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Optimal Sizing and Assignment of Distributed Generation and Energy Storage System using Hybrid Techniques in Radial Distribution System

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Abstract: The relevance of Distributed Generation (DG) has grown in recent years as a result of rising commercial and industrial loads, which places greater demand on traditional sources due to a scarcity of natural resources. As a consequence, in order to fulfil the enormous load without jeopardizing natural resources, new power generation methods are required. The placement of Energy Storage Systems (ESSs) could be a huge chance to enhance the appearance of the distribution system. And DG is one of the most effective answers to the economic and ecological challenges of traditional sources. Some possibilities, it appears, need a large area and a significant expenditure. The optimal DG size and location decreases power loss, whereas the improper DG size and location increases loss due to excessive reverse flow from the load to the supply, causing protection issues. An Improved Shuffled Frog Leap Algorithm (ISFLA) with Reptile Search Algorithm (ISFLA-RSA) for the ideal placement and size of DG and ESS in the IEEE Radial Distribution System (RDS) is proposed in this study to minimize power losses and retain voltage magnitude. While related to the conventional Analytical Index Method and Whale Optimization Algorithm, the suggested ISFLA-RSA achieves loss reduction and voltage profile of 92.4766 % and 0.9729, respectively.

Keywords: Improved shuffled frog leap algorithm, Reptile search algorithm, Distributed generation, Energy storage system, Radial distribution system.

1. Introduction

DG technology is the easiest and convenient way to generate electricity. Furthermore, when compared to the case of reactance [1] the Radial Distribution System (RDS) has a high resistance. A large-scale power generation capability that is typically linked to the structural radial network is commonly referred to as DG [2]. DGs are typically employed at various integrated equipment that are spread throughout the site in order to lower the provision charge. DG is a procedure that decreases overall feeder line loss by supplying the required power at or around the load's midpoint, or by conveying it smoothly in an equivalent arrangement [3, 4]. The RDS's major purpose is to identify the load need as consistently and cost-effectively as feasible at each location within the radial system [5]. The operation of some classic generation facilities, on the other hand, is completely reliant on a consolidated switch interconnected to the service grid. Utilities distribute driven power across a broad radial distribution infrastructure to fulfil the needs of widely dispersed users [6, 7]. The motivation for larger chief power plants is currently dwindling due to high-tech improvements, the shrinking nature of existing assets, differentiating conservational growing concerns, deregulation improvements, and improved feeder line charges [8].

DGs will continue to exist and will be allocated to the highest capability in addition to enhancing the structure's effectiveness and decrease power loss [9], [10]. Similarly, despite the fact that it must maintain system uniformity even under dynamic loading, it causes a slight increase in voltage stability [11, 12]. Because it is fully reliant on its category, load, and proximity to the construction power point, the main consequence of assigning a DG will be different. [13].

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The voltage uncertainty, diffusion level, ideal position and its capacities, as well as other analytical data experienced in the DG assignment have encountered in the DG apportionment. For FC-based DGs, an improved version of Artificial Bee Colony (ABC)gives the finest capabilities. If the DGs are positioned with an inappropriate location and size which presents major issues with distribution loss and voltage [14]. Therefore, it is crucial to determine the proper positioning and size. Therefore, this researchexamines the ideal location for adding distribution generators and the ideal size foremploying ISFLA-RSA on IEEE 33 & 69 bus systems.In this study, RDS limits are satisfied while effectively lowering the total power loss by the use of hybrid ISFLA-RSA for DG placement. In identifying the sizes and positions, the process is quick and precise. Byimplementing DG at all potential places, the system's overall power loss is significantly decreased andsystem's voltage profile gets enhanced.

The following are some of the contributions of this research:

1. The position of the DG/ESS, as well as the reconfiguration method, is carried out in a supporting system to assess the system's ability to minimize power loss and enhancethe voltage profile.
2. The nonlinear optimization problem is explained by combining ISFLA and RSA.
3. For the goal of DG/ESS optimal size and placements, this procedure is quick and precise.

The organization of this research are mentioned as follows; Section 2 describes the literature review based on optimal location and sizing of DG units. Section 3 represents the problem statement of this research work. Section 4 demonstrates the objectives of this study. Section 5 describes the procedure of proposed method in terms of mathematical equations. Section 6 elaborates the simulation results along with comparative analysis. Finally, the conclusion is stated in Section 7.

2. Literature review

The New Enhanced Symbiotic Organisms Search (NeSOS) for Ideal Placement and Sizing of DG in RDS has been presented by Umar Umar [15]. To reduce power loss and voltage profile, this research optimises DG size and location in RDS. TDG size is calculated by utilising New Enhanced SOS method whereas the position of the DG is detected utilising Loss Reduction Sensitivity Factor (LRSF). The proposed scheme was also evaluated against alternative approaches using the IEEE 33 and 69 bus test systems. However, they have a broad search range, which makes the dimensionality as large, so, the convergence speed gradually decreases.

