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International Journal of Electrical and Electronics Research (IJEER)

Research Article | Volume 10, Issue 4 | Pages 1199-1205 | e-ISSN: 2347-470X

# Strategic Integration of DG and ESS by using Hybrid Multi Objective Optimization with Wind Dissemination in Distribution Network

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**ABSTRACT-** The importance of distributed generation (DG) has increased recently as a result of the growth in commercial and industrial loads, which has put more pressure on conventional energy sources and utilities. Alternative power generation methods that can handle the massive load without endangering the environment are therefore urgently needed. The installation of Energy Storage Systems (ESSs) may give a substantial opportunity to enhance the aesthetic appeal of the distribution system. DG is a practical substitute for conventional energy sources, which have drawbacks for both the economics and the environment. It goes without saying that there are situations in which a large amount of land and money are required. However, improper DG location or sizing increases safety issues because to the increasing power loss caused by larger reverse flow from the load to the supply. In order to reduce power losses and maintain voltage stability, the ideal location and dimensions for the DG and ESS in IEEE Radial Distribution systems are evaluated. To accomplish these objectives, a hybrid Shuffled Frog Leap Algorithm (SFLA) and Improved Firefly Algorithm (SFLA-IFFA) is suggested. The SFLA-IFFA produced better results in terms of the ideal location and DG size when compared to other existing algorithms.

**Keywords:** DG and ESS, Hybrid Shuffled Frog Leap Algorithm and Improved Firefly Algorithm.

**ARTICLE INFORMATION**

**Author(s)**: P. Munisekhar, G Jayakrishna and N Visali;

**Received**: 26/08/2022; **Accepted**: 09/12/2022; **Published**: 25/12/2022;

**e-ISSN**: 2347-470X;

**Paper Id**: IJEER220740;

**Citation:** 10.37391/IJEER.100469

**Webpage-link**:

https://ijeer.forexjournal.co.in/archive/volume-10/ijeer-100469.html

**Publisher's Note:** FOREX Publication stays neutral with regard to Jurisdictional claims in Published maps and institutional affiliations.

## 1. INTRODUCTION

The best and most effective way to produce power is with DG technology. Additionally, the RDS's resistance is considerable in comparison to its reactance value [1]. Power plants used to have vast footprints and outputs between 150 and 1000 MW. Because these facilities are constructed distant from where the demand truly is, it also results in greater fuel costs and more pollution. The aforementioned facts highlight the necessity of abandoning the conventional way of power generation and introducing DG that is situated closer to the load station [2, 3]. Smaller-scale generators are frequently featured in distributed generation (DG) (between 15 kW and 10 MW in capacity). Distributing this electricity *via* the distribution systems to final consumers [4]. The various benefits of DG include less pollution and energy expenditures, as well as a safer and more dependable power system and a more constant voltage supply [5]. To address RDS stability issues, DGs are probably used to deliver reactive and real power [6]. By properly positioning and sizing DG in any power grid, the voltage dependability and network security can be improved. Unfavourable placement of the DG will result in considerable network losses and unsteady voltage [7]. Important factors that prompted this research are:

1. A system that can help with the DG/ESS placement and reconfiguration process is used to monitor the system's ability to reduce power losses and increase voltage stability.
2. The combined usage of SFLA and IFFA provides insight into the nonlinear optimization problem.
3. Third, this method is quick and effective when deciding where to place the DG/ESS for maximum efficiency.

This strategy has been accepted as a compensation-based strategy to address load flow and allocation issues in distribution networks. Branch currents will be replaced by the better power flow, which will also be exhibited. In this research, we suggest adopting a multi-objective hybrid optimization approach to improve the DG allocation and size of the distribution system with the integration of wind energy using SFLA-IFFA.

## 2. LITERATURE REVIEW

The DG and Battery Energy Storage Systems (BESSs) can restrict the fast power ramps present research is growth in this in RDN.

