PSO and GSS algorithms are used to arrange DG optimally for voltage profile enhancement and loss reduction

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Abstract: This project looks at the best locations for Distributed Generation (DG) units in power distribution networks to reduce system losses and simultaneously enhance voltage profiles. The suggested methodology makes use of a hybrid optimization approach that blends fuzzy logic with the Particle Swarm Optimization (PSO) and Golden Section Search Algorithm (GSS). To evaluate the effectiveness and robustness of the suggested method, the study focuses on the IEEE-15 bus and IEEE-69 bus systems as test cases. This project thoroughly evaluates the suggested methodology on the IEEE-15 bus and IEEE-69 bus systems in order to validate and assess it. Comparative research indicates that fuzzy logic hybrid PSO and GSS are better than classical optimization techniques. The results demonstrate a noticeable improvement in loss reduction and voltage profile improvement

1 Introduction

The current power environment is changing dramatically in favour of efficient and sustainable energy systems, which calls for creative ways to improve power distribution network performance. Given this, integrating Distributed Generation (DG) has become a key tactic with the ability to lower losses and raise voltage profiles. The appropriate placement of DG units inside a distribution network is a difficult problem requiring sophisticated algorithms that balance global exploration with local [2] exploitation. This study tackles the crucial issue of arranging distributed generation in power distribution networks optimally for concurrent loss reduction and voltage profile enhancement. The potential for this initiative to significantly increase the resilience, sustainability, and efficiency of distribution networks makes it significant. By carefully installing DG units, it is possible to decrease power losses, enhance voltage stability, and boost the overall reliability of the electricity supply. The suggested methodology makes use of a hybrid [7] optimization strategy that combines the benefits of the Gravitational Search Algorithm (GSS) with Particle Swarm Optimization (PSO). By working together, we hope to maximize the potential of worldwide exploration while maintaining effective local exploitation. Fuzzy logic is used in the optimization process to address the inherent uncertainties in power system characteristics. By allowing for the dynamic modification of weighting elements, fuzzy logic improves the algorithm's ability to adapt to complicated situations in the real world. In this study, real test cases from the IEEE-15 bus and IEEE-69 bus systems are used to validate and analyse the suggested technique. The IEEE-standard [4] bus systems serve as a reference point for evaluating how well the suggested method performs in actual distribution networks. Fuzzy logic hybrid PSO and GSS have advantages over classic optimization algorithms and will be shown to be superior in obtaining optimal DG placement through comparative experiments.

2 Literature Review

The potential of Distributed Generation (DG) to address problems with power losses, voltage instability, and overall system reliability has drawn a lot of interest to DG integration in power distribution networks in recent years. A key factor in maximizing the advantages of these decentralized power sources is the location of DG units. With an emphasis on voltage profile enhancement and loss reduction, we examine important research and techniques pertaining to DG location optimization in this review of the literature.

2.1 Optimization Techniques

- Several optimization techniques have been applied to solve the issue of DG placement optimization. Traditional methods such as Genetic Algorithms (GAs), Ant Colony Optimization (ACO), and Particle Swarm Optimization (PSO) have been

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widely applied. By figuring out the best mix of DG size and location, these techniques seek to reduce power losses and improve voltage profiles.

- P**. Mahat. (2018)** used PSO to locate DG while taking voltage stability and power losses into account in radial distribution systems. The study showed how effective PSO is at locating almost-optimal DG allocation options [2].
- A hybrid GA-PSO technique for DG deployment in distribution networks was presented by **H. B. Tolabi al. (2017).** The hybrid algorithm demonstrated enhanced convergence and quality of solution, underscoring the possible advantages of merging optimization methods [8].

