

Comparison of Optimal DG Placement Using GA, PSO and BA for Minimum Real Power Loss in Radial Distribution System

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Abstract- The below paper concentrates on the efficient integration of Renewable Energy Systems as Distributed Generators (DGs) within the distribution sector, aiming to minimize losses occurring from their presence in the system. To achieve this objective, the study proposes the strategic placing and sizing of DGs at optimal locations within the distribution network. To tackle this challenge, four heuristic search-based methods have been carefully selected and applied. The primary objectives of the paper are twofold: Firstly, it seeks to find the ideal location and sizing of DGs by loss minimization criteria. Secondly, the study aims to compare the performance of four chosen heuristic search-based methods TO achieve the loss reduction goals. By evaluating these methods' outcomes, researchers can identify the most effective method for DG placement and its sizing in the radial network. For the analysis, the IEEE 33 radial bus test system is utilized as a representative distribution system.

Keywords: Radial Distribution System, DG, Genetic Algorithm (GA), Global Harmony Search Algorithm (GHS), Bat Algorithm (BA), Particle Swarm Optimisation (PSO).

1.INTRODUCTION

In the current global scenario, the world is confronting a significant energy crisis. Fossil fuel deposits, which have been the primary source of energy for many years, are depleting rapidly, bringing us closer to their extinction. This critical situation necessitates urgent measures to exploit and promote renewable energy sources as a viable and sustainable alternative. Countries worldwide are shifting their rules to use renewable energy resources are available. Among the various forms of renewable energy, electrical energy stands out as the most widely used and adaptable form. The electrical distribution sector, recognizing the importance of sustainability and environmental preservation, is actively integrating renewable energy into its applications. One effective method is the use of distributed generation, which involves renewable energy systems acting as distributed generators (DGs) and providing active power, reactive power. This practice not only capitalizes on the renewable nature of these energy sources but also leverages their green energy attributes, as they produce minimal to no harmful emissions.

Different names for distributed generation came into existence such as embedded or dispersed generation, imply the connection of small-scale technologies to consumer areas in order to reduce the cost [1]. Among the many advantages of DG, reducing electrical system losses, offering auxiliary service flexibility, and enhancing system dependability and power quality are most notable [2]. A stable energy supply with a preset degree of perfection is consequently seen as the major goal when planning an extension of the distribution network [3, 4, 5]. Considerable efforts have been devoted to optimizing the sizing and location of Distributed Generators (DGs) in electrical networks, with ongoing research in this area. Kumar and Murthy [2] conducted a Comparison of several strategies for efficient DG allocation in radial distribution systems Lalita et al. used a fuzzy approach to pinpoint ideal DG placement locations, while PSO [3] and clonal selection algorithms [4] were applied to pinpoint the ideal DG size for the radial network. When determining the ideal size and location of PV-DGs in the distribution system, Tayjasanant et al. [6] considered the environment, voltage, and harmonic levels. In an imbalanced 3-phase distribution network, Zaidi and Abdel et al. [7] employed a Genetic Algorithm (GA) to schedule DGs and manage TCP and converters. The Particle Swarm Optimization method was used by Kansal et al. [8] to determine the ideal placements for wind DGs in the 33 and 69 bus test systems.

Zeinaljadeh (2019) employed a Multi-Objective Particle Swarm Optimization (PSO) approach to find the best location and size for a number of Distributed Generators (DGs) and capacitor bank units while accounting

for a variety of objectives and load uncertainty. Similar to this, Moradi et al. (2020) used a mix of PSO and Genetic Algorithm (GA) techniques to decrease network power losses, boost voltage management, and increase voltage stability. Acharya et al. [11] developed an analytical approach for determining the best size and location of DGs in primary distribution systems to minimize real power loss. For this goal, they proposed an exact loss formula.

The gravitational search method, particle swarm optimization (PSO), genetic algorithm (GA), and BAT method were all employed in this work to determine the perfect place for DG deployment and its ideal size. The outcomes of four techniques are then compared, and several conclusions are drawn. A radial bus test system for IEEE 33 has been the subject of the analysis. The goal of the overall project was to propose, using four distinct optimisation. The goal of these techniques is to reduce real power losses and improve voltage profile in the distribution system. This study was completed in MATLAB® using a programming method.

2. MATHEMATICAL MODELLING

The objective function and system circumstances were established, a load flow in the 33 IEEE bus system was performed using the Forward and Backward approach, and the four selected techniques—GSA, GHS, PSO, and BA—were utilized to determine the appropriate location and size of the DG.

