Optimal Distributed Generator Sizing and Placement by Modified Particle Swarm Optimization (MPOS) Algorithm for Minimization of Distribution Power Loss

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ABSTRACT
We address the critical issue of optimal sizing and placement of distributed generators (DGs) in distribution systems to minimize power loss. the study focuses on leveraging the innovative MPSO algorithm to achieve optimal solutions. The integration of DGs into distribution systems is a key strategy, and the research explores the intricate aspects of determining the appropriate size and strategic placement of DGs to mitigate power losses effectively. We propose the Modified Particle Swarm Optimization (MPSO) algorithm as the primary tool to address this optimization problem. Drawing inspiration from bird foraging behaviour, MPSO is highlighted for its efficiency in local optimal searching. The study emphasizes the algorithm's capability to outperform traditional approaches, such as GWO and MINLP, through empirical comparisons.

Keywords
Power System, distributed Generations (DGs) Swam intelligence, MPSO, Loss minimization.

1. INTRODUCTION
Distributed or dispersed generation (DG) refers to a form of electrical power generation directly linked to customer sites or distribution networks [1]. The integration of DG into distribution systems can result in both positive and negative effects on their operations. Several factors influence the impact of DG, including the size or capacity of the DG, the type of DG (renewable or non-renewable), and the specific location or placement of DG units. The strategic installation of DG units within a distribution network to maximize positive outcomes is a task that demands meticulous attention [2]. Addressing this challenge involves treating DG placement as a combinatorial optimization problem, necessitating the application of optimization algorithms for informed decision-making. Utilizing such algorithms is crucial to ensuring a favourable impact on the overall network. The challenges of power losses and weak voltage profiles (VP) in radial distribution systems have spurred researchers to explore the integration of distributed generation (DG) into power systems. This concept has gained considerable global attention, as the introduction of DG into distribution systems is now a focal point of interest. Additionally, advancements in DG technologies have positioned them as a practical and intelligent solution for enhancing system performance [3]. Researchers widely acknowledge the effectiveness of the meta-heuristic approach in addressing network reconfiguration problems. Numerous meta-heuristic algorithms, including Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Fireworks Algorithm (FWA), Cuckoo Search Algorithm (CSA), Ant Colony Search Algorithm (ACS), Runner-Root Algorithm (RRA), and Shuffled Frog Leaping Algorithm (SFLA), have been proposed in the literature for tackling these challenges. Among these algorithms, modified particle swarm optimization (MPSO) stands out as a recent innovation that emulates the foraging behavior of birds and demonstrates notable efficiency in optimization problems. This efficiency is attributed primarily to its high accuracy in local optimal searching [4]. Notably, a study [5] revealed that the MPSO outperformed the Genetic Algorithm (GA) and Simulated Annealing (SA) by efficiently discovering optimal solutions in fewer iterations. This study introduces a Modified Particle Swarm Optimization (MPSO) approach designed for the optimal placement of multiple Distributed Generators (DGs) in networks. The primary objective functions targeted for optimization include total power losses, voltage deviation (VD), and voltage stability index (VSI). To identify the best solution among the non- dominated particles achieved by MPSO, a differential function is implemented. The three objective functions undergo normalization and characterization using clause functions. The incorporation of a clause functions controller in the decision- making process offers a notable advantage, providing decision makers with increased flexibility in determining a compromise solution by adjusting the clause based on their preferences. The efficacy of MPSO is evaluated using an IEEE standard system and compared against Particle Swarm Optimization (PSO) solutions. The paper is organized as follows: related work is given in Section II, and Section III proposed MPSO algorithm, whereas Section IV, gives the achieved results and lastly, Section V concludes the paper.