Aref Jalili and Bahman Taheri [16] has demonstrated a Robust Procedurebased on Firefly Algorithm (FA) for Distribution and Dimensions of Renewable DG on RDS. A multi-objective function index strategy is used to ensure power quality (PQ) by increasing the voltage level while lowering the system's power losses and overall grid operating costs. Meanwhile, increasing the DG size lowers the cost of real/reactive power. However, after a given period of time, the size of the loss begins to increase.

The Dual-Phase Parasitism (DPP) Symbiotic Organisms Search (SOS) with Crossover Operator for Optimal Multi Single-Phase DG in Unbalanced RDS has been proven by Umar Umar [17]. This research examines the best position and size of multiple single-phase DGs in distribution networks to reduce power loss and increase voltage while keeping harmonic and voltage unbalance within acceptable range. On the other hand, despite the fact that those advancements were fall short of the single-phase DG scheme's performance.

S.A. Chithra Devi, L. Lakshmi Narasimman, R. Balamurugan [18] have demonstrated the Stud Krill Herd Algorithm (SKHA) for the result of ideal sizing/allocation of DG in RDS. SKHA was exploited for solving the ideal DG placement issue inradial system also. The proposed method prominently progresses the accuracyof the overall idealist and supremacy of the solution. The implemented SKHA can be executed to some extent of DG count, but while considering the consistency, DG count is restricted to 3 only.

Ling Ai Wong [19] proposed a Whale Optimization Algorithm (WOA) method for optimum installation of battery Energy Storage System technologies to decrease power loss in the system. The suggested WOA technique was incorporated with the Power Flow process to produce a novel technique. This WOA technique was evaluated in the standard RDS bus systems. The proposed method could precisely deliver the optimum result with quick computational speed, but could not deliver the optimal result for assigning a combination of ESS that belonged to dissimilar categories.

Haider [20] proposed a Multi-Objective Particle Swarm Optimization (MOPSO) method for optimum installation of multiple DG technologies to decrease power loss in the system. The suggested technique was incorporated with the Power Flow process to produce a novel technique. This technique was evaluated in the IEEE 33 and 69 RDS. The proposed method could precisely deliver the optimum result with quick computational speed, but could not deliver the optimal result for assigning a combination of DGs that belonged to dissimilar categories.

Gholamreza Memarzadeh, Farshid Keynia [21] has presented an Analytical Index Method (AIM) for determining the optimal size and location of distribution generation in a network. This article purpose is to present a new DG placement index for the small and big distribution network. In contrast to current methods in this sector that require complex optimization algorithms, the suggested method may solve the optimal DG placement problem very simply and quickly, especially for large networks. The simulation approach has been implemented on the IEEE 33 and 69 bus distribution network to evaluate the efficiency of technique in the preceding section. However, this strategy outperforms all others in terms of lowering power losses, with the exception of ALO.

3. Problem statement

The following are some of the issues that arise with a matured DG system.

1. Many existing optimization approaches for DG sizing and location do not take into account the dominance of characteristics like cost, localization and sizing.
2. DG location can sometimes result in improved computing performance and the capacity to search globally. It does not, however, have the adaptability for real-time performance and does not solve the non-linearity problem.
3. Some of the optimization techniques deliver the assignment of DGs and ESS completely but the experiment results are not sufficient enough to prove the system efficiency.
4. One of the issues with DG and ESS allocation is the cost function, and the overall loss in the network is determined by nonlinear equality controls.

4. Objectives

The goal of this study is to create the necessary simulation programs for optimizing specific features of radial distribution systems. The main goals of this study are to:

- Show a backward forward sweep distribution load flow.
- Provide a framework for ISFLA-RSA implementation in RDS for certain optimization challenges.
- Apply the proposed method to various test systems to demonstrate its efficiency.
- In this study, the ISFLA-RSAis used to control the ideal DG/ESS size and placement, as well as the optimal network configuration and power losses.

5. Proposed method

The block diagram for the idealemployment in IEEE radial network is revealed in Fig. 1.

