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Minimizing Power Loss in a Distribution System by Optimal Sizing of DG using PSO

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Abstract: *The distribution network becomes more unstable as distributed generator penetration levels climb. As a result, employing cutting-edge solutions is required to increase the network's stability and dependability. Finding the best placement and sizing for distributed generators is necessary, keeping in mind the need to optimize the voltage profile and reduce electrical power losses. In this paper, Particle Swarm Optimizer (PSO) methods are presented for network issue solving when several DGs of various sorts are installed. outcomes are compared using PSO methodologies with those with and without DG to demonstrate how the outcomes have improved. When the suggested approach is used with IEEE 33, It is shown by the findings that the voltage profile, active losses, and reactive losses have been significantly improved. For simulations, MATPOWER-DigSILENT software is employed. The performance and efficacy of the suggested strategies are well demonstrated by the simulated outcomes.*

Keywords: Particle Swarm Optimizer (PSO),Radial Distribution System (RDS),Optimal Power Flow(OPS),Distribution Network (DN),Distributed Generator (DG).

I. INTRODUCTION

The presented work focuses on optimizing both DG placement and capacity, addressing the challenge of increasing load demand while injecting both active and reactive power into the distribution system. This research aims to offer a comprehensive solution and compares its results with a reference using analytical methods. [1] Distributed generation is becoming increasingly important due to its potential to enhance the efficiency and reliability of distribution systems. Kansal et al. focus on determining the optimal locations for installing DG units in the distribution network. [2] The reference from the EIA is a valuable source for understanding the modeling of distributed generation within the building sector. Distributed generation, particularly in the context of buildings, has gained significant attention due to its potential for sustainable energy generation.[3] The focus is on improving voltage profiles within the network, which is crucial for maintaining the quality and reliability of the power supply. By considering DG and capacitors in the optimization process, this research contributes to the efficient integration of DG into distribution systems. [4] Network reconfiguration is a crucial aspect of distribution system optimization. This research is likely to delve into the use of mathematical techniques and continuation power flow theorem to optimize the network configuration, allowing for the maximum loading of the system while maintaining stability [5] The use of the cuckoo search algorithm is a notable feature, highlighting the application of nature-inspired optimization techniques in distribution system management.

[6] This technique is an example of nature-inspired optimization methods that have gained popularity in the field of power system optimization., this work contributes to the efficient operation of distribution networks.[7] Network reconfiguration is an important strategy for improving the efficiency of distribution networks, and this paper investigates how it affects loss allocation. [8] This research, although lacking specific publication details, provides insights into the application of AI techniques for distribution system optimization.[9] The application of graph theory in conjunction with these algorithms is a novel approach to solving network reconfiguration problems.[10] They propose an improved binary particle swarm optimization algorithm to tackle this problem, aiming to find the optimal combination of network configuration and capacitor placement to minimize power losses, this work presents an advanced optimization approach for loss reduction in distribution systems.

[11] In this paper present an approach that combines OPF and sensitivity analysis to reduce losses in power distribution systems. OPF is a powerful mathematical tool used in the optimization of power systems, and sensitivity analysis helps

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identify key parameters and variables that significantly influence system performance.[12 considering the economic aspects related to losses and potential disruptions.[13] Their approach is based on mixed-integer convex programming, a mathematical technique that optimizes network configuration while considering integer variables and convex objectives.[14] The paper introduces a methodology for loss reduction through reconfiguration, which is a fundamental aspect of improving distribution system efficiency.[15] The paper considering not only loss reduction but also voltage quality. [16] Their method utilizes a hybrid Grey Wolf Optimizer (GWO), combining the strengths of the GWO algorithm with other optimization techniques. DG allocation is a crucial factor in improving efficiency.

II. SYSTEM MODELLING AND METHODOLOGY

2.1 Distributed Generator

This includes a formulation of the problem. Reducing power loss dependent on DG size and seating is the challenge. To minimize losses as much as possible, two case studies will be used as examples. In addition to lowering actual P_L, using real power loss as an objective function will reduce reactive power losses and enhance the system's voltage profile. PSO approach should be used to tackle this issue.