Distributed Generation Impact Analysis

- A lot of research has been done on how distribution networks are affected by DG integration. **H. L. Willis and Mithu Ananthan** (2010) looked at the effects of distributed generating installations on voltage profiles and power losses. The study emphasized that careful consideration of DG penetration levels is necessary to ensure optimal system functioning [3].
- **Wang et al. (2014)** carried out a thorough examination of DG integration in distribution networks, taking into account both the technical and financial issues. The study emphasized how crucial it is to strike a balance between a number of goals, such as voltage stability, loss reduction, and economic viability [6].

Hybrid Optimization Approaches

- To enhance the efficiency of optimization, hybrid approaches have been proposed. **9) A. J. G. Mena. (2015)** introduced a hybrid GA-PSO method for DG placement, integrating the strengths of both algorithms. The hybrid approach demonstrated improved computational efficiency and robustness [9].

Fuzzy Logic in DG Placement

- Fuzzy logic has been integrated into optimization algorithms to handle uncertainties associated with power system parameters. **R. Salgotra. (2011)** applied fuzzy logic in DG placement considering load variations and system uncertainties. The study highlighted the adaptability of fuzzy logic in addressing real-world complexities [11].
- **F. Keynia (2020)** incorporated fuzzy logic into a multi-objective optimization framework for DG placement. The fuzzy-based approach allowed for dynamic adjustments in decision-making, considering imprecise information and enhancing the overall robustness of the optimization process [12].

Ch. Naga Sai Kalyan; B. Srikanth Goud used an optimal technique order to examine load frequency control (LFC), A two-degree-of-freedom PID (2DOFPID) controller is designed using the donkey and smuggler optimization technique (DSOA). An extensive model of the two area reheat hydro-thermal (TARHT) system is chosen for the investigation, and analysis is carried out for a 10% step load perturbation on area-1. In controller optimization, the integral time square error (ITSE) goal index is taken into account. However, traditional PID and PID plus filter (N) controllers show how successful 2DOFPID may be. The integration of the TARHT system with the DC line is examined more closely in an effort to boost performance. To show that the suggested control technique is reliable, a sensitivity test is conducted at the end. **[14]**

The proposed system involves recognizing areas that have not been thoroughly explored or addressed in existing literature. There are Limited comparative studies between PSO and GSS in terms of their efficiency, convergence rate, and computational complexity for DG placement and Lack of comparative analysis with other optimization techniques such as Genetic Algorithms (GA), Differential Evolution (DE), or Hybrid Methods **[9].**

The Limited research on multi-objective optimization frameworks that consider multiple criteria (e.g., loss reduction, voltage profile improvement, cost, environmental impact) simultaneously. The opportunity by the Design and implement multi-objective optimization models to balance and optimize various performance metrics for DG placement **[10].**

The Lack of comprehensive assessments of the economic benefits and environmental impacts of using PSO and GSS for DG placement this problem can be overcome by conduct cost-benefit analyses and environmental impact studies to justify the adoption of these optimization techniques in practical settings **[8].**

Renewable energy sources (RES) have erratic power availability; hence efficient management is necessary for optimal use. In this situation, a hybrid energy storage system (HESS) is essential. In a DC micro grid setting, the combination of hybrid energy storage devices with renewable energy sources can improve power management. The best hybrid energy storage system for a DC micro grid based on PI controllers is suggested in this research in order to efficiently use renewable energy sources. In this model, the particle swarm optimization (PSO) method is used to generate the suggested ideal PI controller. A 72 W DC micro grid system is taken into consideration to verify the efficacy of the suggested ideal PI controller **[1].**

PSO Optimization technique

PSO, or particle swarm optimization, is a popular optimization technique that takes social behaviour in fish and birds as its model. Particles [3] collaborate and share ideas among themselves to find the best answer to a given issue. PSO works very effectively with multi-dimensional and continuous optimization issues. It is frequently used to solve optimization issues and find the global optimum in a search space. The fitness or objective function is evaluated for each particle. The objective function quantifies how good or bad a solution is with respect to the optimization problem's goals. Each particle has several [5] properties, including its position and velocity. These properties are initially assigned random values.

