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Research paper

Multi-objective for optimal placement and sizing DG units in reducing loss of power and enhancing voltage profile using BPSO-SLFA

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ABSTRACT

Algorithms are used to optimize both single and multi-objective system limits. This research aimed to detect the optimal location and size of the DGs, which can significantly minimize power loss and improve the stability of the voltage. The research uses binary particle swarm optimization and shuffled frog leap (BPSO-SLFA) algorithms for simulation and testing of an optimal power flow (OPF) on 33 and 69 bus radial distribution system. The result shows that the algorithms give better DG allocation and minimizes the power losses but at the nascent stage of advancement. The power losses associated with the system have significantly reduced up to 31.8244kW using multi-DGs reconfiguration placement. The outcomes are established to verify the potency of the recommend algorithm to minimize losses, general improvement in voltage profiles and cost saving for various distribution system. However, the proposed methodology can be used as a reliable method in DG settings and sizing in distribution network system which produce better outputs rather than hybrid grey wolf optimization (GWO) and hybrid big bang big crunch.

1. Introduction

The Institute of Electrical Electronics Engineering (IEEE) gives a concise definition of distributed generation as a power generation that is adequate compact than central generating plants and are connected closer to the distribution system (Chiradeja and Ramakumar, 2004; Pepermans et al., 2005; Singh and Parida, 2015). The rapid development in technology, global concern about the environment and the demand of the customers for cheap and consistent electric power have led to an increasing interest in DG (Kansal et al., 2016). However, optimal allocation and sizing of DG may bring various advantages such as voltage control through cost (El-Khattam et al., 2004), boosting reliability (Rohatgi et al., 2006), harmonic reduction (Tagore and Gupta, 2017), minimization of real and reactive losses (Mallipeddi et al., 2017), voltage stability and network loss reduction (Esmaili et al., 2014), and infeasible network configuration (Nguyen et al., 2016).

Many optimization algorithm and techniques have been developed for the application of energy technologies problem. Among the various techniques, algorithms and optimization present the highest potential for use in the placement of DG. Nguyen et al. (2016) adopted the novel cuckoo based (CSA) algorithm for placement of DG with the technical objective of minimizing the active power loss and improving the strength of the voltage. Yahiaoui et al. (2017) proposed GWO for the optimal sizing of hybrid renewable systems to lessen the cost of hybrid power generation. Other researchers have proposed a hybridization algorithm in order to replace the traditional algorithm. A particle artificial bee colony (PABC)-hybrid harmony search algorithm (HSA) approach was developed to optimal size and location of the DG in distribution system (Muthukumar and Jayalalitha, 2016). Their results showed that the efficiency of the proposed hybrid algorithm in obtaining optimal solution for simultaneous placement of DGs and shunt capacitors in distribution networks. Kefayat et al. (2015) applied artificial bee colony and hybrid ant colony optimization to the distribution system in order to control emissions expelled by the substation and overall improvement of the voltage stability. Doagou-mojarrad et al. (2013) reported a fuzzy based intelligent system based on shuffled frog leap algorithm to resolve optimal allocation problem with the aim of minimizing power loss, energy cost and control of emission produced. Results showed that the simulation illustrate the good performance and applicability of the proposed method. Another research conducted by Moradi and Abedini (2012), which obtained a better result in terms of reduction of loss of power, boosting voltage regulation, and maintaining voltage stability by application of particle swarm algorithm and genetic algorithm. Selim et al. (2019), proposed chaotic sine cosine algorithm for optimal location and sizing DG in distribution network with minimum

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power loss and high convergence rate. Their results significantly shows how the new algorithm can be used to optimal allocate multiple DG units into radial distribution networks with technical objective of minimizing power loss, voltage deviation and maximize voltage stability index. Menesy et al. (2019), developed a Chaotic Harris Hawks optimization techniques for estimating the exact operating parameters for proton exchange of fuel cell for high electrical performance. The author's findings are estimated data obtained by the proposed CHHO shown a good agreement with the experimental data of different commercial PEM fuel cell stacks.