A robust Firefly Algorithm (FA) procedure for the distribution and dimensions of renewable DG on RDS. In order to guarantee power quality (PQ), a multi-objective function index technique is employed to raise voltage levels while reducing system power

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losses and overall grid operating expenses. Meanwhile, the cost of real/reactive electricity decreases as DG size increases. However, the size of the loss starts to grow after a certain amount of time [16]. In order to adjust the PID (proportional-integral-differential) gains of the blade pitch controller on the wind turbine side and the gains of the Superconducting Magnetic Energy Storage (SMES) controller, the mine blast algorithm (MBA), a novel and reliable optimization technique, has been demonstrated. SMES was installed to quickly release and absorb active power in order to balance the power coming from the generator and the power coming from the load, and as a result, manage the frequency of the system. On the other hand, the suggested MBA-SMES plan had values that were significantly lower and more consistent [17]. How to use the Stud Krill Herd Algorithm (SKHA) to produce the appropriate DG sizing and allocation in RDS. The optimal DG placement problem in the radial system was likewise resolved using SKHA. The suggested approach significantly improves the solution's superiority and overall ideality. The implemented SKHA can be partially executed with respect to DG count, although DG count is limited to 3 only when consistency is taken into account [18].

To reduce system power loss, it was suggested using the Whale Optimization Algorithm (WOA) method to install battery energy storage devices in the best possible way. A novel technique was created by combining the suggested WOA method with the Power Flow procedure. The typical RDS bus systems were used to evaluate this WOA approach. The suggested method was able to quickly and precisely offer the optimal outcome, but it was unable to do so when categorising a combination of ESS that belonged to different categories [19]. MOPSO (Multi-Objective Particle Swarm Optimization) technique for the best placement of numerous DG technologies to reduce system power loss. The Power Flow procedure was combined with the recommended technique to create a revolutionary technique. The standard IEEE 33 and 69 RDS bus systems were used to test this method. The suggested technique could exactly and quickly compute the best result, but it could not assign a combination of DGs that belonged to different categories with the best result [20].

## 3. PROBLEM STATEMENT

Only when the substation is situated at the hub of customers is this research's RDS preserved as radial and employed for little power generation. Offer simplicity and inexpensive initial costs as well, allowing several feeders to radiate out from a substation and feed the distributors at one end. The following are just some of the issues that arise in a fully functional DG system.

1. Dominance of criteria like cost, location, and size is frequently overlooked by existing optimization approaches for sizing and positioning the DG.
2. In some circumstances, DG placement can enhance processing performance and global search capabilities. However, it doesn't deal with the non-linearity problem and doesn't have the flexibility required for real-time operation.
3. We are unable to escape the local minimum due to premature convergence, which is a result of additional problems with the positioning and sizing of DG and ESS.

Even when some optimization techniques allocate all DG and ESS, the experimental data that is produced is insufficient to show the system's efficacy.

When allocating DG and ESS due to problems with the cost function, nonlinear equality constraints are necessary to minimise overall network loss, which is difficult.

### 3.1 Objectives

The goal of this project is to develop the simulation software required to enhance various radial distribution network characteristics. Major goals of this study are to:

- ✓ Make sweeping motions from the back to the front to distribute the weight.
- ✓ Give an application framework for SFLA-IMFF for specific RDS optimization issues.

Show that the suggested strategy yields trustworthy findings by applying it to various test systems. This study specifically examines the SFLA-IMFF to determine the optimum placement and size of DGs and ESSs.

- ✓ The best possible setup for a network.
- ✓ Lower the power leakage.

## 4. MODELLING OF DG UNITS

DGs, which are typically presented as a PQ bus, may be presented in one of three distinct types.

- In the first modelling approach, DGs are shown to exhibit a negative type of load due to their continuous production of P (real) and Q (reactive).
- In the next-generation model, DG use a fixed amount of P and Power Factor (PF), displayed as a constant PF machine.
- DGs are displayed as a flexible Q generator in the last type.

Consequently, the continuous PQ model, which is suitable given that DGs are often smaller in size, is designed to operate with the load flow analysis of DS.

### 4.1 Proposed Method

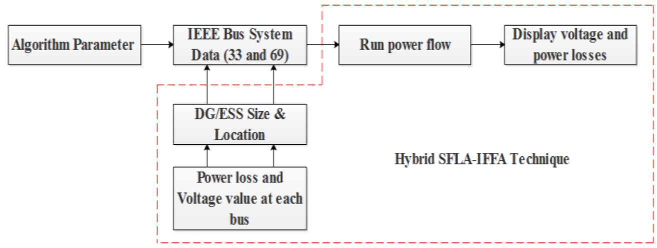


**Figure 1:** Block diagram of optimal placement in IEEE bus system

If you look at *figure 1*, you'll see a block diagram depicting the ideal placement for an IEEE radial bus system.