5.1 Improved SFLA method

Shuffled Frog-Leaping Algorithm (SFLA) is a type of memetic meta-heuristic which has been created to solve combinatorial optimization problems. The SFL design combines the benefits of both genetic and social characteristics-dependent PSO computations. In this computation, the population contains of a large number of frogs which are divided into subclasses known as memeplexes. The numerous memeplexes are compared to various societies of frogs, each of which is engaged in a local adventure. The many frogs develop through a process of memetic progression within each memeplex. Thoughts are transmitted among memeplexes in a

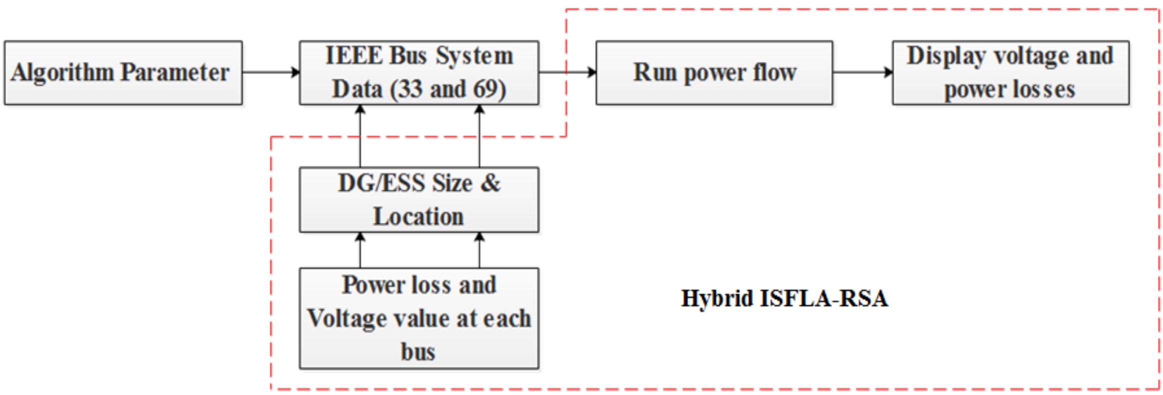

Figure. 1 Block diagram of idealDG/ESS assignment in RDS

rearranging mechanism subsequently a demarcatedquantity of memetic growth steps. The shuffle and local exploring operations continue until the required convergence requirements are met. A frog is used to solve S-dimensional issues. A frog i is characterizedby means of

$$X_i = \{X_{i1}, X_{i2}, \dots . X_{in}\} \quad (1)$$

Following that, the frogs are organized into downwarddirection based on their appropriateness. The population is then distributedinto m, each of which contains n frogs. The main frog visits the principal memeplex, the following visits the subsequent memeplex, frog m visits the m memeplex, and frog $m+1$ visits the leading memeplex, etc. The frogs through the finest fitness within each memeplex are designated as X_g. At that time, in a development similar to PSO, merely the frog using weakest fitness in each cycle is improved.

As a result, the poorest fitness of frog has his place altered as follows:

Alteration in frog location

$$D_i = rand * (X_b - X_w) \quad (2)$$

The following equations summarise the impact of the revised algorithm on system reliability. The location of the frog with the lowest fitness is improved as follows:

New locationX_w= current location$X_w + D_i$ (3)

$$X_{Kw}^{t+1} = X_{Kw}^{t} + D_K^t \quad (4)$$

$$D_{max} > D_i > -D_{max} \quad (5)$$

D_{max} is the maximum allowable change in a frog's location, and $rand$ (*) is a random value amongst 0 and 1.

If this method provides a better result, it substitutes the worst frog; or else, the computations are redone, but using the global best frog as the reference point ($X_g$replaces X_b). If there is no way to remedy this situation, a novel solution is chosen randomly to substitute the frog. To reduce losses and voltage profile, SFL algorithm is used to optimize DG location and capacity.

5.2 Reptile search algorithm (RSA)

The suggested RSA is stimulated by the encompassing processes, hunting machineries, and social activities of Crocodiles is presented in this part, along with the exploration and exploitation stages [22]. Crocodiles encircle and pursue their prey. These mechanisms have been theoretically simulated in order to show the suggested RSA and carry out the optimization procedures. Crocodiles are massive semi-aquatic creepers found across the tropics, including Tasmania, Europe, Indochina, and the Caribbean. Only the species belonging to the "Crocodylinae" subfamily are referred to be crocodiles. The physical qualities of a crocodile, in general, complement its ability to be a powerful predator. Their exterior shape indicates that they live in water and hunt prey [23].

The optimization technique in RSA begins with a collection of candidate solutions (X) as indicated in Eq. (6), which are created randomly, and the best-obtained solution is deemed the nearly optimal in each cycle.

$$X = \begin{bmatrix} x_{1,1} \dots x_{1,1} x_{1,n-1} x_{1,n} \\ x_{2,1} \dots x_{2,j} \dots x_{2,n} \\ \dots \dots x_{i,j} \dots x_{1,n} \\ \dots \dots \dots \dots \dots \\ x_{N-1,1} \dots x_{N-1,1} \dots x_{N-1,n} \\ x_{N,1} \dots x_{N,j} x_{N,n-1} x_{N,n} \end{bmatrix} \quad (6)$$

Where X signifies the j_{th} position of the i_{th} solution, N denotes the amount of candidate solutions, and $n$represents the dimension size, and Eq. (7) displays $x_{i,j}$ which provides the j_{th} position of i_{th}solution.

$$x_{ij} = rand \times (UB - LB) + LB,\ j = 1,2, \dots n \quad (7)$$

$rand$ is a random rate, LB and UBsignify to the lower and upper bound of the given problem, respectively.