2. RELATED WORK
In recent times, numerous meta-heuristic algorithms have been introduced to optimize the allocation of Distributed Generators (DGs) with the goal of minimizing power losses. This overview outlines the proposed techniques for sizing and placing DGs, employing algorithms rooted in swarm intelligence. The author

[1] has explored various strategies in earlier literature to address challenges in system improvement. Among the emerging trends, DG integration, particularly GrMHSA, has proven more effective than MOPSO in reducing voltage variation and power losses in the system, as evidenced by a performance comparison. In a similar vein, the author [2] employs the IEEE 69 bus system to implement a multi-objective whale optimization approach for optimal DG placement. Real power loss minimization and VSI maximization are key considerations in this multi-objective optimization, revealing that adding DG to the system incurs an additional cost of 90%. The author [3] introduces the PPSO method, demonstrating its superiority over existing techniques for power loss reduction in distribution systems. This nonparametric PSO algorithm efficiently determines the optimal position and size for DG units. In a different approach, the author

[4] utilizes TDFA to select the appropriate size of DG under various load scenarios, tested on IEEE 33-bus and IEEE 85-bus radial distribution systems. However, none of the compared methods can simultaneously optimize nearly a thousand different objectives. The author [5] advocates for the effectiveness of ASFLA in providing superior solutions, showcasing significant power loss reductions (up to 75.57% and 84.90%) and VSI enhancements in 33- and 69-bus systems, respectively. To showcase the viability of MOWOA, the author

[6] employs conventional IEEE 33-bus and IEEE 69-bus systems, comparing it rigorously with MOPSO. The findings support the effectiveness of MOWOA with fuzzy logic decision making for integrating multiple DGs in radial distribution networks. The author [7] evaluates a proposed method using IEEE 30 and 57 bus test systems, comparing it with hybrid GA-PSO, genetic algorithm, and particle swarm optimization. The suggested system demonstrates efficiency in providing results based on collected values. EMA, introduced by the author [8], uses searching and absorbent operators to extract global optimal points for DG placement. The study explores various load levels for the DG placement problem, offering a comprehensive examination of the study's objectives. The author [9] employs the AFSO algorithm to optimize the overall real power losses of the system, adhering to equality and inequality constraints. MATLAB is utilized for implementation, with the study achieving significant reductions in power loss. In the context of the IEEE-30 bus test system, the author [10] validates a proposed method, achieving a 20.35% reduction in system loss by optimally sizing DG at Bus 21. The study emphasizes the importance of DG allocation in the integrated grid era. The author [11] evaluates an optimization algorithm using three different IEEE standard RDSs, demonstrating its applicability and performance through numerical simulations. The MFO algorithm's validity is established through comparisons with existing optimization approaches. In a different approach, the author [12] fixes the ideal DG position using loss-sensitive techniques and determines the optimal size using PSO. The study compares different sizing approaches and specifies a minimum size for DG to minimize losses. The author [13] evaluates a method on a wind turbine/PV/fuel cell/hydrogen tank MGs system, determining the best sizing and siting for renewable energy sources and energy storage systems. The study considers the impact of load growth and observes only a 2% increase in overall spending during the first year. Wind-based DG units are explored in the study by the author [14], emphasizing the importance of size and placement for maximum power loss reduction and VSI enhancement in the 69-bus system. The author [15] assesses a method for simultaneous planning of FCSs and DGs in a linked electrical distribution and transportation network, showcasing reductions in MVD and NPL costs across different cases. A hybrid approach based on the loss-sensitive grey wolf optimizer is proposed by the author [16], demonstrating significant reductions in system power loss with the integration of renewable energy sources. The author [17] emphasizes the importance of proper sizing and location of generators in the IEEE14 standard system, recommending the use of PSO optimization techniques. In the simulation of 69-bus and 33-bus test systems, the author [18] presents a technique with the least active power loss among equivalent articles, fully utilizing installed total SC and DG capacities. The author [19] introduces a fine-tuned PSO methodology for determining the best placement and size of various types of DGs, outperforming alternative optimization techniques. The author [20] proposes an algorithm with faster convergence for the ideal placement of DG in radial distribution systems, demonstrating its applicability on different bus systems. A novel strategy for arranging charging stations and capacitors optimally, named quantum-behaved Gaussian mutational DA (QGDA), is suggested by the author [21], emphasizing the impact of EV charging situations on voltage balance. The author [22] focuses on enhancing the voltage profile and reducing power losses in IEEE 33-bus and 69-bus radial power distribution systems, achieving optimal

