation operator $(X_{r2,3})$ produces mutant vectors.

$$V_i^{PG} = X_{r1}^{PG} + F(X_2^{PG} - X_3^{PG}) \quad (19)$$

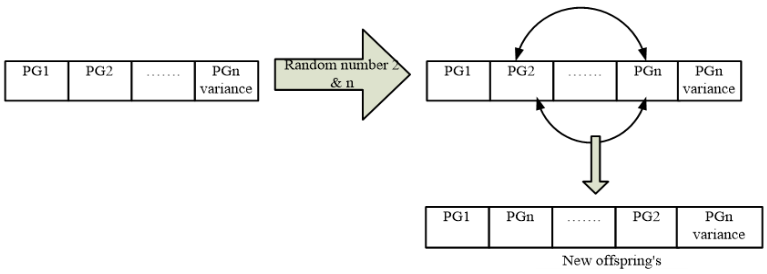


Fig. 2: Mutation process

At this point, we choose the number of Quiet populations from the general population, as shown in figure 2, without having a clear end aim in mind. Randomly selected vector indices r1, r2, and r3 are assigned to {1....Np}, where r1 ≠ r2 ≠ r3 ≠ i. A user-defined constant called the scaling mutation factor, or F, is typically chosen from the range [0,1].

Step 6: Updating new position of generation unit

Here, adjust the ideal size and location of the DG units according to the (p) value. If a better solution is found =i+1, update the T (target solution) when the values are modified. In the event that the particle was unable to arrive at a satisfactory solution, the ant lion search equation (21) was utilized in the ALO technique to generate a random number in quest of a better solution.

Step 7: Random walk of ants

At each stage of optimization, ants use a random walk to update their positions. However, since each search space has a boundary (a range of variables), it is not possible to utilize it directly to update the position of the ants.

$$PG_{wi} = [0, S_c(2 \times f - 1)] \tag{20}$$

$$f = \begin{cases} 1 & if\ random(x_i,1) > 0.5 \\ 0 & if random(x_i,1) \le 0.5 \end{cases} \tag{21}$$

$PG_{w\ i}$ is the total of all random walks. A random function is $S_c$determined by the maximum number of iterations. The definition of random is a random number with uniform distribution. For every iteration, ξ_i^{iter} and $\eta_i^{iter}$the upper and lower limits are set to and.

$$PG_i^{iter} = \frac{(PG_i^{iter} - a_i)(b_i^{iter} - c_i^{iter})}{(d_i - a_i)} + c_i^{iter} \tag{22}$$

$$b_i^{iter} = X_j^{iter} + c^{iter-1} \qquad d_i^{iter} = X_j^{iter} + a_i^{iter} \tag{23}$$

In the current iteration, where $PG_j^{iter}\ j^{th}$ chose the Ant Lion. Hence, a minimum and maximum random walk of the ant on the ith dimension is $a_i\ and\ c_i$. The anthills' haphazard strolling set traps are unaffected by the lions. The ant's movement's random walk is modified at each iteration to prevent this action. Take measurements of the dimensions' upper and lower bounds.

Step 8: Change the size of the trap for the ant

The ants create pits to escape and become imprisoned in order to do so. After that, to keep the ant from fleeing, the antlion tosses sand on it. This behaviour scuttles the ant that is stuck and attempting to get away. To mathematically describe this behaviour, the radius of the hyper-sphere formed by the random journeys of the ants is lowered adaptively [25].

$$b_i^{iter} = \frac{b^{iter}}{R} \qquad d_i^{iter} = \frac{\eta^{iter}}{R} \tag{24}$$

$$R = 10\ \psi \times iter\ /\ mi \tag{25}$$

To increase its chances of capturing fresh prey, an antlion must then change its position to match the location of the chased ant. There is a constant. lowers the search space and raises R for the random walk of ants.

Step 9: Elitism process

Store the fittest ant lion position to preserve the best possible solution. determines how each ant moves in order to obtain the ideal answer. Using the roulette wheel, each ant $(W_{X\ antlion}^{iter})$ is randomly allowed to walk in the vicinity of the chosen ant lion.

$$New\ ant\,(PG)_i^{iter} = (W_{X\ antlion}^{\ iter} + W_{elite}^{iter})/2 \tag{26}$$

At the end of each iteration, determine the global best position. The worldwide optimal locations for every solution shift in response to requirements. A highly optimized value is achieved by avoiding a few snags and fine-tuning the regulating parameters. Create the parameter function's maximum or minimum [25].