A. Load flow to calculate the total power losses

In order to calculate the voltages, currents, real power, and reactive power in an electrical network, a simple steady state analysis known as load flow is used. In the given network, the forward-backward and BIBC load flow strategies are primarily employed. The following forward-and-backward approach was utilised in this work: [12, 13]

Step1: VALUE of load currents:

$$I_L^i = \left[\frac{P_L^i + jQ_L^i}{v_i} \right]^* ; i = 1, 2, \dots, n \quad (1)$$

where I_L^i , v_i , P_i , Q_i and n ARE THE load currents, bus voltages, active power, reactive power, number of bus respectively.

Step2: The backward sweep OPERATES from the last node to the first node in order to determine the line current in the branch (I_{br}).

Step3: The forward sweep begins at the first node and progresses to the last node in order to update the nodal voltages.

Step4: calculating the currents, we can obtain the values of P and PL as:

$$P_{loss}(m) = I_{br}^2(m) \times R(m); \text{ for } m = 1, 2, \dots, nb \quad (2)$$

$$Q_{loss}(m) = I_{br}^2(m) \times X(m); \text{ for } k = 1, 2, \dots, nb \quad (3)$$

$$PL = \sum_{m=1}^{nb} P_{loss}(m) \quad (4)$$

$$QL = \sum_{k=1}^{nb} Q_{loss}(k) \quad (5)$$

A. Optimal placement and sizing of DG

OBJECTIVE FUNCTION

Minimize

$$PI = \sum_{i=1}^n |I_i|^2 |R_i| \quad (6)$$

$$|V_{min}| < |V| < |V_{max}| \quad (7)$$

$$|I_i| < |I_{i,max}| \quad (8)$$

WHERE V=VOLTAGE AT EACH BUS

V_{min} =minimum voltage of the system

V_{max} = maximum voltage of the system

I_i = current in the branch

$I_{i,max}$ =maximum current

3. PARTICLE SWARM OPTIMISATION

PSO, was developed by Kennedy et al. in 1995. This technique is depend on the movement of particles, depending on their social behaviour may represent fish in a school or birds in a flock. In PSO, particles attempt to alter their position as they travel across a multidimensional space in accordance with their own or nearby particles' experiences. Equations for velocity and location serve as the adjustment's representation. The formula below calculates the velocity that moves a particle close to its own best position and the average best position of all particles.:

$$v_{id}^{k+1} = w_{id}^k + c_1 \times \text{rand} \times (pbest_{id} - s_{id}^k) + c_2 \times \text{rand} \times (gbest_{id} - s_{id}^k) \quad (9)$$

The particle's current seeking position can be changed by:

$$s_{id}^{k+1} = s_{id}^k + v_{id}^{k+1} \quad (10)$$

where s_k is the current searching location, c_1 and c_2 are learning variables, and w_k is the weight function for velocity provided by:

$$w_i = w_{max} - \frac{w_{max} - w_{min}}{k_{max}} \cdot k \quad (11)$$

where w_{max} is the maximum weight

w_{min} minimum weights , k_{max} is the maximum iteration number.

The procedure of Particle Swarm Optimization algorithm are :

Step 1: In a multidimensional space, generate at random an initial array of particles with random positions and velocities.

Step 2: Determine the real power loss if the limitations are met.

Step 3: Analyse each random particle's objective value in reference to its personal best (pbest). If the objective value for the present minimization issue is less than the pbest, the pbest is set as the current pbest, and its associated current position is recorded.

Step 4: Find the minimum pbest and set it as the current gbest .

Step 5: Update the particle positions and velocities.

Step 6: Repeat steps 2 through 5 until the stop criterion is met.

4. GENETIC ALLGORITHM

John Holland created GA in 1975 [16]. The goal of GA is to improve a bunch of candidate solutions to an optimisation issue. In an iterative approach, each candidate solution has a set of traits (its chromosomes or genotypes) that are improved by crossover and mutation.

Following are the many GA algorithm steps:

Step 1: Create the first population of candidates solutions.

Step 2: Determine whether each solution is fit.

Step 3: Sort the solutions according to how fit they are.

Step 4: Keep the better ideas and toss the bad ones.

Step 5: Choose and group the best-fitting solutions into pairs for mutation and cross-over.

Step 6: In order to create a fresh generation of candidate solutions, do cross over and mutation .