3. METHODOLOGY

The MPSO, as an iteration of the original PSO, employs an indirect method to address the limitations of the original algorithm. Instead of directly updating particles' positions and velocities, the indirect method employs a set of parameter vectors to represent swarm particles. Particle behaviour is defined by iteratively updating these vectors using equations, influencing particle movement towards optimal solutions[16,17,18]. The indirect method incorporates various techniques, such as leveraging local and global knowledge and dynamically adjusting parameters, to enhance exploration and exploitation. By effectively employing a set of parameter vectors to guide the search process, the indirect method in MPSO offers a promising approach to solving optimization challenges and increasing the algorithm's efficiency. The loss of line bus in dedicated network under flow of load. The process of load variation and normalization control the behaviors of objective functions of optimal DGs. For the optimization purpose applied multi-objective particle swarm optimization. The description of multi-objective problem is

The objective function m expressed as

Consider x = (x1, x2, ,xn)$\in D, D \cap Rn$

$where\ n\ is\ the\ space\ of\ varibale$

D Min y=f(x)=[f1(x), f2(x), ,fm(x)]

Such that $gi(x) \leq 0$, $i = 1,2, \dots, p$

hj(x) = 0, j = 1,2,…,q

where y = (f1, f2, ,fn) ∈ Y is the objective function, Y is the

objective variable, gi(x) is the i-th inequality constraints and hj(x) is the j-th inequality constraints the MPSO set the dual function for the load normalization of network. The process of optimization describes here.

1. Define the population of particle as objective A
    a) For i = 0 to M where M is maximum of particle
    b) Initialize A[i]
2. Define the speed of particle
    a) For i = 0 to M
    b) Velocity[i]=0
3. Estimate particle in M
4. Reallocate the positions that represent the objective of network load.
5. Generate search space D
6. Define memory on each particle
7. Compute the speed of particle

    Velocity[i] = W*Velocity[i] +R1*(Pbest[i]-M[i]+R2*(objective[h]-A[i])

Where the range value of R is [0,1]

8. Estimate new position of particle A[i]=A[i]+velocity[i]
9. Measure current position of particle Pbest[i]=A[i]
10. Increment of counter
11. End

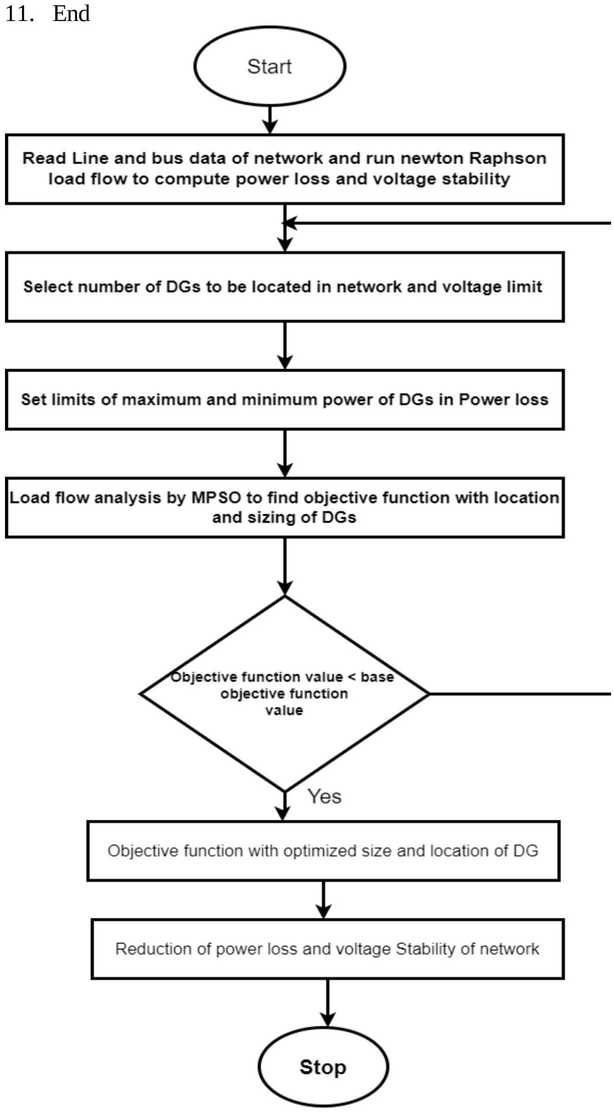

Fig 1: Proposed model of MPSO for optimal allocation of DGs.