Step 10: The requirements are as follows to verify the iteration range:

The value is increased by i = i + 1 if the iteration does not reach the maximum value. The process ends when the iteration reaches its maximum value.

Step 11: Convergence

There are three stop conditions that are similar to other evolutionary algorithms: (a) a predetermined number of times. seeing that the best widow's fitness value did not change even after several cycles. obtaining the required level of accuracy. Once the process is complete, the system provides the most cost-effective size and placement of the DG units in the distribution network. Figure 3 provides a brief description of the proposed adaptive strategy.

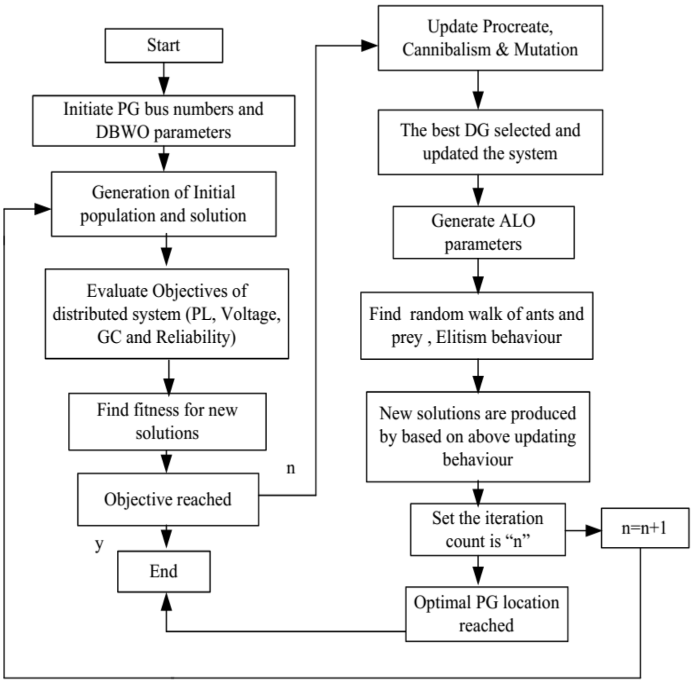


Fig. 3: Steps followed in proposed Hybrid model: DBWALO

Simple Procedure proposed distribution system: DBWALO

Defining the distribution system data loading, bus voltage limitations of the distributed generators (DGs) in the system, and input line and bus data establishment.

i. Finding the value of DBWALO
ii. Generates a random first population (array) of particles in the solution space, randomly distributed throughout the dimensions. Put k = 0 as the iteration counter.
iii. Finding the fitness function for every RD.
iv. Evaluate each generated solution's objective value against each person's personal best. confirming the system's limitations for each and every solution.
v. Generating a new set of solutions using the Elitism model and random walk processes;
vi. Repeating the previous stages until the maximum iteration or halting criteria are satisfied.

SIMULATION RESULTS ANALYSIS

DG are examined and put to the test in order to assess the efficacy and performance of the suggested method. The MATLAB/Simulink platform is used to implement the environmental setups of the technique, and the dynamic stability performance is compared with each benchmark system and existing optimization. This part verifies the efficiency gain of the model that is being given on two common distribution networks, namely IEEE 33, IEEE 69, Indian 52, and IEEE 119 Bus system with 12.66 kV base voltage.

Cases of our work

Case 1: Alternate between 0 and 1 operations

The suggested model is utilized to assist in reconfiguring the distribution system's settings to manage switches' operation.

Case 2: just DG units This includes several DG units (up to three DGs) from the bus system

that don't require reconfiguration.

Case 3: Installation of a single DG unit.