As previously reported that the electric DG system for reduction of power loss and improvement of bus voltage stability, most widely used methods are reconfiguration and DG allocation (Sambaiah and Jayabarathi, 2019). Optimal network reconfiguration and DG allocation offer maximum essential benefits. Since combination between reconfiguration and DG allocation is an important and complex non-linear constrained optimization problem. The optimal configuration of feeder for minimizing forms of cost and maximizing reliability index can be obtained using hybrid PSO-SLA (Gitizadeh et al., 2012). A hybrid particle swarm optimization (HPSO) was presented by Alrashidi and Member (2007), the research aimed to lessen the real power, fuel cost, and reduction of gaseous emission produced by the generating plant units. Similarly, Khalesi et al. (2011) examined the multi-objective function of locating DGs in radial distribution networks. Time varying load is employed in this optimization to attain the practical outcomes of the study and their needs are based on cost or benefit forms. They concluded that to eliminate the multi-objective problem, novel approach based on dynamic programming is required.

There are various researches published on optimal allocation and placement of DG, but very few have evaluated BPSO-SLFA, because it can be difficult to define the initial parameters. But BPSO-SLFA are proposed to decrease high dimensionality of the feature set and to select optimized feature subsets. A new methodology is proposed to minimize loss of power and boost the voltage profile using a combination of BPSO-SLFA. The BPSO-SLFA is a new proposed algorithm that works based on reconfiguring the DG in a momentary path, and is used to solve multi-objective function. This paper developed a BPSO-SLFA-based algorithm to optimal locate and size DG position with the suggestion of multi-objective function for reconfiguration and DG installation, loss of power system, and stability of voltage. The developed methodology is analyzed on IEEE 33 & 69-bus radial distribution systems. The obtained results shows effectiveness and robustness of the proposed methodology in solving optimal location and sizing the DG in the DN and reduces total power loss and boost voltage profile within a defined network system.

Furthermore, the research aimed to explain the problem formulation methodology, the types of DG and fundamental background of the proposed hybrid and BPSO-SLFA algorithm, and optimization problem for the optimal DG method and simulation. However the main contribution of this research paper are summarized as follows:

– The proposed algorithm is applied for resolving optimal distribution network reconfiguration and optimal DG unit with the technical objective of decreasing power loss and enhancing voltage profile;

– First, the algorithm is exercised for resolving optimal DG placement that assess optimal allocation for connecting DG and their significance for solving reconfiguration transient problem.

– The obtained outcomes clearly indicates that scenario 4 (Multi DG installation with network reconfiguration) is found to be more effective in reducing power losses.

– The simulated results obtained from the proposed BPSO-SLFA are compared with the results of other techniques to assess the performance and effectiveness of the new proposed techniques.

The rest of this paper is structured as follows. Section 2 explains the methodology and problem formulation of BPSO-SLFA. Section 3 illustrates the conventional BPSO and SLFA algorithms for DG placement to access optimal allocation for connecting DG and their significance for solving reconfiguration transient manner. Section 4 describes the results and flowchart algorithm on four (4) different case scenarios. Lastly, the main conclusion are given in Section 5.

2. Methodology

Minimizing the losses of power, bus voltage stability, and maximizing voltage stability are considered as the fitness functions for the placement of the optimal sizing of this current research work.

2.1. Minimization of power loss

Electrical energy is produced from a long distance away from the user and is distributed between the transmission lines to a variety of distribution system on which the electrical utility works. Commonly, the distribution network system takes power and sent it to the consumer of load in order to aid their demands. Nevertheless, not all the power will be delivered 100% efficient due to losses that occur at the distribution network line. The loss of power in the network distribution system is absolutely dependent on the precise position and size of the renewable DG system. The real loss of power in a distribution system with given operational conditions are computed using Eq. (1), and is referred to as exact loss.