4. EXPERIMENTAL ANALYSIS

To analyze the performance of proposed algorithm and existing algorithms uses MATLAB software. The version of MATLAB is 2017R. the employed data on simulation is normalized load variation, DG power injection, DG locations, active power losses, reactive power losses, and minimum busbar voltages have been used for the two test systems, such as IEEE 33-bus and 69-bus distribution systems.

Radial distribution systems of IEEE 33 The IEEE-33 bus system is a radial distribution system (RDS) with a total load of 3.72 MW, 2.3 MVar, 33 buses and 32 branches as shown in Fig. 3. The lineloading system and line data are obtained from Baran and Wu (1989).Table 1, describes the performance of the employed algorithm [29].

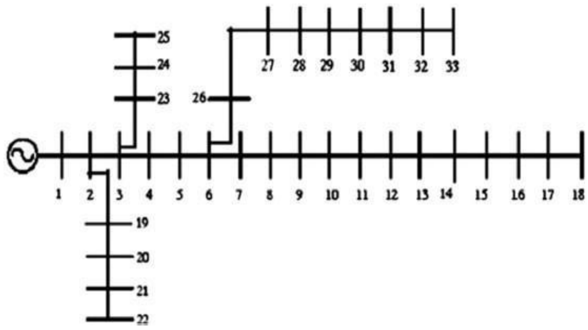

Figure 2 IEEE standard 33 bus radial distribution system single line diagram [28]

IEEE 69 radial distribution systems

The IEEE-69 bus system is a radial distribution system (RDS) with a total real and reactive power load of 3.80 MW, 2.69 MVar, 69 buses and 68 branches. The system load line and line data are taken from Sahoo and Prasad (2006).

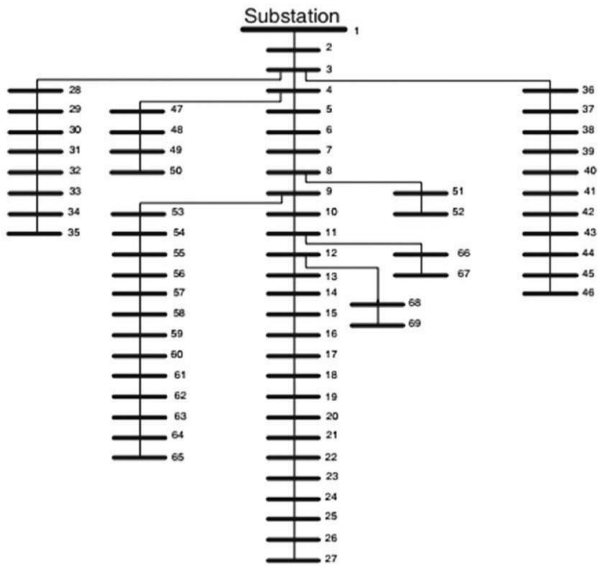

Fig 3: The IEEE 69 bus- radial network single line diagram

Table 1: Simulation result for test bus-33 networks

Network	Power Factor (PF)	1st DG node	1st Size (MW)	2nd DG Node	2nd Size (MW)	3rd DG node	3rd DG Size (MW)	Active Power Loss(kw)	Reactive Power Loss (kvar)	Loss Reduction (%)
IEEE 33 Bus System	Base	-	-	-	-	-	-	211.071	144.438	-
	1	6	2.659	-	-	-	-	103.151	74.975	51.36
		30	1.244	13	0.816	-	-	83.274	58.154	59.35
		16	0.600	26	1.491	31	1.159	71.914	52.589	64.28
	0.9	6	2.921	-	-	-	-	68.035	53.591	67.08
		13	0.914	29	1.465	-	-	35.271	24.4329	83.70
		29	1.273	24	0.832	9	0.895	22.979	16.125	90.53