Case 4: Installation of multiple DG units

Table 1: Results of proposed-DBWALO for different cases

Bus system	Cases	Active PL (KW)	Reactive PL ((kVar)	Optimal DG location	Minimum Voltage (p.u)	GC ($)	Reliability (%)
IEEE 33	Without DG	202.74	135.2	nil	0.99	-	85.2
	With DG-2	81.23	54.23	4	0.946	24	94.23
	With DG-3	74.96	49.56	3	0.95	29	93.14
	With DG-4	69.56	45.36	4	0.956	28	89.23
IEEE 69	Without DG	224.3	102.14	Nil	0.90	24	86.14
	With DG-2	84.84	41.75	4	0.95	30	92.12
	With DG-3	98.45	46.97	3	0.965	24	94.1
	With DG-4	56.21	29.302	4	0.956	26	90.25
IEEE 119	Without DG	1473.233	958.10	nil	0.856	31	83.26
	With DG-2	1149.20	795.2	3	0.95	29	79.2
	With DG-3	1157.56	794.16	3	0.99	25	81.2
	With DG-4	1150.78	790.2	4	0.95	29	78.2
Indian 52	Without DG	1473.23	958.25	nil	0.845	28	92.12
	With DG-2	1149.20	795.2	4	0.96	25	86.1
	With DG-3	1157.58	794.199	3	0.92	31	78.1
	With DG-4	1150.78	790.23	4	0.92	32	89.1

Table 1 presents the results of the suggested DBWALO-ODG approach for several benchmark bus systems, including real and reactive power loss, optimal DG location, and minimal PL. Additionally, in example 3, the power loss (PL) was reduced from 704.26 kW to 46.8965 kW, or 86.2%, using the CAFO-OPSDG technique, which yielded the lowest PL. Furthermore, by cutting 202.68 kW to 41.23 kW, the DBWALO-ODG approach had the lowest power loss (PL) of 86.7461%. These comparisons' outcomes show how effective the recommended approach is at minimizing power loss. The results show how well the recommended approach works in identifying the optimal choice with the lowest real power losses of 102.91 kW. The deviation for different DG ratings in the 1–20 MW range for the modified IEEE 69 bus system in relation to the weighting factor.

Table 2: Multi Objective results of IEEE 33bus system

Method	**Active PL (kW)**	**Reactive PL (kVar)**	**Number of DG**	**Minimum voltage (p.u)**	**Minimum voltage bus**	**GC ($)**	**Reliability (%)**
Hybrid-DBWALO	'130.2115'	'86.2853'	'2'	'0.93351'	'17'	32	92.32
DBWO	'134.5675'	'88.348'	'2'	'0.9278'	'18'	35	90.21
ALO	'136.5518'	'88.7591'	'2'	'0.87928'	'33'	37	84.25
GA	'141.6502'	'91.9516'	'2'	'0.87634'	'33'	38	72.58

Table 3: Multi Objective function results of IEEE 69 bus system

Method	Active PL (kW)	Reactive PL (kVar)	Number of DG	Minimum voltage (p.u)	Minimum voltage bus	GC ($)	Reliability (%)
Hybrid-DBWALO	'113.6691'	'54.4724'	'2'	'0.93539'	'65'	40	94.2
DBWO	'117.8665'	'56.5018'	'2'	'0.91474'	'65'	30	89.26
ALO	'121.5046'	'59.3271'	'2'	'0.86238'	'65'	33	76.2
GA	'124.4016'	'65.7475'	'2'	'0.81795'	'65'	35	74.7

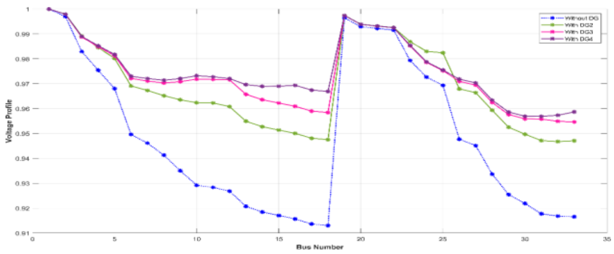
Table 4: Multi-Objective function results of IEEE 119 bus system

Method	Active PL (kW)	Reactive PL (kVar)	Number of DG	Minimum voltage (p.u)	Minimum voltage bus	GC ($)	Reliability (%)
Hybrid-DBWALO	'1228.1159'	'833.4742'	'2'	'0.9'	63	39	92.856
DBWO	'1230.2051'	'834.18'	'2'	'0.88308'	63	32	89.2
ALO	'1234.3528'	'837.8196'	'2'	'0.87941'	63	35	79.23
GA	'1236.1937'	'843.8266'	'2'	'0.83081'	63	37	71.14