1. To start, create some baseline conditions using common control variables.
2. Analysis of line and bus data for the IEEE radial distribution system under consideration.
3. We regard the creation of random particles to be the initiation phase of the evolutionary process, rather than starting from scratch with each new generation of organisms.
4. After that, the load flow was analysed to ensure accuracy.
5. A fitness function that takes into account the voltage profile, power loss, and cost must also be determined.
6. Use the information gathered to determine the fitness values that must be added to the system data before it is analysed once more during the following iteration.
7. The analysis of the load flow has also been verified in a similar manner utilizing the suggested hybrid optimization to determine the best fitness values.
8. The suggested hybrid optimization technique, using DG/ESS, controls computations and values of active and reactive power fitness for a random position.
9. The best values are used as input to the SFLA-IFFA methodology presented here to determine the placement of the DG and ESS that is ideal for evaluating multiple objectives.

## 4.2 Shuffled Frog-Leaping Algorithm (SFLA) Method

In response to problems with combinatorial optimization, the SFLA is a memetic meta-heuristic (SFLA). To produce the best result, the SFL technique combines the genetic and social PSO algorithms. The population is made up of many frogs and for the computation is broken down into smaller groupings termed memeplexes. Each distinct memeplex is comparable to a different frog community undertaking its own independent research. Each memeplex has an own collection of frogs that are all different from one another and change over time due to memetic selection. The memeplexes start to rearrange the amassed memes after they reach a specified limit for how many iterations are required for a meme to spread. The local exploration and shifting operations cannot be stopped until some a priori convergence requirement is satisfied. A frog I in S-dimensional space (S variables) is denoted by

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

The frogs are sorted from least fit to fittest once their fitness levels have been determined. After that, the total population is divided into m memeplexes with n frogs each (p=mn). This process starts with the first frog visiting the first memeplex, followed by the second frog visiting the second memeplex, the frog visiting m memeplexes, the frog visiting m+1 returning to the first memeplex, and so on. We determine which frogs (xg) in a particular memeplex are performing best and worst. Then, using a method similar to PSO, the frog in each cycle with the lowest fitness is selected and improved. Because of this, the position of the unsuitable test frog has been changed to let PSO know:

Positional shift of the frog $D_i = rand * (X_b - X_w)$ (2)

Position updated $X_w$= present position $X_w + D_i$ (3)

$D_{max} > D_i > -D_{max}$

Where rand (*) stands for a random number between 0 and 1, D max stands for the largest permissible position of a frog change. If this process yields a better result, the worst frog is replaced; if not, the calculations are repeated using the best frog in the world this time (Xg replaces $X_b$). If no improvement can be achieved, a different solution will be chosen at random to replace the frog. The calculations are then performed a specific number of times after that. The frog's p count, the number of memeplexes, the number of generations in each memeplex prior to shuffle, the number of shuffle iterations, and the maximum step size are the essential settings for SFL. Using the SFL algorithm, the DG's capacity and position are optimized to cut down on losses and improve the voltage profile.

## 4.3. Improved Firefly Algorithm

The FA is a fictitious computation used to simulate curiosities based on swarm aptitude and serves as a demonstration of the instrument used to pique firefly interest. The following glorification standards are used to highlight some of the most admirable features of fireflies when developing numerical models of FA.

- Fireflies of any gender, male or female, will be entranced by the sheer intensity of the light coming from groups of them.
- The mutual attraction of fireflies is related to the brightness of their lights.
- Constant capacity values are symbolized by the beauty of fireflies.

To improve an enhancement execution above the standard FA, which had certain restrictions, a test work through FA individualities was advanced. The outcomes reveal that FA was successfully applied to the problem of tension funnelling plan on a global scale, proving that it effectively deals with the problem of global streamlining. But in conventional FA, the borders are already set, which results in early convergence that cannot concurrently adjust for imperfect boundary circumstances. Therefore, it is crucial to improve the current FA in order to increase advancement effectiveness.