The revolutions introduced to various reigns that are dedicated to the exploratory search. Crocodile motions, unlike in another search phase, do not allow them to quickly approach the intended prey because of their commotion (hunting phase). Then they used the most basic guideline, which can imitate Crocodiles' encircling movement. The position update equations for the exploration phase are provided in this study as Eq. (8).

$$x_{i,j}(t+1) = \begin{cases} Best_j(t) \times -\eta_{i,j}(t) \times \beta - R_{(i,j)}(t) \times rand t \le \frac{T}{4} \\ Best_j(t) \times x_{r_1,j} \times ES(t) \times rand t \le 2\frac{T}{4} and t > \frac{T}{4} \end{cases} \quad (8)$$

where $Best_j(t)$ denotes the j_{th} position in the obtained solution. The term $rand$ refers to a randomintegeramong 0 and 1, where t is the current iteration and T is the maximum iterations. The hunting operator ($\eta_{(i,j)}$) specifies the j_{th} position in the i_{th} solution, which is determined by Eq. (9). $\beta$is a sensitive constraint that determines the surrounding stage exploration precision throughout the progression of iterations and is set to 0.1.

$$\eta_{(i,j)} = Best_j(t) \times P_{(i,j)} \quad (9)$$

Reduce function $R_{(i,j)}$ is a rate calculated using Eq. (10) to decrease the exploration area. $x_{r_1,j}$signifies a random point of i_{th} solution, and r_1 is a random value between $[1\ N]$. The quantity of candidate solutions is N. Evolutionary Sense $ES(t)$ is a probability fractionthat is derived using Eq. (11) that takes progressively diminishing values among 2 and -2 across the number of cycles.

$$R_{(i,j)} = \frac{Best_j(t) - x_{r_2,j}}{Best_j(t) + \varepsilon} \quad (10)$$

$$ES(t) = 2 \times r_3 \times (1 - \frac{1}{T}) \quad (11)$$

r_2 is a random number between $[1\ N]$, and $\varepsilon$is a small value. 2 is utilized as a correlation rate in Eq. (11) to yield standardsamongst 2 and 0, and r_3 is a random characteramong -1 and 1. The percentage difference between the j_{th} location of the optimal results and j_{th}location of the present solution using Eq. (12).

$$P_{(i,j)} = \alpha + \frac{x_{(i,j)} - M(x_i)}{Best_j(t) \times (UB_{(j)} - LB_{(j)}) + \varepsilon} \quad (12)$$

$M(x_i)$ denotes the average positions of i_{th}solution, as computed by Eq. (13). The upper and lower bounds of j_{th} position are denoted by $UB_{(j)} - LB_{(j)}$, respectively, which is set to 0.1 in this paper,α is a critical parameter that determines the exploration accuracy for hunting co - operation well over number of evolution.

$$M(x_i) = \frac{1}{n}\sum_{j=1}^{n} x_{(i,j)} \quad (13)$$

These tactics refer to many intensive procedures that are dedicated to the exploitation investigation. Then used the most basic guideline, which may be used to imitate Crocodile foraging behaviour. The accompanying location changing equations (Eq. (14)) are provided in this study for the evaluation stage:

$$x_{i,j}(t+1) = \begin{cases} Best_j(t) \times P_{(i,j)}(t) \times rand t \le 3\frac{T}{4} and t > 2\frac{T}{4} \\ Best_j(t) - \eta_{i,j}(t) \times \varepsilon - R_{(i,j)}(t) \times rand t \le T and t > 3\frac{T}{4} \end{cases} \quad (14)$$

where $Best_j(t)$signifies the j_{th} position in the best-obtained solution thus far, and $\eta_{i,j}$ is the hunting operator for the j_{th} location in i_{th} solution, as determined by Eq. (9). $P_{(i,j)}$ represents the percent error between the j_{th} place of the best-obtained solution and j_{th} position of the current solution, as computed by Eq. (12). The hunting operator $\eta_{i,j}$ specifies the j_{th} position in i_{th} solution, which is determined using Eq. (9) which is a small amount of change,$R_{(i,j)}$ is a value that is calculated using Eq. (9) decrease the search area. Exploitation search methods try to avoid becoming stuck in local optima. This approach helps the search in selecting the best answer while also preserving the diversity of potential solutions. Then, using two carefully calculated constraints (i.e., β and α), generate a stochastic rate at every iteration.

6. Results and discussion

The proposed ISFLA-RSA method for DG distribution networks not only reduces distribution network loss but also improves the system voltage profile. The hybrid ISFLA-RSA technique is employed for this distribution system. Because of its excellent searching efficiency and capacity to prevent premature maturation throughout the search phase, ISFLA is widely used. In the hybrid ISFLA-RSA approach, the RSA method is used to determine two key DG parameters: size and location. The test system's DG rating, load flow, and DG placement are all determined using the RSA method. RDS through DG consist of minimum loss and enhances voltage profile, according to the results of the hybrid ISFLA-RSA approach.