The formula is used to determine all losses on the line segment joining buses iand(i + 1).

$$Losses = \frac{|V_i - V_{i+1}|^2}{R_i - j\,X_i} \qquad (1)$$

$$P_{Loss(i,i+1)} = Real|Losses| \qquad (2)$$

$$Q_{Loss(i,i+1)} = Imag|Losses| \qquad (3)$$

Where,

Vi is the voltage on bus i.,Ri is the resistance of the line segment between busses i and i + 1. X_i is the reactance of the line segment between busses i and i + 1.

$P_{Loss(i,i+1)}$ is the true power loss from bus i to bus i + 1.

$Q_{Loss(i,i+1)}$ is the reactive power loss from bus i to i + 1.

1) Constraints

following are the issue inequality constraints: 1) The voltage on each bus should be kept within certain limits:

$V_{min} \leq |Vi| \leq V_{max}$(4)

Where V_{max} denotes the maximum bus voltage. The minimum bus voltage is $V_{min.}$

2) Each line's current should be kept within certain limits:

$$|Ii,i+1| \leq |Ii_{,i+1,max}| \qquad (5)$$

Where$Ii,i+1$represents the current in the line segment between buses i and i+1. The current maximum limit of the line connecting buses i and i+1 is$Ii,i+1$max.

3) The total produced power at each bus should be less than the entire load plus total losses:

$$\sum_{i=1}^{n} P_{Di} \leq \sum_{i=1}^{n} (P_i + P_{Loss(i,i+1)}) \qquad (6)$$

Where Pi represents real power going out of bus i. $P_{Di}$is the actual power delivered by DG at bus i.

4) DG units' sizes ought to fall under certain bounds:

$P_{Di,min} \leq P_{Di} \leq P_{Di,max}$

Pmax is the maximum power provided by DG and $P_{Di,max}$the minimal power provided by DG is P, Q.

5) Power Loss for DG Installation

The proper allocation and size of Distributed Generators will delay the system upgrade and reduce peak demand. When a DG is deployed at any position in the system, the actual power loss is provided by.

$$P'_{T,Loss} = \sum_{i=1}^{n} P'_{Loss(i,i+1)} \qquad (7)$$

Where Q_i is the reactive power exiting bus i, PD is the actual power delivered by DG. QD is the DG-supplied reactive power. D denoted the distance in kilometers between the source (DG) and the DG bus. The total length is indicated by L.

2.2 OPTIMIZATION TECHNIQUES

Optimization approaches, namely PSO DG sizing, and DG siting problems, all tackled concurrently. This approach mitigates the drawbacks associated with employing sensitivity analysis for determining the optimal DG unit placement and underscores the benefits of addressing this challenge simultaneously. In this chapter, optimization methods are introduced: PSO, DG sizing, and DG placement problems, all handled. This approach addresses the limitations of sensitivity analysis when identifying the most suitable location for DG units and highlights the merits of addressing this issue concurrently.

A. Mathematical Model of PSO

$$\boxed{v_i^{t+1} = \underbrace{v_i^t}_{\text{Inertia}} + \underbrace{c_1 r_1 (pbest_i^t - p_i^t)}_{\text{Personal influence}} + \underbrace{c_2 r_2 (gbest^t - p_i^t)}_{\text{Social influence}}} \qquad (8)$$

The variables 'k','s_1', and's_2' indicate the weighting factors, 'r_1' and 'r_2' are random values between 0 and 1, and 'W' stands for the weighting function in this formula. The velocity of particle 'i' at iteration 'k' is represented by 'V_i' (k), while the updated velocity of particle 'i' is indicated by 'V_i' (k + 1). The particle 'i' position at iteration 'k' is shown by 'Yi' (k), while the revised position of particle 'i' is indicated by 'Y_i' (k + 1). For particle 'i', 'Pi' (k) denotes the particle that is personally best; 'G' (k) denotes the particle that is globally best.

III. RESULT AND DISCUSSION

Two scenarios have been examined to ascertain the optimum arrangement and sizing of distributed generation for a specified load.