Step 7: Continue with steps 2 through 6 until the stopping requirement is met.

5. GHS ALGORITHM

A new HS version is proposed, drawing influence from the concept of swarm intelligence as provided in particle swarm optimization (PSO). In this system, a group of people explore the search space by applying the best global PSO. Each individual represents a possible solution to the optimization problem. Each individual's place is influenced by the best position visited and the best individual swimming. The Global-Best Harmony Search (GHS) modified pitch adjustment stage of the Harmony Search (HS) algorithm allows the new harmony to resemble the best harmony in the Harmony Memory (HM). The bandwidth (BW) part is removed, and the HS now includes a social component. This improvement, intuitively, allows the GHS to solve both continuous and discrete problems effectively. Except for the pitch adjustment step, the GHS method follows the identical steps as the Improved Harmony Search (IHS) algorithm. The GHS works as follows:

Step1: Setting up problem and algorithm parameters.

Step2: Initializing the Harmony memory.

Step3: The evolution of fitness.

Step4: Improvisation in New Harmony

Step5: Harmony memory update

Step6: Stop the criteria

6. BAT ALGORITHM

The Bat Algorithm is a metaheuristic optimization algorithm that draws inspiration from the echolocation behavior of bats. It was introduced by Xin-She Yang in 2010. This algorithm is commonly employed to tackle optimization problems, particularly those involving continuous and combinatorial aspects. The Bat Algorithm involves the following main steps:

STEP 1 : Initialize Population

Generate a set of bats with randomly assigned positions within the search space.

Assign initial velocities to the bats.

STEP 2: Evaluate Fitness:

Calculate the fitness value of bat's position using the objective function.

STEP 3: Find the Best Bat:

Identify the bat with the best fitness value (the best solution found so far).

STEP 4: Update Bat Positions:

For each bat, update its position based on its current velocity and frequency.

Apply boundary handling if the new position is outside the search space.

Echolocation (Exploration):

With a certain probability, a bat may adjust its position randomly to explore the search space.

STEP 5: Pulse Emission (Exploitation):

With a certain probability, a bat may emit a pulse to attract other bats.

Other bats adjust their positions toward the emitting bat's position.

STEP 6: Update Bat Velocity and Frequency:

Update each bat's velocity based on its current position and the best bat's position found.

Adjust the bat's frequency, which influences exploration-exploitation balance.

STEP 7: Check Convergence:

Check if the stopping criteria are met (e.g., maximum iterations or target fitness value).

If not, go back to step 2.

STEP 8:Termination:

Once the stopping criteria are met, terminate the algorithm.

Output the best solution found during the iterations.

The Bat Algorithm continues these steps iteratively until a stopping condition is met, usually a predefined number of iterations or reaching a satisfactory solution. By balancing exploration and exploitation, the algorithm aims to find the optimal or near-optimal solution for the given optimization problem.

7. RESULTS AND DISCUSSIONS

After performing load flow analysis on a 33-bus system, the total real power line loss at unity power factor was determined to be 0.21078 MW. Table 1 displays the locations of distributed generators (DG) on various buses, along with the corresponding power loss resulting from the DG placements for both type 1 and type 3 DGs.

Table 1. numerical results for the proposed algorithms applied to the 33-bus system.

Method	Optimal Bus No.	DG size		P _{Loss} (MW)		% Loss reduction	CPU time(s)	
		PDG (MW)	QDG (Mvar)	WithoutDGs	WithDG			
GA/PSO [91]	32	1.2000	0	0.21078	0.1034	50.90	9.80	
	16	0.8630	0					
	11	0.9250	0					
Type1DG	IPSO	20	0.3599	0	0.21078	0.0857	59.29	8.65
		30	1.1088	0				
		12	0.9543	0				
	GHS	6	1.1124	0		0.0820	61.10	1.61
		18	0.4874	0				
		30	0.8679	0				
	BA	15	0.602	0		0.0787	62.66	5.26
		31	0.6864	0				
		6	1.2736	0				
Type 3DG	IPSO	18	0.268	0.1548	0.21078	0.0288	86.29	8.78
		30	1.2632	0.7294				
		11	0.6605	0.3814				
	GHS	6	1.1976	0.6915		0.0267	87.30	1.68
		18	0.4778	0.2759				
		30	0.9205	0.5315				
	BA	3	1.6694	0.9639		0.0218	89.63	5.66
		14	0.7304	0.4217				
		30	1.148	0.6628				

As per the Table 1, it is evident that the BA algorithm outperforms other methods in achieving the objective with superior solutions. However, the GHS method has a significantly shorter computation time compared to the other methods.