By looking at the FA's boundaries, the light retention coefficient is incredibly large and serves as good value. Each firefly has a bright effect I (r), which is represented by the *equation (4)*

$$I\,(r) = I_0 e^{-\gamma r^m} \; m \geq 1 \quad (4)$$

So, firefly attraction $\beta$ can diverge conferring to the calculation assumed through (5),

$$\beta(r) = \beta_0 e^{-\gamma r^m} \; m \geq 1 \quad (5)$$

Where $\beta_0$ denotes the highest level of interest (at r = 0), and is the light assimilation constant, which controls the loss of light

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intensity. The distance between the two fireflies at positions $p_i$ and $p_j$ is referred to as

$$r_{ij} = |p_i - p_j| = \sqrt{\sum_{k=1}^{l} p_{i,k} - p_{j,k}{}^2} \qquad (6)$$

Where $p_{i,k}$ is three-dimensional harmonize $p_i$. The effort is defined by

$$p_i = p_i + \beta_0 e^{-\gamma_{ij}{}^2}(p_i - p_j) + \alpha(rand\,\tfrac{1}{2}) \qquad (7)$$

Where the initial phrase refers to a firefly's current condition (the firefly's arrangement is $p_i$). Every iterative step registers the beauty and alluring nature of every firefly. Every firefly's brightness is compared to any surviving fireflies, and their locations are updated using *equation (7)*.

The following issues are brought on by the best placement of DG units in a mesh network employing SFLA-IFFA.

- The mesh network topology is exceedingly difficult to install;
- It is more expensive than other network topologies.
- Because each node will need to share the load and be active constantly, the power demand is larger.

So, proposed method is applied to radial network; it generates power at a lower cost and is simple to install at the centre of the consumer. Additionally, offer ease of use and inexpensive initial costs, causing several feeders to radiate from a substation and feed the distributors at one end.

## 5. RESULTS AND DISCUSSION

The DGs are implemented to a small subset of viable sites, and using the many options available, a list of location solutions is developed. It is true that some solutions make distribution system bottlenecks worse. The distribution system uses a combined SFLA and IFFA technique to address the aforementioned problems. Due to its greater searching effectiveness and ability to prevent early maturation while searching, SFLA has gained widespread use. The hybrid SFLA-IFFA method uses the IFFA method to determine the size and placement of the DG. The ideal DG placement, load flow, and DG rating are determined by IFFA. DG-equipped distribution systems have lower power losses, maintain system voltage, and have improved system stability, according to the results of the hybrid SFLA-IFFA technique. The suggested SFLA-IFFA method, which takes into consideration the load flow of the test system, is used to determine the best position for each DG and the appropriate rating for each DG. The suggested distribution network using the SFLA-IFFA algorithm Simulated simulations show that the DGs enhance system voltage profile while reducing distribution network loss.

### 5.1 Analysis of SFLA-IFFA

When the DG is used at a trailing PF, losses are experienced that are lower than those experienced at a unity PF.

**Table 1: Performance of DG at unity PF**

| Parameters | Exclusion of DG | Existing SFLA-ALO | Proposed SFLA-IFFA |
|---|---|---|---|
| Cost of real power dg | -- | 31.104 | 28.482 |
| DG location | -- | 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 |

The achieved results are detailed in *table 1*. The voltage profile at a power factor of 1 is shown in *figure 2*.

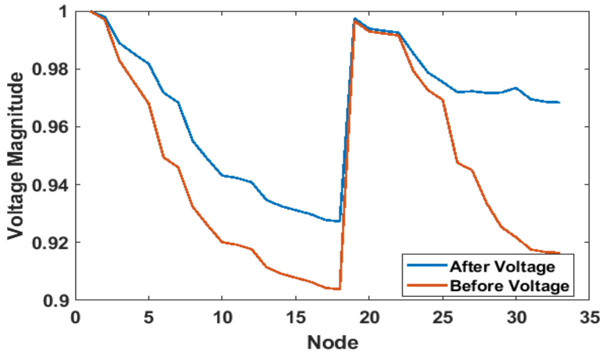


**Figure 2:** Voltage profile at a unity power factor

### 5.2 Results for 33-bus System

To evaluate the hybrid SFLA-IFFA strategy's performance, the simulated results are compared to those obtained using other methods.