Optimal Position: $x_i = (x_{i,1}, x_{i,2} \dots . x_{i,n}) \in r^n$

Optimal Velocity: $v_i = (v_{i,1}, v_{i,2} \dots . . v_{i,n}) \in r^n$

Each particle maintains individual best position and swarm maintains its global best (G_{best}),

$$p_i = (p_{i,1}, p_{i,2} \dots . p_{i,n}) \in r^n$$

$$P_{best(i)} = f(P_i)$$

This approach's main objective is to use the following formulae to get to the best particle. We may [11] obtain both international good role (i.e. gbest) and private first-class function (i.e. Pbest) in a swarm by changing the position and place using the following formulas. Original Velocity update equation is as follows.

$V_i^{(k+1)} = v_i^k + C_1 rand_1 (p_{best\,i} - X_i) + C_2 rand_2 (g_{best\,i} - X_i)$

With rand1, rand 2

C1, C2: acceleration constant

In each iteration (or generation), particles adjust their velocity and position based on their past experiences and the experiences of their neighbors in the population. The velocity and position updates are determined by two key factors:

Cognitive Component (Personal Best): Every particle attempts to go in the direction of its personal best, or its best-known location.

Social Component (Global Best): In addition, every particle strives to approach the global best, which is the best-known location among all the particles in the population. The balance between these two components is controlled by two acceleration constants, often denoted as cognitive and social acceleration coefficients (usually represented as c1 and c2).

The fig 1 shows flow chart of PSO technique.

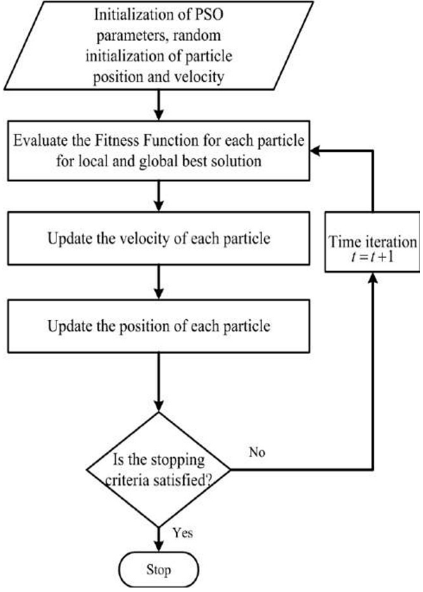

Fig 1 Flowchart of particle swarm optimization

Particle position update equation is as follows

$X_i^{k+1} = X_i^k + V_i^{k+1}$

Inertia weight:

$V_i^{(k+1)} = W v_i^k + C_1 rand_1 (p_{best\,i} - X_i) + C_2 rand_2 (g_{best\,i} - X_i)$

Weight update equation is as follows

$W = w_{max} - ((w_{max} - w_{min}) * t)/T$

Considered constraints are as follows

$V_i^{min} \leq V_i \leq V_i^{max}$

$X_i^{min} \leq X_i \leq X_i^{max}$

Particle swarm behavior, which reacts to individual and collective experiences by changing locations [6] and velocities, enables PSO to efficiently search the search space and settle on optimum or nearly optimal solutions.

The major advantages of PSO is its simplicity and ease of implementation, making it a popular choice for optimization problems in various domains, such as engineering, machine learning, and finance. However, the performance of PSO **[7]** can be influenced by the choice of parameters (e.g., acceleration coefficients) and the initialization of particles, so tuning these parameters is often required to achieve good results for specific problems.

3 GSS optimization technique

A univariate optimization technique called the Golden Section Search (GSS) method is used to determine a function's lowest (or maximum) within a certain range. It's a numerical optimization method that belongs to the family of interval reduction algorithms. The GSS algorithm is particularly useful, when the function being optimized is unimodal, meaning it has only one local minimum (or maximum) within the given interval.