Table 2: Simulation result for test bus-69 networks

Network	Power Factor (PF)	1st DG node	1st Size (MW)	2nd DG Node	2nd Size (MW)	3rd DG node	3rd DG Size (MW)	Active Power Loss(kw)	Reactive Power Loss (kvar)	Loss Reduction (%)
	Base	-	-	-	-	-	-	237.145	105.465	-
		61	1.998	-	-	-	-	83.506	38.957	66.34
IEEE 69 Bus System	1	62	1.908	15	0.711	-	-	73.649	35.405	68.08
		3	3.940	62	1.879	22	0.557	72.122	34.868	70.71
	0.9	61	2.191	-	-	-	-	28.409	15.209	87.49
		17	0.621	61	2.134	-	-	14.268	10.129	95.02
		61	1.894	15	0.568	47	1.289	11.028	8.954	95.94

Table 2: Comparison of simulation results of IEEE 33 bus system with existing work

Ref.	Method	Location	Power factor=1 size (MVA)	LR (%)	Location	Power factor=0.867 size (MVA)	LR (%)
	MPSO	12	1.6000	58.62	-	-	-
		28	0.4229				
		29	1.0715		-	-	-
[27]	GWO	14	0.9817	51.07	-	-	-
		31	0.8298				
		9	1.1769		-	-	-
[28]	MINLP	31	1.3000	50.98	-	-	-
		15	0.8629				
		12	0.9251		-	-	-

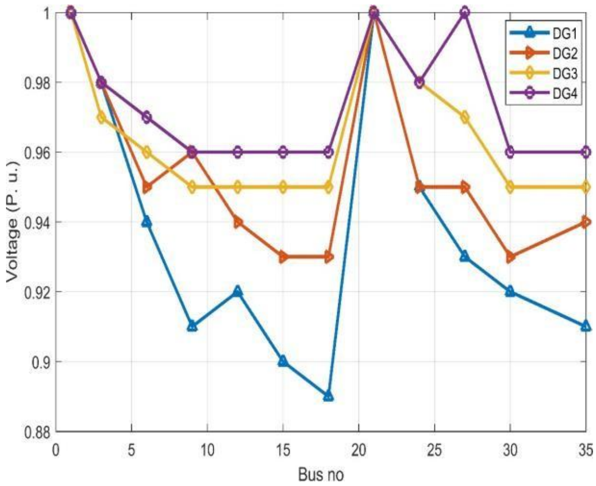

Fig 4: Comparative performance of result analysis using voltage (pu) and bus no 33

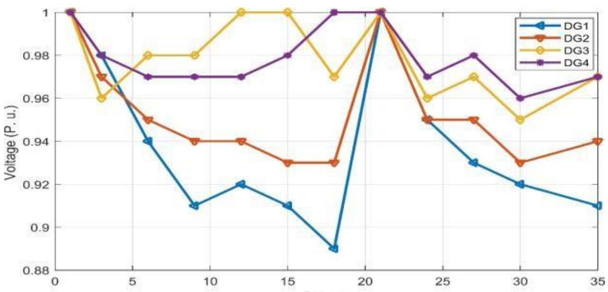

Fig 5: Comparative performance of result analysis using voltage (pu) and bus no 33

We observed that the method with 1 DG outperforms the other three methods with 2 DGs, 3 DGs, and 4 DGs. Specifically, Bus No. 20 exhibits superior performance at 1, consistently across scenarios with 1 DG, 2 DGs, and3 DGs. The method with 1 DG consistently performs better at Bus No. 20.