6.1 Analysis of ISFLA-RSA

When the DG is utilized at trailing PF, the losses are lower than when the DG is used at unity PF. Table 1 and 2 show the results obtained. Fig. 2 shows the voltage curve at a power factor of one.

6.2 Results of 33-bus system

The hybrid ISFLA-RSA approach is utilized to analyses the simulated results.

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Table 1. Performance of DG at unity PF

Parameters	Exclusion of DG	Existing SFLA-ALO	Proposed ISFLA-RSA
Cost of real power dg	--	31.104	28.482
DGlocation	--	30	25
DG size(kW)	--	1542.7	1411.9
Minimum bus voltage(p.u.)	0.9040	0.9553	0.9612
Real power loss(kW)	211	125.1650	115.3863

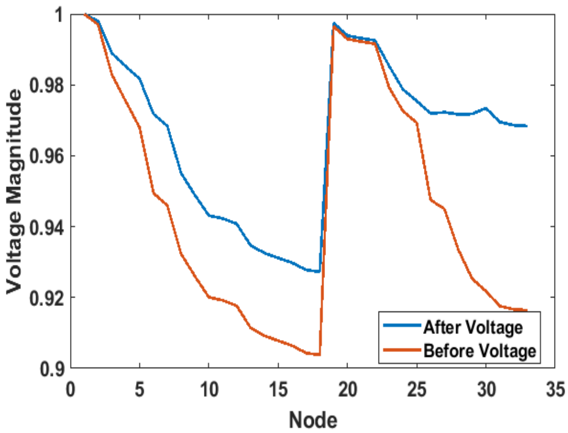

Figure. 2 Voltage magnitude at a unity PF

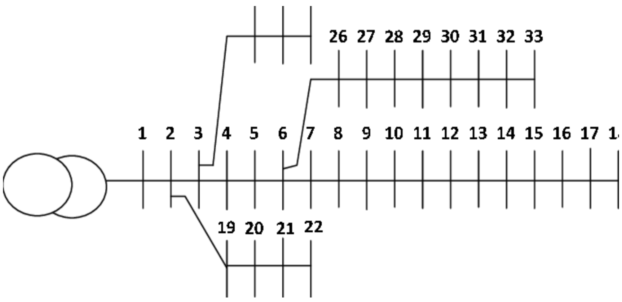

Figure. 3 Representation of 33-bus

Case 1: A bus system with reconfiguration is considered.

Case 2: A network with reconfiguration and random DG is studied.

Case 3: A network with reconfiguration and single/multi DG is being studied.

Case 4: A network with various ESS is considered.

In example 1, the Type 1 DG is used to operate the 33 bus system. Table 2 shows the outcomes of the case 1 performance study.

Table 2. Performance analysis of case 1

Case 1	BEFORE DG	ISFLA-RSA
DG Location	-------------	33 12 28
DG size	-------------	0.15 MW
Power loss	202.68 KW	79.9591kW
Reduction (loss)	-------------	61.9855%
Tie switches	33 34 35 36 37	33 26 15 6 30

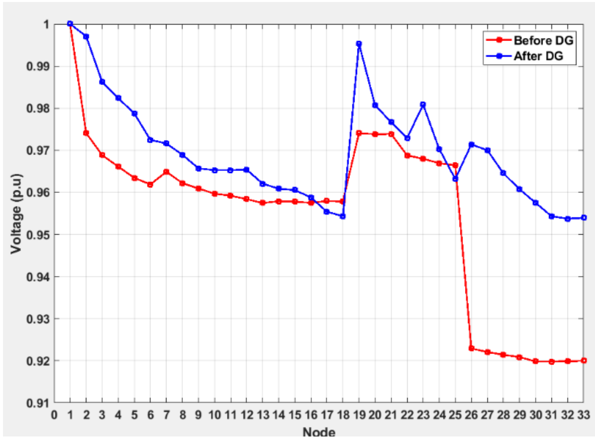

Figure. 4 Voltage stability for test case 2

Table 3. Performance study of case 2

Test case 3	BEFORE DGs	ISFLA-RSA
Power loss	202.68 kW	57.426 kW
Power loss reduction	-------------	71.7328 %
Tie switches	33 34 35 36 37	7 10 14 37 36
Minimum voltage:	0.91075pu	0.97981pu
Size (location of DG)	-------------	1.13 MW (25 30 18)