The GSS algorithm's main concept is to iteratively narrow the search window where the function's minimum (or maximum) is anticipated [8] to be located. The golden section ratio, represented by the Greek symbol phi (φ), which is roughly equivalent to 0.618, serves as the foundation for the interval reduction. This method uses the ratio to split the current interval into two subintervals.

Steps:

Initialization:

Choose an initial interval [a, b] such that the minimum (or maximum) lies within this interval.

Calculate Midpoints:

Calculate two interior points, x1 and x2, within the interval [a, b] using the golden section ratio.

$$x_1 = b - \frac{b-a}{\phi}$$

$$x_2 = a + \frac{b-a}{\phi}$$

Evaluate Function:

Determine the function's values at f(x1) and f(x2), the two inner sites.

Update Interval:

Update the interval [a, b] based on the function evaluations:

The interval should be updated to [a, x2]

If f(x1) < f(x2).

The interval should be updated to [x1, b]

If f(x1) > f(x2).

Repeat:

Repeat the process until a stopping criterion is met (e.g., a specified tolerance level is reached).

The fig 2 shows flowchart of Golden Section Search Algorithm.

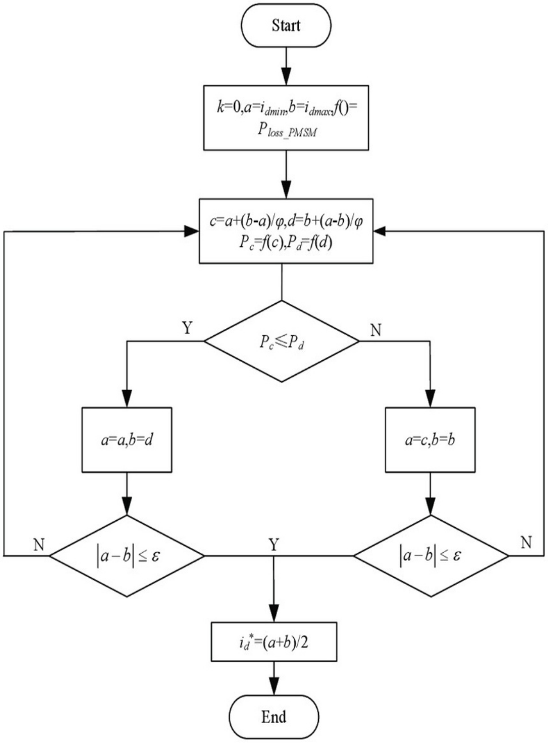

Fig. 2: Golden Section Search Algorithm flowchart

Optimal placement of DG using fuzzy approach Main objectives considered while designing fuzzy logic is Minimizing Power losses maintaining voltage with in permissible limits. A set of criteria called the Fuzzy Inference System (FIS) is utilized to identify where to place DG. Acceptability of every node in the distribution system under consideration First, load flows 15] are carried out to determine actual power loss; then, they are carried out once more to reduce power loss by correcting for the total real power load at each distribution system node. Reductions in losses normalized linearly in the interval [0, 1]. Variety where the lowest cost is zero and the fine loss discount has a value of one. The following formula may be used to get the strength loss index value for the nth node.

$$PLI(n) = \frac{LR(n) - LR(\min)}{LR(\max) - LR(\min)}$$

The formation of a fuzzy logic controller and its criteria to assess a node's appropriateness for DG setup is necessary for the high-quality, optimal placement of DG. Fuzzy's rules desk, as shown in Table 1

Table. 1 Fuzzy Rules

AND		**VOLTAGE**				
		NS	NB	Z	PS	PB
PLI	NS	NB	NB	NS	NS	NS
	NB	Z	NB	NB	NS	NS
	Z	PS	Z	NB	NS	NS
	PS	PS	PS	Z	NB	NS
	PB	PB	PS	Z	NB	NB

The membership plots for PLI, Nodal voltages and DG suitability index as shown in Fig 3, Fig 4, Fig 5.