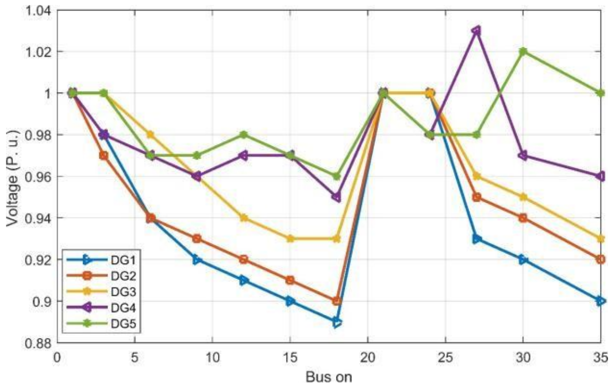

Fig 6: Comparitive performance of result analysis using voltage (pu) and bus no 33

We observed that the method with 1 DG outperforms the other three methods with 2 DGs, 3 DGs, 4 DGs, and 5 DGs. Specifically, Bus No. 30 exhibits superior performance at 1.03, consistently across scenarios with 1 DG, 2 DGs, 3 DGs, and 5 DGs. Additionally, Bus No. 30 performs better at 1.02, indicating its superior performance even in scenarios with 4 DGs. This underscores the effectiveness of the method with 1

DG, particularly at Bus No. 30.

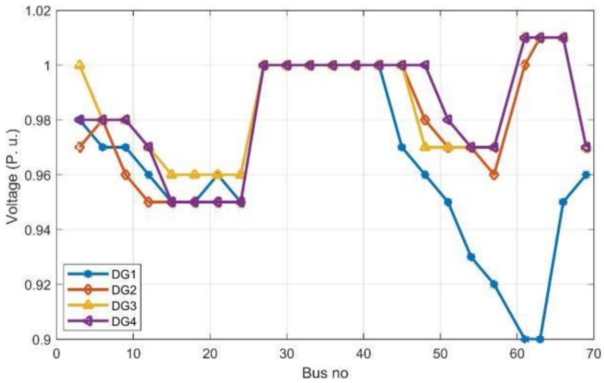

Figure: 7 Comparative performance of result analysis using of voltage (Pu) and bus no 69.

We observed that the method with 1 DG outperforms the other three methods with 2 DGs, 3 DGs, and 4 DGs. Specifically, Bus No. 30 exhibits superior performance at 40, consistently across scenarios with 1 DG, 2 DGs, and 3 DGs. Furthermore, this method performs even better at Bus No. 30 and 40, highlighting its overall superior performance in these scenarios.

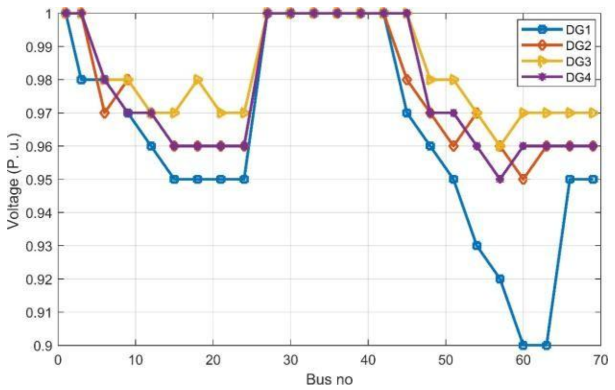

Figure: 8 Comparative performance of result analysis using of voltage (Pu) and bus no 69.

5. CONCLUSION & FUTURE WORK

The proposed algorithm for minimizing power losses utilizes the MPSO algorithm to optimally assign Distributed Generators (DGs) in a power network distribution. It is evident from the results that the technical objective of hybrid DG installation and reconfiguration in scenario 4 has been successfully accomplished. The study was conducted on the IEEE 33 and 69-bus power network systems by installing DGs at the 13th, 10th, and 30th buses, demonstrating a reduction in network power losses and an enhancement in the voltage profile. The outcomes reveal that the MPSO algorithm outperforms GWO and MINLP in terms of power loss reduction, voltage profile improvement, and overall reliability in both test scenarios. Consequently, the proposed methodology emerges as a dependable approach in DG setting and sizing for distribution network systems, showcasing superior performance compared to MPSO and MINLIP.

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