**Case 1:** Multiple DG units and a reconfigured bus system are under consideration (DG-Type-1).
**Case 2:** Multiple DG units and a reconfigured bus system are under consideration (DG-Type-2).
**Case 3:** Multiple ESS are considered in the bus system.

A Type 1 DG system is used for the 33-bus configuration in case 1. *Table 2* displays the results of the analysis of case 1's performance. Case 1's results are depicted in *figure 3*.

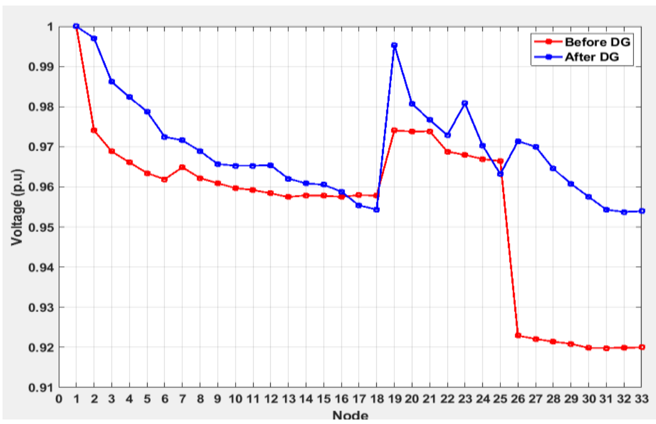


**Figure 3:** Stability of voltage for test case 2

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**Table 2: Performance analysis of case 1**

| Case 1 | Before DG | SFLA-IFFA |
|---|---|---|
| Tie switches | 33 34 35 36 37 | 33 26 15 6 30 |
| Loss of Power | 202.68 KW | 79.9591kW |
| Reduction of Power loss | ------------- | 61.9855% |
| Size of DG | ------------- | 0.15 MW |
| Location of DG | ------------- | 33 12 28 |

A type-2 DG unit operates the 33-bus system in scenario 2. Case 2 results are summarised in *table 3*, and a graph of voltage stability can be seen in *figure 4*.

**Table 3: Performance analysis of case 2**

| Test case 2 | BEFORE DGs | SFLA-IFFA |
|---|---|---|
| Tie switches | 33 34 35 36 37 | 7 10 14 37 36 |
| Loss of Power | 202.69 kW | 57.426 kW |
| Reduction Power loss | --- | 71.7328 % |
| Minimum voltage: | 0.91075pu | 0.97981pu |
| Size and location of DG | --- | 1.14 MW (25 30 18) |

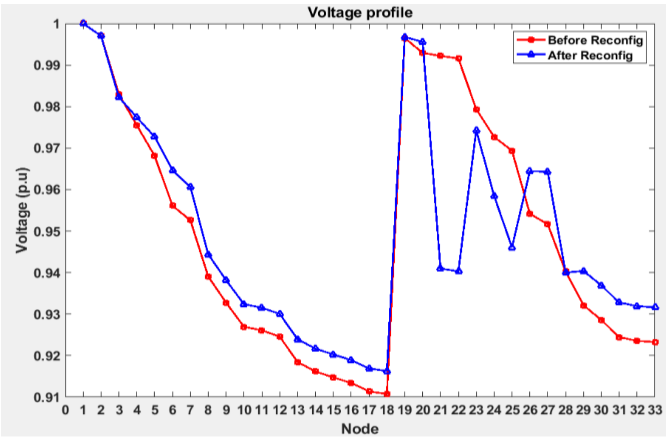


**Figure 4:** Voltage stability for test case 3

In case three, a 33-bus system with ESS support is put into place. The outcomes of Case 3 demonstrate that ESS placement and size significantly affect overall system losses. This study makes use of SFLA-IFFA to learn more about the bus routes that offer the most potential for ESS deployment. *Table 4* demonstrates that the proposed SFLA-IFFA reduces the overall loss from 202.68 kW to 98.0382 kW, a reduction of 52.37 percent.