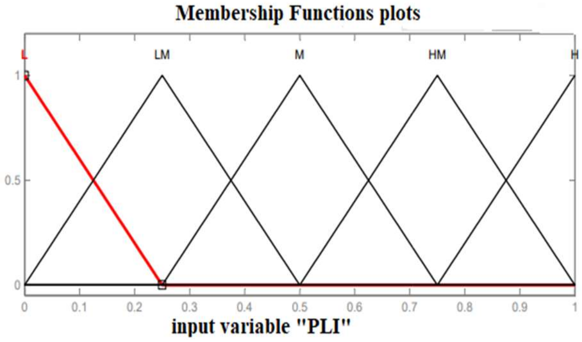

Fig 3 Membership functions for PLI

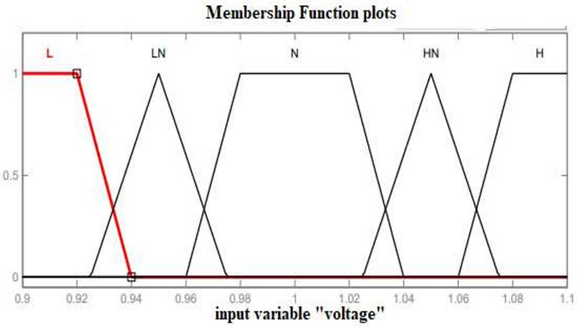

Fig 4 Membership functions for Voltage

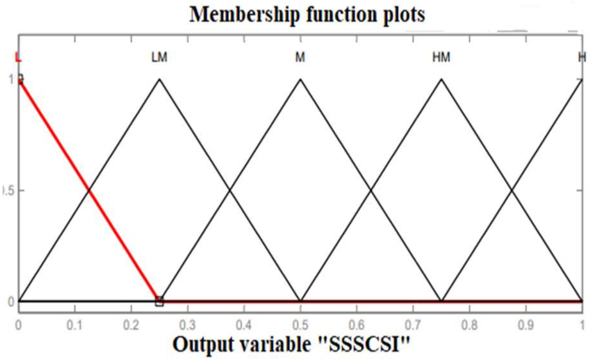

Fig 5 Membership functions DG suitability index

4 Results

The two IEEE standard 15 and 69-bus systems are used to investigate the hybrid mode of GSS and FLC approach. Fig 6 and Fig 7 show the systems with 15 and 69 buses, respectively.