Case I: Without DG (Base Case)
Case II: With DG

The study encompasses two case analyses to assess this approach's analysis. It employs the PSO and Dig Silent Power Factory techniques to evaluate its performance on an IEEE 33 bus distribution systemFig.1 shows a dig silent power factory diagram. Case-1, the Active Power loss is 0.21 MW, and the Reactive Power loss is 0.14 MVAr,The Grid active power is 3.92 MW, and the Grid Reactive power is 2.44 MVAr,as shown in Table 1, respectively. The graphical Representation of the Power factor,current profile, loading profile, Active Power profile, Reactive power profile,voltage profile, for both cases, are shown in Fig 2,Fig 3, Fig4, Fig 5, Fig 6 and Fig7,respectively

The three DG are best arranged at buses 16th, 24th, and 30th of IEEE 33 bus DN in the second scenario that is being suggested. Once these DG are installed. Real power is 0.1 MW, reactive power loss is 0.1 MVAr,Gridactive power is 0.85MW, and Grid Reactive power is 0.53MVArDG active power Generation is 2.88 MW and reactive power Generation is 1.78MVar from Table I, Active Power Loss, Reactive Power Loss which are reduced by 95.23%, 92.85%, respectively

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3.1 IEEE 33-Bus Test System

TABLE 1 Load Flow Calculations For Ieee 33

Case	**Total Power Losses**		**Grid Power**		**DG Generation**	
	P_{LOSS}(MW)	Q_{LOSS} (MVAr)	P(MW)	Q(MVAr)	P(MW)	Q(MVAr)
1	0.21	0.14	3.92	2.44	-	-
2	0.01	0.01	0.85	0.53	2.88	1.78