**Table 4: For ESS comparative table**

| Investigation Case | Prior To ESS | After ESS |
|---|---|---|
| Loss of Power | 202.68 kW | 98.0382 kW |
| Reduction of Power loss | --- | 52.377 % |
| Size and location of ESS | --- | 1.1006 kW<br>1.0165 kW<br>1.9285 kW<br>(31 15 22) |

## 5.3 Results for69-bus System

To evaluate the hybrid SFLA-IFFA strategy's performance, the simulated results are compared to those obtained using other methods.

*Case 1*: Multi DG units and a reconfigured bus system are under consideration (DG-Type-1).
*Case 2*: Multiple DG units and a reconfigured bus system are under consideration (DG-Type-2).
*Case 3*: Multiple ESS are taken into account in a bus system design.

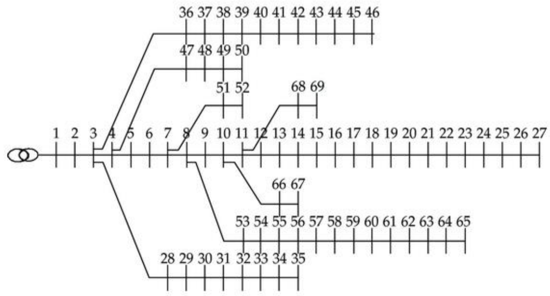


**Figure 5:** Single Line Diagram of 69-bus system

The *Type 1* DG system is implemented with 69 buses in scenario 1. *Case 1* performance analysis is displayed in *table 5*. Case 1 data are presented in *figure 6*.

**Table 5: 1st Scenario results**

| Parameters | Base Values | Proposed SFLA-IFFA |
|---|---|---|
| Tie switches | 69 70 71 72 73 | 14 58 63 49 30 |
| Loss of Power | ------------- | 61.1968 % |
| Reduction of Power loss | 224.9804 kW | 92.5851 kW |
| Lowest voltage: | 0.90919 pu | 0.95917 pu |

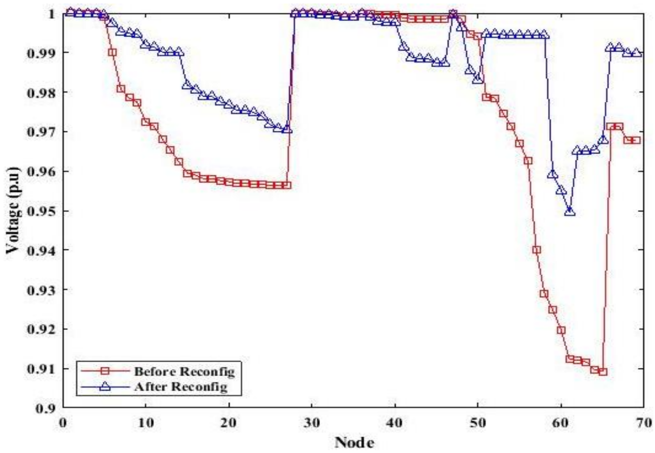


**Figure 6:** Voltage magnitude for second scenario

The Type 2 DG system is implemented with 69 buses in *Scenario 2*. *Table 7* displays the results of the analysis of case 1's performance. Case 1 data are presented in *figure 7*.

**Table 6: 2nd Scenario Results**

| Parameters | Base values | Proposed SFLA-IFFA |
|---|---|---|
| Tie switches | 69 70 71 72 73 | 40 60 5 30 6 |
| Size (location of DG) | 4 KW | 4 KW (39 28 51) |
| Loss of Power | ------------- | 79.1372 % |
| Reduction of Power loss | 224.9804 kW | 46.9193 kW |
| Lowest voltage: | 0.90919 pu | 0.95693 |

*Table 6* provides specifics on the ideal DG magnitude for the IEEE 69 RDN following reconfiguration. Bus numbers 39, 28, and 51, with a magnitude of 0.4 MW, are the finest buses for optimal DG apportionment, reducing real power loss by 79.1372 percent, from 224.6 to 46.9193 kW [6].

The ideal size of the DG following reconfiguration is given below for the IEEE 69-RDN.