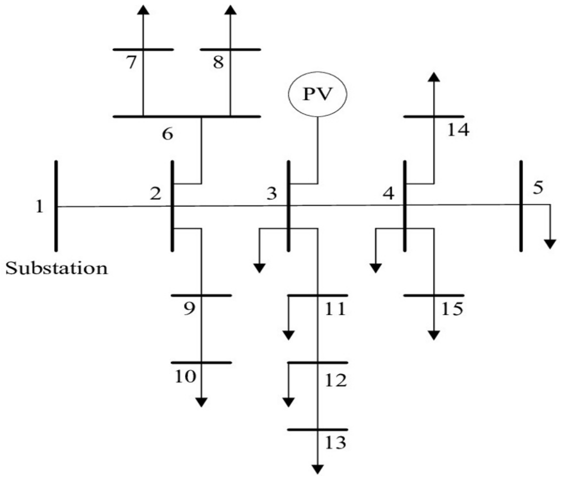

Fig 6 Radial network of 15-bus system

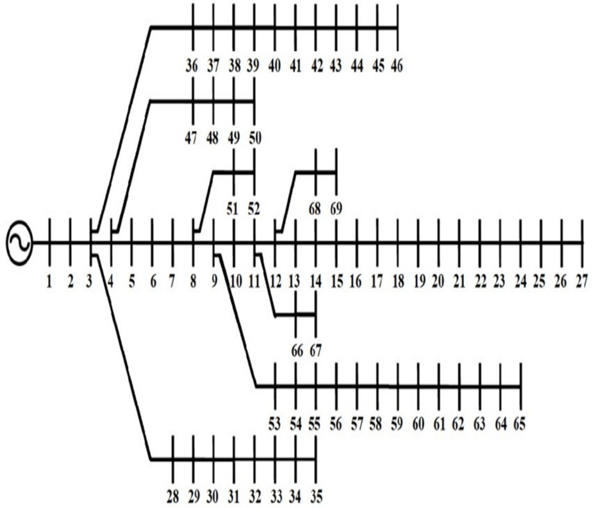

Fig 7 Radial network of 69 bus system

A) For 15-bus distribution system

The results are obtained by GSS+FUZZY are compared with the PSO algorithm results in order to assess the effectiveness of the proposed method. Table 2 presents a comparison between the IEEE 15-bus system's GSS+FUZZY algorithm and PSO method outcomes. According to Table:2, bus 15 was determined to be the ideal site for DG unit deployment using the DG suitability index. The DG unit has comparable capacity of 694.25kW when utilizing the PSO technique and 669.57kW when using the GSS+FUZZY approach. When the DG units are placed at this ideal spot, the voltage profile considerably improves and the system's power losses drop by 35.25 using the GSS+FUZZY technique and 30.21 using the PSO technique. Table 2 shows the DG Placement for the IEEE 15-Bus System using the Particle Swarm Optimization (PSO) and GSS+FUZZY methodologies.

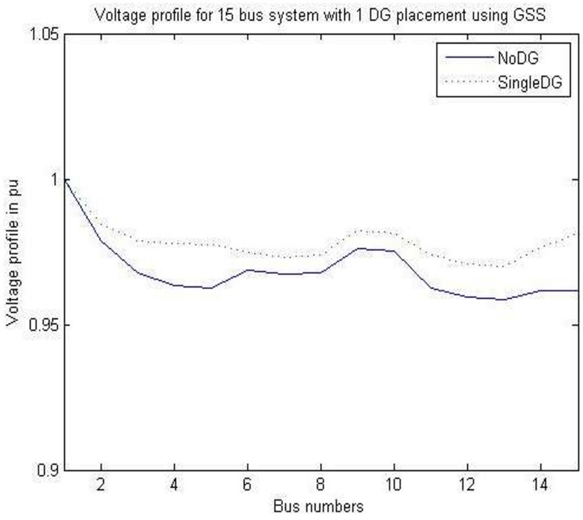

Table 2 DG placement and size at 15-bus system

Case	Technique	Installed DG Schedule		DG (Kw)	Ploss (Kw)	Loss Reduction (%)
Before DG					45.50	0.00
After DG	PSO	Bus	15	694	31.75	30.21
		Size	694			
	GSS + FUZZY	Bus	15	669	28.73	35.25
		Size	669			

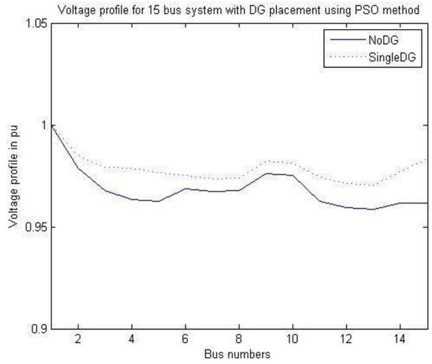

Fig 8 and Fig 9show voltage variations with respect to before and after placement of DG for both PSO and GSS+FUZZY cases.

Fig 8 Bus voltage variations in 15-bus IEEE system with and without DGs by using PSO.

Fig 9 Bus voltage changes in a 15-bus IEEE system utilizing GSS+FUZZY with and without DGs.

B) For 69-bus distribution system

The results are obtained by GSS+FUZZY are compared with the PSO algorithm results in order to assess the effectiveness of the proposed method. Table 3 presents a comparison between the IEEE 15-bus system's GSS+FUZZY algorithm and PSO method outcomes. According to Table:2, bus 69 was determined to be the ideal site for DG unit deployment using the DG suitability index. The DG unit has comparable capacity of 1900kW when using the PSO technique and 1872.7kW when utilizing the GSS+FUZZY approach.