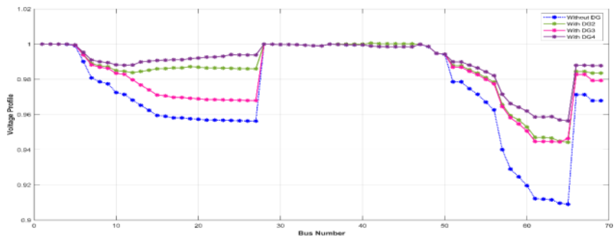
Table 5: Multi Objective function results of Indian 52 bus system

Method	Active PL (kW)	Reactive PL (kVar)	Number of DG	Minimum voltage (p.u)	Minimum voltage bus	GC ($)	Reliability (%)
Hybrid-DBWALO	'2.2979'	'0.98865'	'2'	'0.99894'	'19'	39	89.23
DBWO	'5.8326'	'5.2771'	'2'	'0.99378'	'44'	31	79.2
ALO	'6.8572'	'5.8356'	'2'	'0.9795'	'19'	34	63.25
GA	'11.5101'	'12.0468'	'2'	'0.92825'	'19'	37	62.85

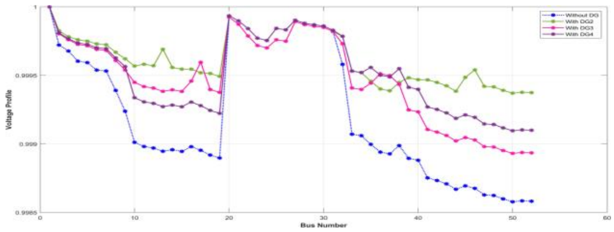
The suggested DBWALO drastically lowers the overall active power loss to 71.052 kW, a 64.9% decrease from the original case. The objective function results for the IEEE 69 bus system are shown in Table 4. The hybrid approach's optimal DG is between 30 and 18, the minimum voltage is 0.93 pu, and the power factor is 130.23kW. It illustrates how effective the proposed DBWALO is at figuring out the perfect position and size of DGs on its own. Tables 3 and 4 displayed the active and reactive power levels (PL) of the IEEE 69 and 119 bus systems, which are 113.69kW and 54.4Kw, respectively. The optimal sites for these PL values are 62 and 21. Then, IEEE 119 specifies that the optimal DG locations are 57 and 61, with a minimum voltage of 0.9pu and a minimum power level of 833kW. Three types of IEEE 69-bus distribution networks with DG units are present in this scenario. Finally, Table 5 presents the results of the Indian 52-bus system: the minimum voltage is 0.99pu, the optimal DG is 11, 41, and the minimum loss is 2.29Kw. In the proposed method, voltage variation, line losses, and system cost define the fitness function. It is important to compare the bus voltages both in the base case and after the DG units are installed. The voltage profile is greatly improved by installing DG units, according to the results.