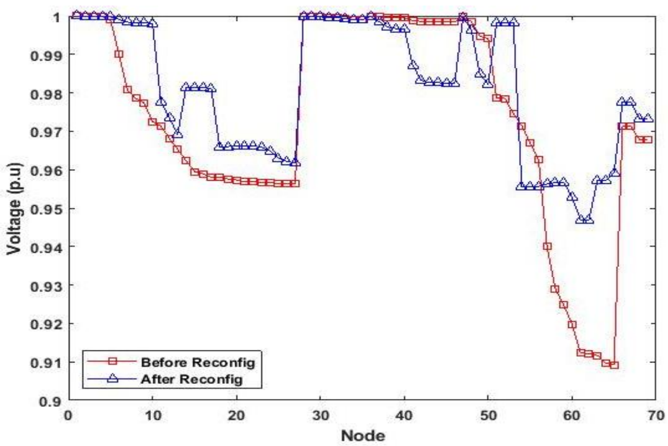


**Figure 7:** Voltage magnitude for second scenario

*Figure 8* displays the voltage diagram for the entire test case following reconfiguration. The ideal bus for DG apportionment was determined to be 21, 32, 63, resulting in a decrease in power loss of 91.0263 percent from 224.6 to 30.9239 kW and a magnitude of 0.4 MW

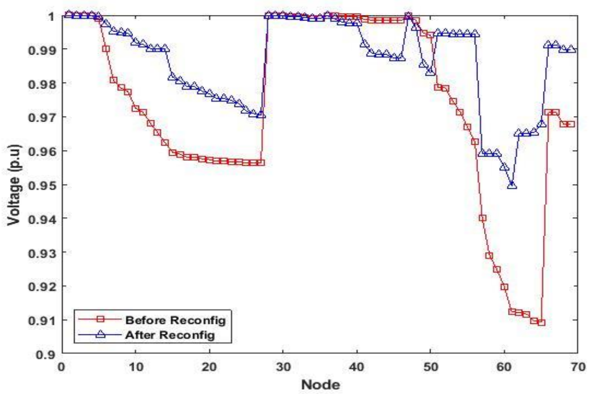


**Figure 8:** Voltage magnitude for third scenario

Presented is the voltage stability for multiple ESS. Based on the data in *table 7*, we can see that the proposed SFLA-IFFA method significantly reduces overall power loss, from 224.9804 kW to 26.1082 kW (a decrease of 88.2179%). This ESS comparison is shown in *table 8*.

**Table 7: Assessment for the case 4**

| Case 4 | Before ESS | SFLA-IFFA |
|---|---|---|
| Minimum voltage: | 0.90919 pu | 0.97276 pu |
| Reduction of Power loss | --- | 88.2179 % |
| Loss of Power | 224.9804 kW | 26.1082 kW |
| Size (location of DG) | 0.4 MW | 0.2, 0.172,0.824 (23, 53, 61) |
| Tie switches | 69 70 71 72 73 | 31 39 62 19 28 |

**Table 8: comparative analysis of ESS**

| Scenario | Existing FA [19] | Existing WOA [19] | Proposed SFLA-IFFA |
|---|---|---|---|
| Power loss (kW) | 51.42 | 51.15 | 41.19 |
| Location | 7,22 | 7,15 | 35, 59 |
| Size (MW) | 0.37 & .72 | 0.67& 1.50 | 0.31&0.59 |

According to the aforementioned results, it is possible to improve voltage control and greatly minimise power loss without sacrificing the influence system's functionality. Similar to this, the suggested SFLA-IFFA resolves widespread transportation systems, especially large ones, more quickly and effectively.

## 6. CONCLUSION

The radial network's deregulation and a dearth of transmission measurements have made it possible for DG/ESS use to rise. DGs/ESS must be properly positioned inside a radially spread network to achieve the required future improvements. With a focus on minimising power loss in the radial distribution system, the proposed method is examined in MATLAB for both the 33 bus and the 69 bus benchmark structures. By placing the DGs/ESS in the ideal locations and using the ideal sizes, as determined by this method, the overall losses in a radial distribution system can be decreased. The location of the DG/best ESS in the radial system can be determined using a innovative approach in this research thesis that considers the necessity to minimise structure loss despite knowing of its characteristics. The suggested study (SFLA-IFFA) makes use of voltage enhancement and power loss reduction techniques. The simulation outcomes supported the developers' claims that their innovative approach was superior to the competition. The experimental results acquired from the simulation illustrate the enhanced performance in locating and sizing the DG/ESS system.

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International Journal of
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