When the DG units are positioned at this ideal spot, the voltage profile considerably improves and the system's power losses drop by 67.0 using the

GSS+FUZZY technique and 63.0 using the PSO technique.

Table 3 for DG Placement Using Particle Swarm Optimization (PSO) and GSS+FUZZY techniques for IEEE 69-Bus System.

Table 3 DG placement and size at 69-bus system

Case	**Technique**	**Installed DG Schedule**		**DG (Kw)**	**Ploss (Kw)**	**Loss Reduction (%)**
Before DG					224.9	0.00
After DG	PSO	Bus	61	1900	83.23	63
		Size	1900			
	GSS + FUZZY	Bus	61	1873	78.21	67
		Size	1873			

Fig 10 and Fig 11 show voltage variations with respect to before and after placement of DG for both PSO and GSS+FUZZY cases.

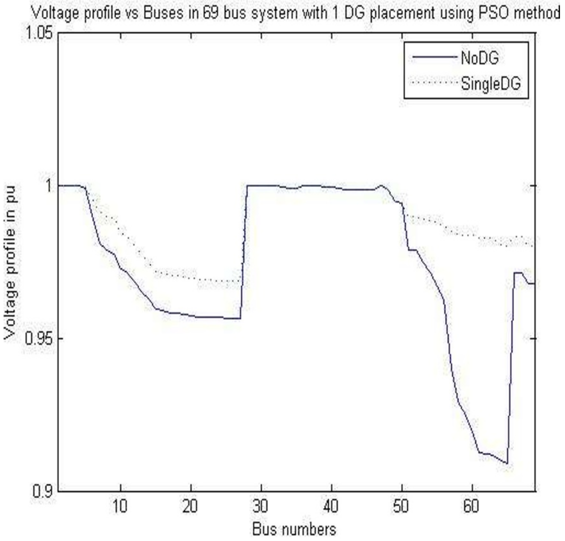

Fig 10 Bus voltage variations in 69-bus IEEE system with and without DGs by using PSO

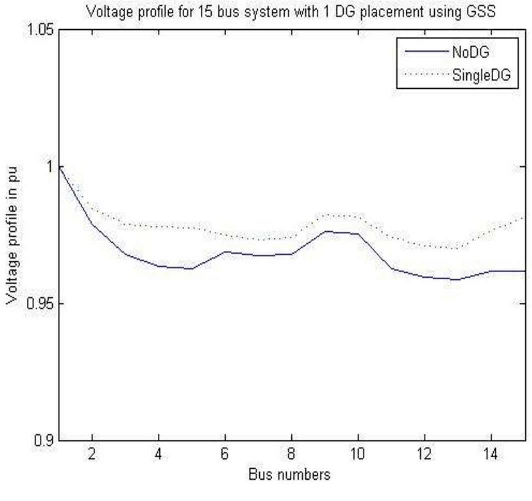

Fig 11 Bus voltage variations in 69-bus IEEE system with and without DGs by using GSS+FUZZY.

5 Conclusion

This project has suggested the PSO methodology and a Fuzzy-GSS method for multiple DG allocation for loss reduction and voltage profile improvement in distribution networks to serve the main objective of distributed generation. The PSO technique is based on PSO expressions and is used to identify the optimal size and position of available four types of DGs. Only one of the four types of DG one that introduces active power is looked at in this article. This thesis determines the optimal location and size for many DG units using a two-stage approach that blends fuzzy and GSS.

The results clearly show that while two methods PSO and GSS approaches may improve voltage profiles and minimize loss, the GSS technique yields more precise results and a higher percentage of loss reduction than the PSO method. Even though the PSO method computes more quickly, the GSS technique offers a greater percentage of loss reduction with a smaller DG size for the same number of installed DG units.

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