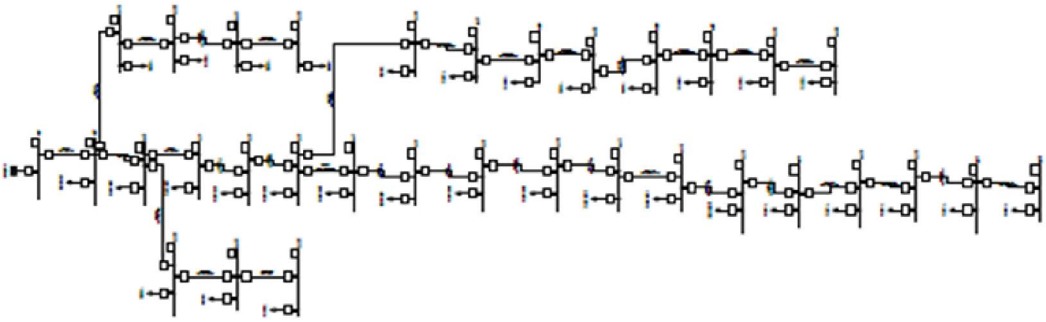

Fig.1IEEE 33 Bus DigSILENT Diagram

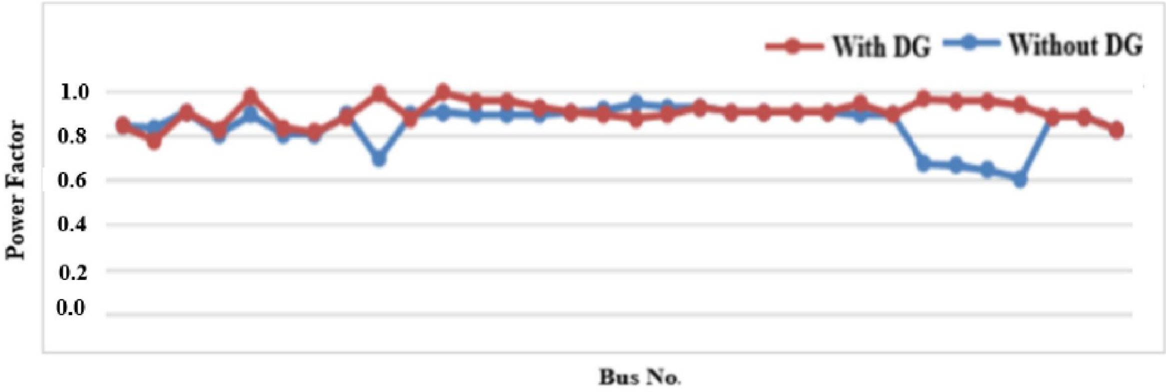

Fig.2Power Factor

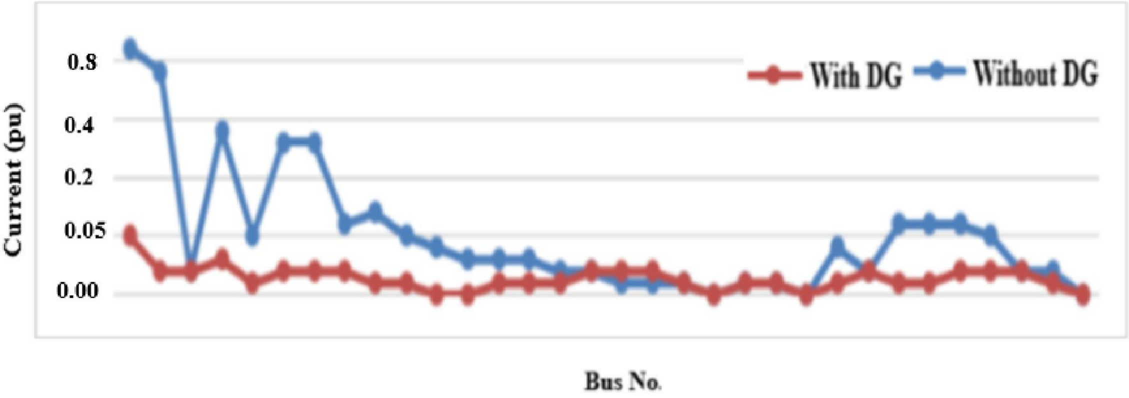

Fig. 3 Current in Line

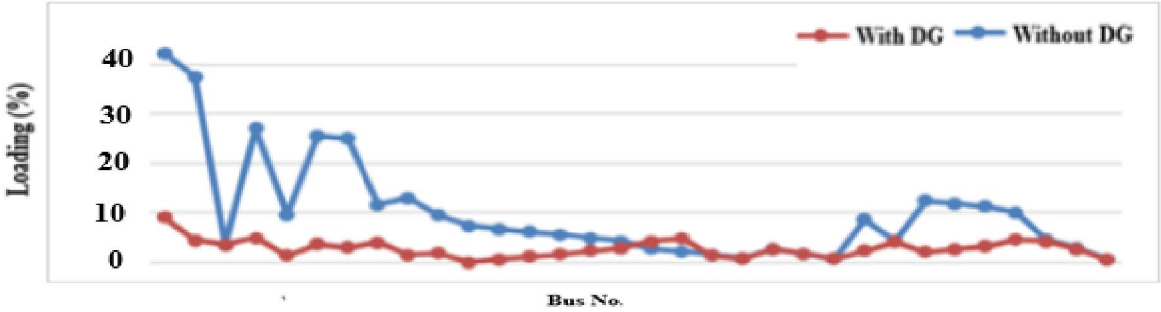

Fig.4Loadingin IEEE 33 Bus

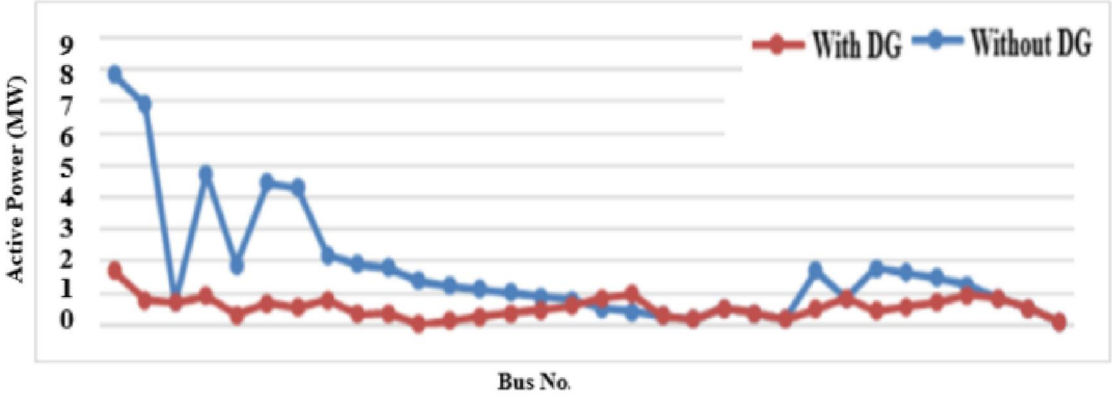

Fig.5 Active Power

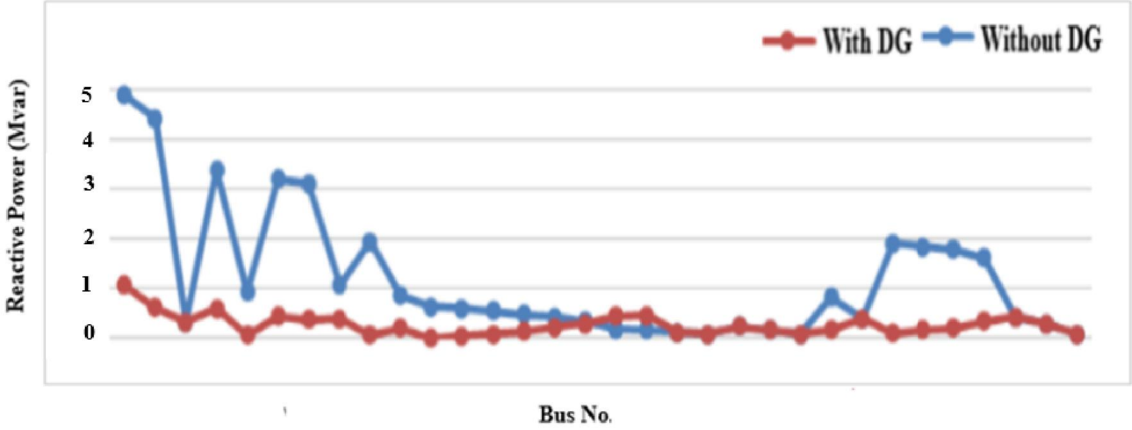

Fig.6 Reactive Power

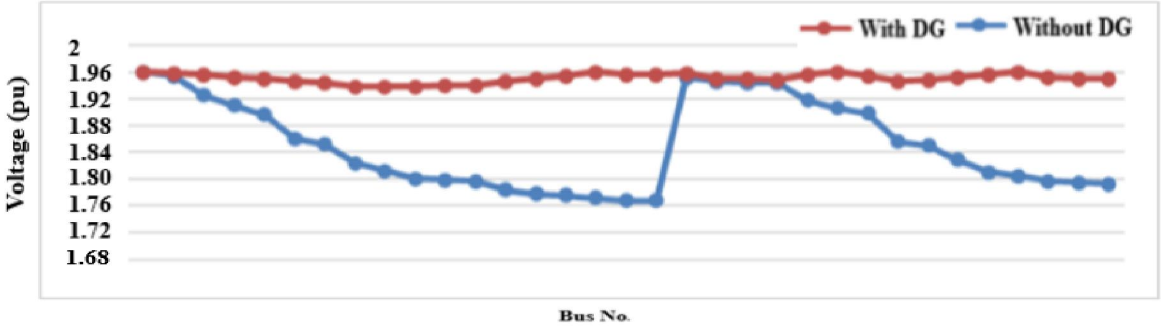

Fig.7Voltage Profile in IEEE 33 Bus

IV. CONCLUSION

The best placement and size for distributed generators (DGs) in a realistic distribution system have been presented using the Dig Silent Power Factory software and the Particle Swarm Optimization approach (PSO) approach. Two scenarios, with and without DG, have been examined. DGs have been coupled in 33-bus RDS to lower active power loss, Reactive Power Loss and enhance the voltage profile. To determine the ideal placement and size of DG, following the application of optimization techniques to analyze the outcomes of all scenarios, it was found that in case II the simultaneous post of all three DG at bus nos. 16th, 24th, and 30th provide the best outcome in terms of adding DG to the redesigned system, The obtained results of case 2 are analyzed, and it is found that the case performs better in terms of computation, convergence, techno-economic benefits, and Active Power Loss, Reactive Power Loss which are reduced by 95.23%, 92.85%, respectively. With forethought, this effort may be expanded much further. ideal charging stations for electric vehicles as well as the modified DSTATCOM renewable Wind-DG system.

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