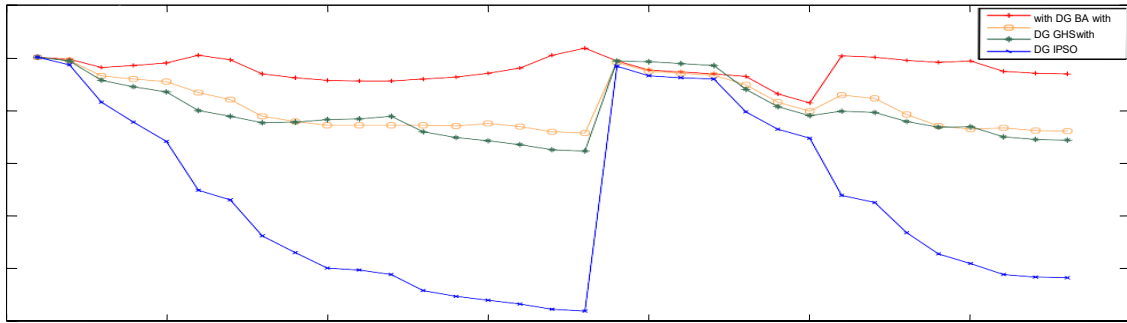


Figure 1. Graphical representation of voltage for 33-bus Radial system with Type-1 DGs