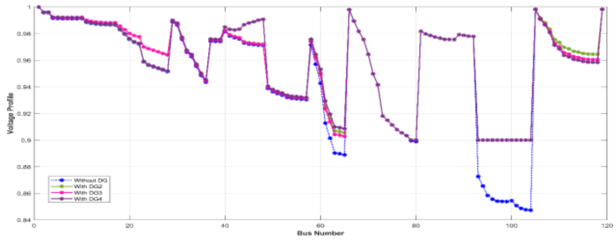
(a) IEEE 33 bus system



(b) IEEE 69 bus system



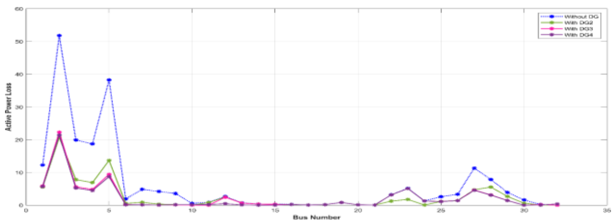
(c) Indian 52 bus system



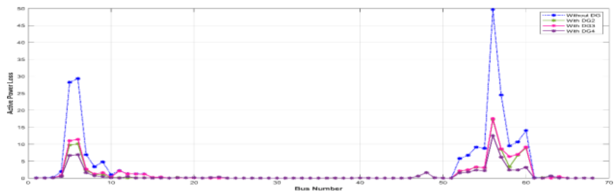
(d) IEEE 119 bus system

Fig. 4: Voltage profiles analysis different cases

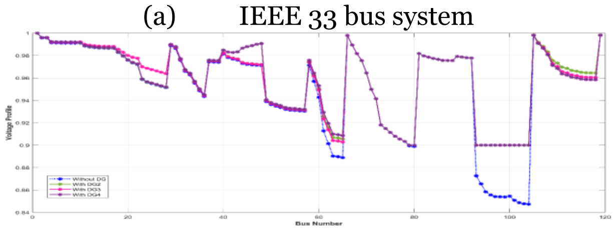
In the voltage profile analysis, the voltage level (p.u.) is displayed on the y-axis and the bus numbers are displayed on the x-axis as bus numbers. The voltage profiles of all IEEE 33, 69, 119, and 52 benchmark bus systems were shown in Figures 4(a) through (d). This can be accomplished by improving the voltage profiles of the power distribution network and reducing overall power losses through the optimization of DG sizing and placement. The voltage profile of the suggested method for varying load kinds is shown in the power loss analysis for load kinds 2, 3, and 4 both with and without DG. Bus number 25 has an ideal voltage of 0.77 to 0.99pu with a 4DG unit for the IEEE 69 bus system, with a minimum and maximum voltage limit of 0.77 to 0.99pu. Similar research was done on additional benchmark problems with voltage profiles.



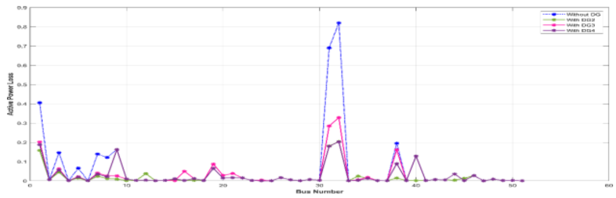
(a) IEEE 33 bus system



(b) IEEE 69 bus system



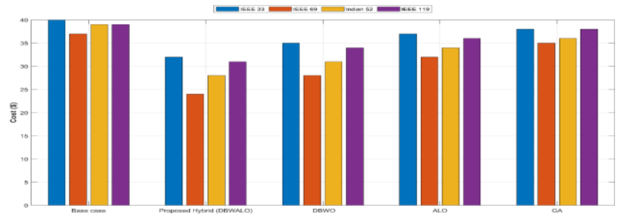
(c) IEEE 119 bus system



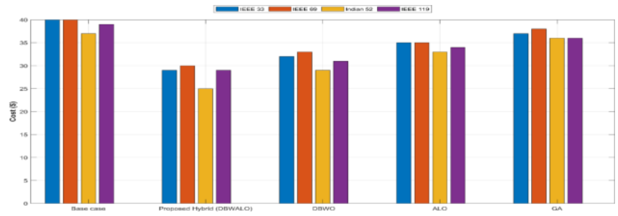
(d) Indian 52 bus system

Fig. 5: Power loss of different cases

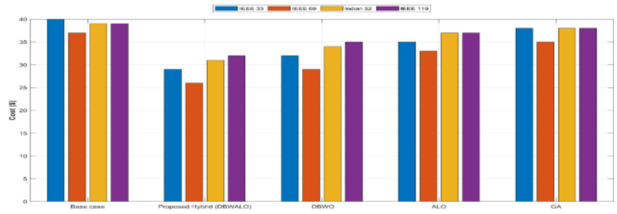
By changing the bus number in Figure 5, the PL of every bus system with different scenarios was depicted. As a result, the placement of the DGs improves power loss reduction and optimizes the distribution system's energy use. When the DGs are arranged in the IEEE119 system in position 4, the greatest reduction in power losses (833.47 kW) is measured. The position and size of the DG determine how much the overall power loss decreases. In radial distribution systems, to reduce overall real power loss and improve the voltage profile while meeting security requirements, the DBWALO method is suggested as the best way to locate and size multi-DGs. It is evident that location had a far greater impact on reactive power support and power losses than dependability did. The findings demonstrate the effectiveness of the suggested approach in locating the best option for the IEEE 69 bus system's 113.15kW active power loss with the lowest real power losses



(a) With 2DG system



(b) With 3DG system



(c) With 4DG system

Fig. 6: Generation cost analysis

These are anticipated to be the primary cost components. Reactive power compensation was really extremely inadequate at the most reliable location, which cost 40% less than it would have without distributed generation. Compared to the compensation requirement without DG, 100% more compensation is needed. As a result, the site would be the genuine optimum point. In comparison to other methods, the hybrid model's minimum generation cost is 20.13$. Similar to other bus systems, the minimum cost in DBWALO for the IEEE 69 subsystem is 21.22$. It is crucial to take into account the installation costs of compensatory devices, particularly in areas with weak grids. When DG sources are added to the distribution network, the voltage profile there is improved.