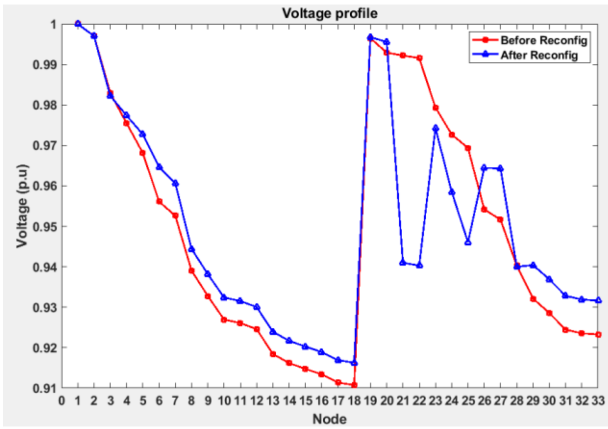

Figure. 5 Voltage stability for test case 3

In case 2, the 33-bus is carried out type-2 DG. The behavior of case 2 is revealed in the Table 3 and voltage stability graph is shown in below Fig. 5.

In case 3, the 33-bus is conceded with DG. The behaviour of case 3 is revealed in Table 4 and voltage stability graph is shown in below Fig. 6.

ESS position and sizing have exaggerated mainly on the network losses. In this research, the maximum candidate buses for connecting ESS are adapted/initialized through ISFLA-RSA. From the Table 9, it determined that suggested ISFLA-RSA minimizes the total loss from 202.68 kW to 98.0382 kW which indicates a 52.377% of overall loss decrease.

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Table 4. Performance study of case 3

Test case 4	BEFORE DGs	ISFLA-RSA
Tie switches	33 34 35 36 37	7 18 17 22 30
Power loss	202.68 kW	39.71 kW
Size (location of DG)	-------------	1.1368 (21), 1.4647 (33), 0.8199 (29)
Power loss reduction	-------------	82.4472%
Minimum voltage:	0.91075 pu	0.9847pu

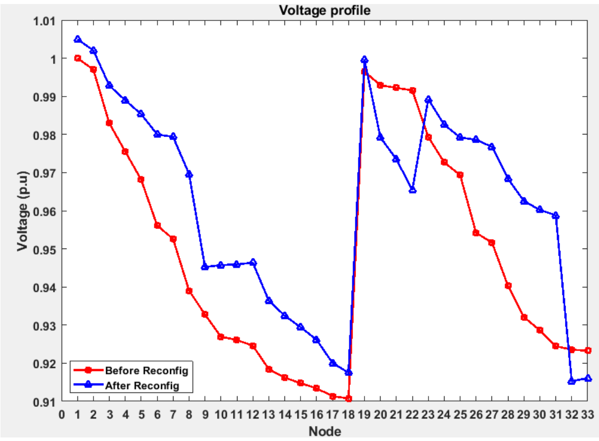

Figure. 6 Voltage magnitude of case 3

Table 5. Comparative table for ESS

Test case	BEFORE ESS	AFTER ESS
Power loss	202.68 kW	98.0382 kW
Power loss reduction	-------------	52.377 %
Size (location of ESS)	-------------	1.1006 kW 1.0165 kW 1.9285 kW (31 15 22)

6.3 Results of 69-bus system

To confirm the presentation of the hybrid ISFLA-RSA method, the simulated results are compared to the outcomes of other methodologies.

Case 1: A network with reconfiguration is considered.

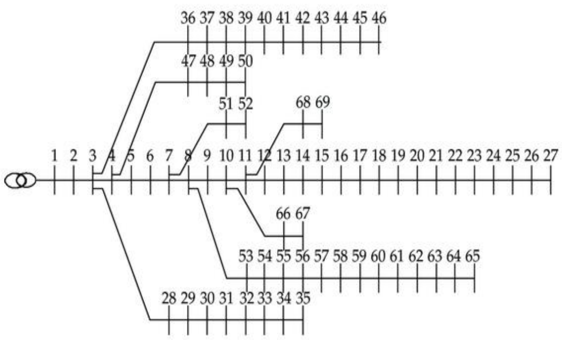

Figure. 7 Representation of 69-bus system

Table 6. Results for first scenario

Parameters	Base Values	Proposed ISFLA-RSA
Power loss	224.9804 kW	92.5851 kW
Minimum voltage	0.90919 pu	0.95917 pu
Tie line switches	69 70 71 72 73	14 58 63 49 30
Power loss reduction	-------------	61.1968 %

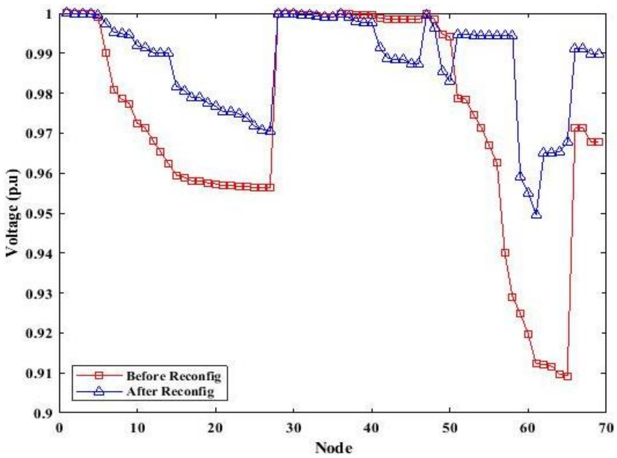

Figure. 8 Voltage magnitude for second scenario

Case 2: A network through reconfiguration and random DG units is studied.