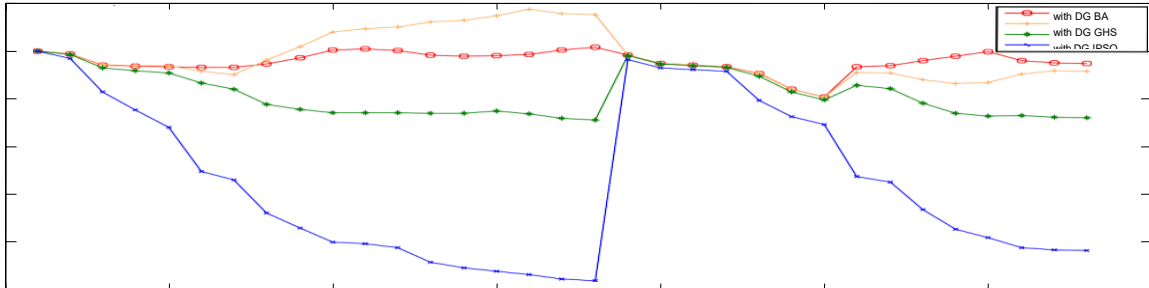
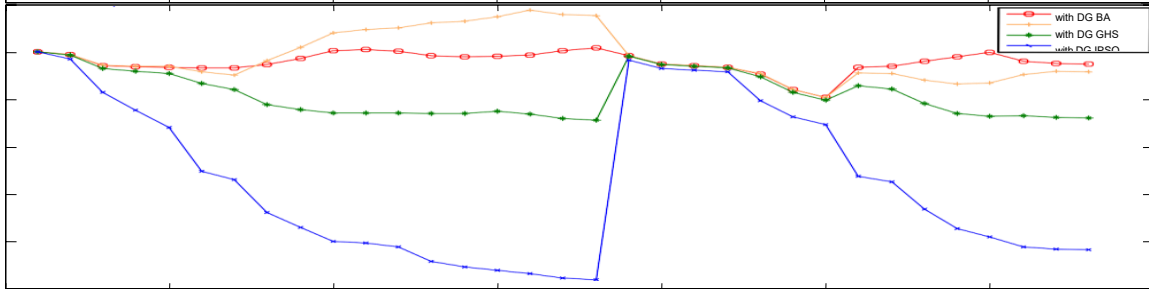
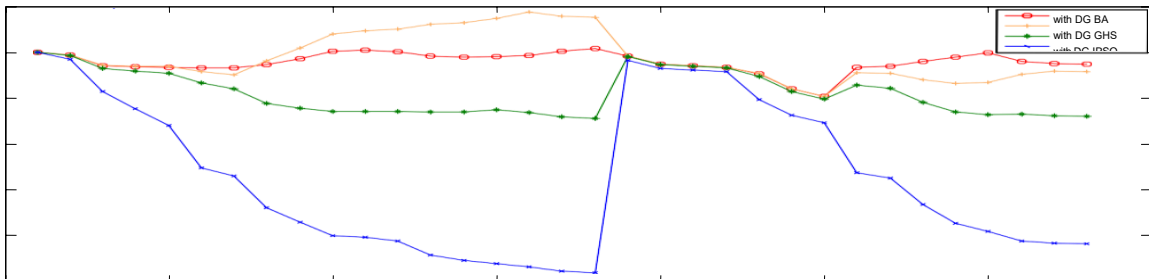
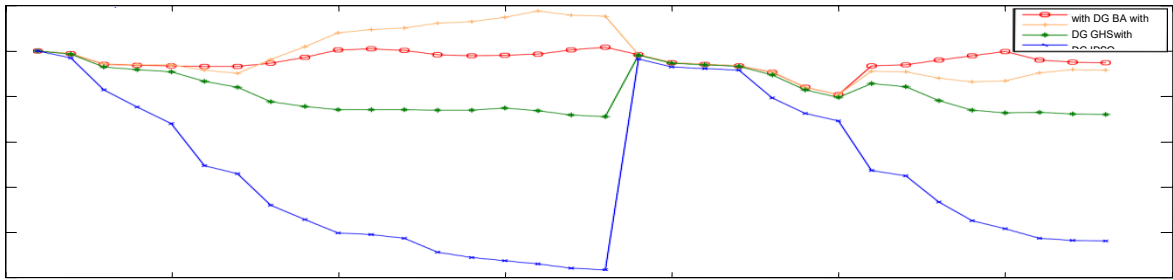
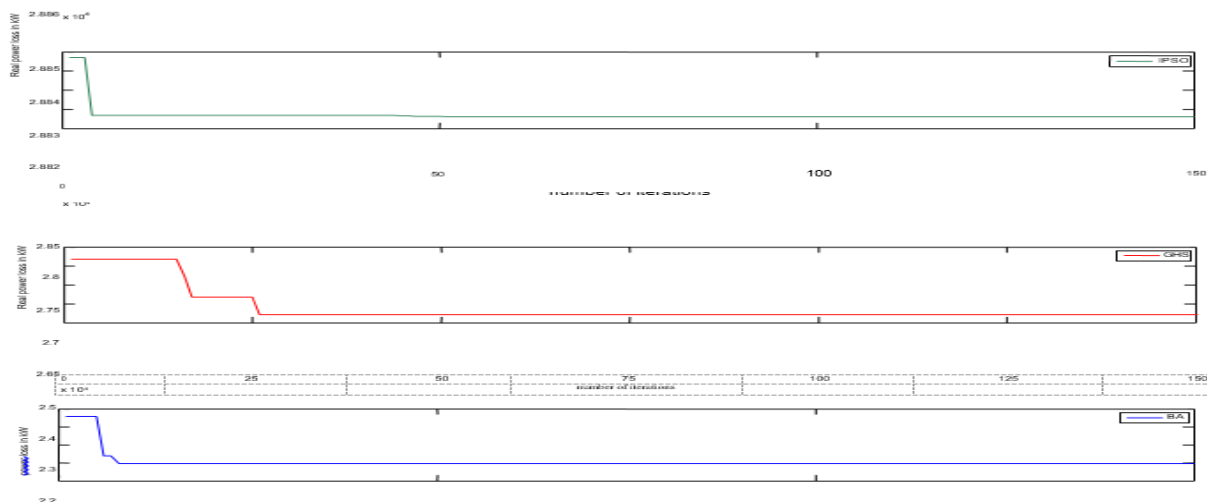


Figure 2. Graphical representation of voltage for 33-bus Radial system with Type-3 DGs





It has been observed that Type-1 DGs have a lower loss reduction compared to Type-3 DGs. The main reason for this is the improved node voltage provided by Type-3 DGs, which offers reactive power support to the system. All algorithms with Type-1 and Type-3 DGs have the same computation time. When using Type-1 and Type-3 DGs, it has been found that real power line losses are reduced more significantly with BA than with IPSO or GHS.

CONCLUSIONS

This study uses the GA, GHS, PSO, and BA optimization algorithms to compute the positioning and sizing of DG in the IEEE radial distribution test system. In locating and estimating the size of DGs, each of these strategies performed similarly. The difference in real power loss in KW was minimal. GA was the slowest technique, while BA was the fastest. In addition to the current work, it is possible to compare and derive hybrid techniques by exploring more optimization techniques.

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