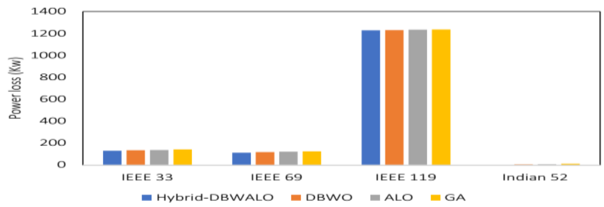


Fig. 7: Comparative analysis of Power loss

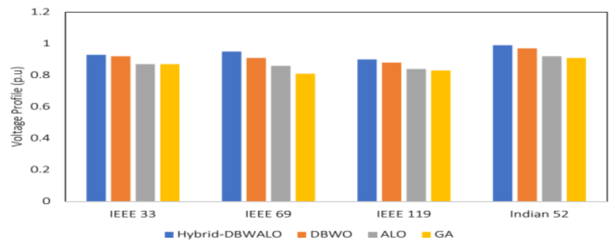


Fig. 8: Comparative analysis of Voltage profile

The suggested hybrid model is compared to existing optimization techniques, such as genetic algorithms (GA), ALO, and BWO, in Figures 7 and 8. These figures depict the voltage level comparison for the IEEE 69,119,52, and 33-bus system with and deprived of the installation of DG system. The voltage profile is greatly improved by installing DG units, according to the results. There is a large power loss at the distribution stage since the voltage is lowest and the current is highest. These figures unequivocally demonstrate that the ODG-DBWALO method that was offered produced the least amount of PL. Nevertheless, the ODG-DBWALO approach yielded a high minimized voltage when the performance was compared to the minimized voltage. The hybrid big bang technique performed the worst out of all the approaches, with a PL of 139.530 kW, as can be shown by comparing the ODG-DBWALO technique's PL performance to state-of-the-art methods.

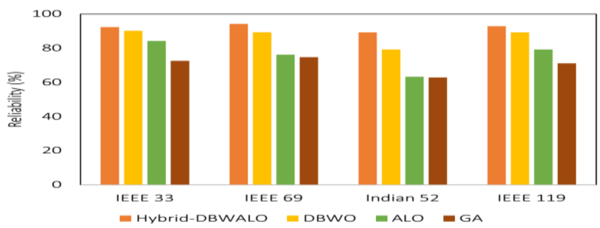


Fig. 9: Comparison of reliability

The reliability study of every benchmark bus system was shown in Figure 9, with these characteristics compared to other optimization problems that were inspired. The cost decreased when the DG was positioned farther away from the source. This is mostly because the DG has access to a larger client base than it would if it relied just on the primary source. When compared to other BWO with ALO, the hybrid model's reliability rate is the highest at

95.23%. It is evident that location had a far greater impact on reactive power support and power losses than dependability did.

CONCLUSION

The validity of the recommended strategy is illustrated by comparing its results with those of other existing approaches. The highest reliability, lowest PL, GC, and optimal DG position of the proposed technique validate the results of the IEEE 69, 119, 33, and 52 bus system observations. The proposed DBWALO has good convergence qualities, as we have seen. It is observed that when the perfect DG size is positioned at its ideal location, losses are greatly reduced and load bus voltages are increased. The enhanced minimal path technique evaluates the distribution system's reliability using DG. The suggested strategy is shown to be reasonable and successful by applying it to a typical distribution system and obtaining certain findings that are consistent with well-known facts. By adding DG at all feasible locations, the system's voltage profile is also improved and its overall power loss has been much reduced. Since it aids in the most efficient use of resource allocation, the suggested DBWALO-ODG technique can be expanded in the future to the development of algorithms for short-term load prediction in order to predict the approaching load.

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