Case 3: A network through reconfiguration and single/multi DG units is being studied.

Case 4: A network through various ESS is considered.

In this situation, the Type 1 DG bus system is used. Table 6 shows the results of the case 1 performance analysis. The results for Case 1 are shown in Fig. 8.

Type 2 DG is used in Case 2 of the 69 bus system. Table 7 shows the results of the case 1 performance analysis. The results for Case 1 are shown in Fig. 9.

The ideal DG magnitude with reconfiguration for the IEEE 69 RDN is described in Table 7. It has been established that bus number 39, 28, 51 is optimal bus location for DG apportionment with a magnitude of

Table 7. Results for second scenario

Parameters	Base values	Proposed ISFLA-RSA
Power loss	224.9804 kW	45.1239 kW
Minimum voltage:	0.90919 pu	0.95693
Power loss reduction	-------------	79.1988 %
Tie switches	69 70 71 72 73	35 5315 24 61
Size (location of DG)	4 KW	4 KW (39 28 51)

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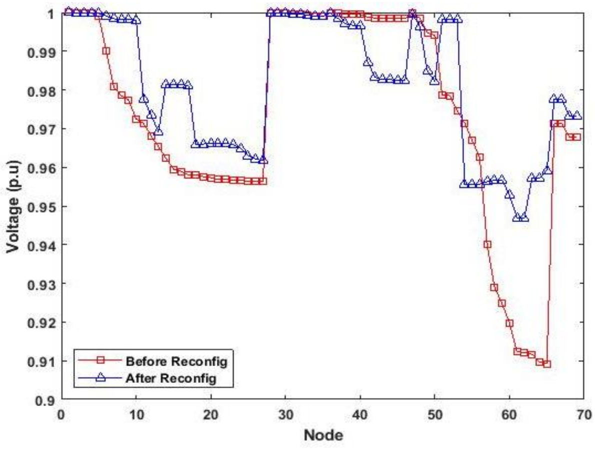

Figure. 9 Voltage magnitude for second scenario

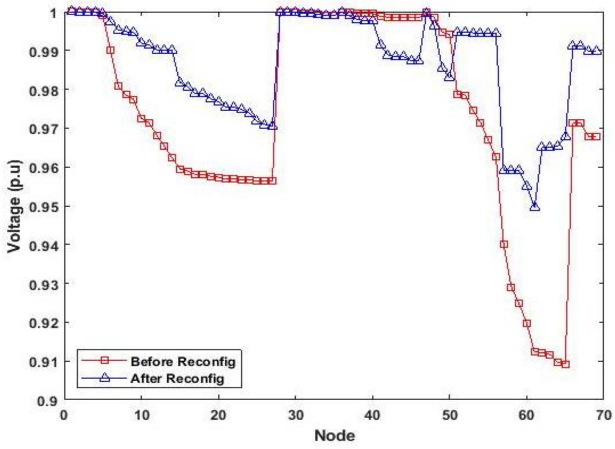

Figure. 10 Voltage magnitude for third scenario

Table 8. Results for third scenario

Parameters	Base Values	Proposed ISFLA-RSA
Power loss	224.9804 kW	29.5833 kW
Minimum voltage	0.90919 pu	0.9721pu
Tie switches	69 70 71 72 73	19 27 11 59 66
Size (location of DG)	4 KW	0.4 MW (23 44 55)
Power loss reduction	-------------	92.4766 %

0.4 MW, resulting in a real power loss decrement from 224.6 to 45.1239 kW, representing a reduction of 79.1988 %.

In case 3, the ISFLA-RSA methodology is used to determine the best position and size for the DG units. Fig. 9 displays a voltage stability graph. When compared to the power loss of the base configuration, the IEEE 69 RDS with multiple DGs and reconfiguration loses less power.

The optimum size of DG with reconfiguration for the IEEE 69-RDN is described in Table 8. The voltage outline for the final test case with the reconfiguration process is shown in Fig. 10. It was discovered that bus 23, 44, 55 is the finest bus for optimal DG apportionment with a magnitude of 0.4 MW, resulting in a power loss decrement from 224.6 to 29.5833 kW, displaying 92.4766 % of the total discount.

Table 9 shows the comparative analysis overall process. The stability of voltage for multiple DGsare presented. From table 10, it is determined that the proposed ISFLA-RSA method minimizes the loss from 224.9804 kW to 26.1082 kW that indicates an 88.2179 % decrease of overall loss. Where the existing NeSOS [15] and AIM [21] has achieved the power loss up to 69.14 % and 83.42 % respectively. Table 11 shows the comparative analysis of ESS.

Table 9. Comparison table for existing techniques

Base case	Existing MOPSO [20]	ISFLA-RSA Algorithm
Case 1	Min voltage = 0.9428 Power loss = 99.35 Power loss reduction = 55.85 % Tie switch = 69 18 13 56 61	Min voltage = 0.9591 Power loss = 92.5851 Power loss reduction = 61.1968 % Tie switch = 14 58 63 49 30
Case 2	Min voltage = 0.9619 Power loss = 51.30 Power loss reduction = 77.2 % Tie switch = 69 18 13 56 61	Min voltage = 0.95693 Power loss = 45.1239kW Power loss reduction = 79.1988% Tie switch = 35 5315 24 61
Case 3	DG size (location) = 1.0666(61), 0.3525 (60), 0.4527 (62) Min voltage = 0.9736 Power loss = 40.30 Power loss reduction = 82.08 % Tie switch = 69 17 13 58 61	DG size (location) = 0.4(23), 0.4(44), 0.4(55) Min voltage = 0.9729 Power loss = 29.5833kW Power loss reduction = 92.4766% Tie switch = 19 27 11 59 66

While analysing the FA [16] for placing the ESS in Radial distribution system, the system achieved the power loss of 51.42 kW which is less than proposed ISFLA-RSA which accomplished the less power loss of 41.19%. While comparing the existing WOA [19], it achieves power loss of 51.15 kW which is higher than proposed ISFLA-RSA. Based on the abovementioned findings, better voltage guidance

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Table 10. Assessment for multiple DG units

Case 4	NeSOS [15]	Existing AIM [21]	ISFLA-RSA
Minimum voltage:	0.979pu	0.9673pu	0.97276 pu
Power loss	69.43 kW	37.122 kW	26.1082 kW
Power loss reduction	69.14 %	83.42 %	88.2179 %
Size (location of DG)	0.527 (11), 0.381 (17), 1.719 (61)	0.13 (24), 0.45 (45), 0.77 (58)	0.2, 0.172,0.824 (23, 53, 61)
Tie switches	------	69 70 71 72 73	31 39 62 19 28

Table 11. Comparative analysis of ESS

Scenario	Existing Firefly Algorithm [16]	Existing WOA [19]	Proposed ISFLA-RSA
Location	7,22	7,15	35, 59
Size (MW)	0.37 & 0.72	0.67, 1.50	0.31, 0.59
Power loss (kW)	51.42	51.15	41.19

and a significant reduction in power loss can be obtained without causing negative effects on influence framework activity. In addition, the proposed ISFLA-RSA is faster and more powerful in resolving wide-spread distribution networks.

7. Conclusion

The increase in DG/ESS resources is due to deregulation of the radial network and a lack of transmission measures. For DGs/ESS to achieve their expected improvements, they must be placed in the best possible position in a radial dispersed network. The proposed solution is exclusively focused on reducing radial system power loss, and it has been evaluated in MATLAB for topologies 33 and 69 bus. The findings of this method reveal that if the DGs/ESS are located in the right places and are the right size, the radial system's total losses are minimized. This research thesis proposes a novel technique for determining the best location for the DG/ESS in the radial system by evaluating the structure's loss minimization despite its apparent aspects.When compare to the conventional WOA, the proposed research (ISFLA-RSA) put the ESS to enhance voltage magnitude (0.9727) while reducing power loss by up to 41.19 %. The developed technique was improved compared to existing techniques based on simulation. The experimental data show increased performance for localizing the DG system at the time of the modelling, with a loss reduction of 92.4766 % and a voltage magnitude of 0.9729. This study can be expanded in the future using unique hybrid methodologies and validated with larger bus systems.

Notation List

X	Candidate solution
N	Number of Frogs
X_g	Best frog
X_{Kw}^{t+1}	New location
X_w	Current location
$rand$	Random value
X_b	Worst frog
LB	Lower bound
UB	Upper bound
n	Dimension size
T	Maximum iteration
t	Current iteration
$\eta_{(i,j)}$	Hunting operator
β	Sensitive constraint
$R_{(i,j)}$	Reduce function
$ES(t)$	Evolutionary Sense
$M(x_i)$	Average position
α	Critical parameter
$P_{(i,j)}$	Percent error
$Best_j(t)$	Best solution
ε	Constant
D_i	Distance

Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

The paper background work, conceptualization, methodology, dataset collection, implementation, result analysis and comparison, preparing and editing draft, visualization have been done by first author. The supervision, review of work and project administration, have been done by second and third author.

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