$$\text{Minimize Ploss (F1)} = \sum_{i=1}^{nbr} Ii^2 Ri \tag{1}$$

where:

Ii and *Ri* are the current magnitude and resistance corresponding to the circuit branch I, number of branches is represented by br. The branch circuit current is divided into two components, active component (Iac) and reactive component (Irc).

$$\text{PLa (F2)} = \sum_{i=1}^{n} I^2 aciRi \tag{2}$$

$$\text{PLr (F3)} = \sum_{i=1}^{n} I^2 rciRi \tag{3}$$

However, optimal placement of DGs can compensate the active loss components in the branch.

$$PG = PD + Losses \tag{4}$$

The real generator power and the demand power are given as PG and PD respectively.

Voltage limits:

Eq. (5), is useful for improving the voltage profile as one of the key objectives.

$$F4 = \sum_{Ni=1}^{NN} (V_{Ni} - V_{rated}) \tag{5}$$

3. Optimal sitting and sizing problem formulation

The radial distribution system reduces actual losses of power by optimal placement of DGs in order to boost voltage profile and decreases network operating costs that are subject to different operational constraints. Objective functions of the problem are formulated mathematically. This research work uses novel approach based on BPSO-SLFA for resolving the problems related to optimal sizing and sitting of DG in the distribution system.

3.1. Major contribution of this research work

The algorithm is initially exercised to solve the placement of the optimal DG, which determines optimal position for connecting DG and its values for reconfiguring in a momentary path. The simulated outcomes are compared with the ones of other proposed techniques to assess the impact and performance of the proposed technique. The flow chart describing the proposed BPSO-SLFA is shown in Fig. 1.

3.2. Proposed hybrid algorithm

3.2.1. Basic Particle Swarm Optimization (BPSO)

James Kennedy and Eberhart first hosted classical optimization called BPSO, practical swarm optimization in the year (1995). This Particle Swarm Optimization comprises of a collection (swarm) of people (particles) moving in the search space, fitness values are determined by their trajectory movement. The particle is represented by a location-indicating n-length vector and has a vector v for present position update. The velocity vector is calculated according to the following equation in (6). In PSO, the location and each particle velocity at k iteration in the space search is defined by $X^i{}_k$ and $V^i{}_k$. The iterated particle velocity I is described as $k+1$ $P^i{}_{lbest}$ and attained from Eq. (6).

$$V^i{}_{k+1} = \omega.V^i{}_k + C1.R1(P^i{}_{lbest} - X^i{}_k) + C2.R2(P^i{}_{global} - X^i{}_k) \tag{6}$$

where

The random functions are R1 and R2, and where the training coefficients are C1 and C2. This is the dimension of inertia weight. The following result can be defined by Eq. (7).

$$\omega = \omega_{max} - \{(\omega_{max} - \omega_{min}) - \mathrm{k}_{max}\} \times k \tag{7}$$

where, k_{max} donates the possible number of iterations. At the end of each iteration, the sum of the old position and the new velocity position obtains a new location for each particle

$$X^i{}_{k+1} = X^i{}_k + V^i{}_{k+1} \tag{8}$$

The PSO formula remained unaffected. A logistic conversion $S(V^i{}_k)$ is used to achieve this amendment that is written in Eqs. (9) and (10).

$$S(V^i{}_{k+1}) = sig\ mod\ e\left(V^i{}_{k+1}\right) = \frac{1}{1+\exp(V^i{}_{k+1})} \tag{9}$$

$$\text{If rand } \propto S(V^i{}_{k+1}) \text{ then: } X^i{}_{k+1} = 1; \tag{10}$$

Else: $X^i{}_{k+1} = 0$;

The function $S(V^i{}_k)$ is a restrictive sigmoid for achieving a new change and rand is a quasi-quantity selected from a constant distribution in the space of [0, 1]. However, Eqs. (11)–(13) defined the particle's dimension limits.

$$1 \propto B_i \propto B_{max} \tag{11}$$

$$0 \propto P_i \propto P_{max} \tag{12}$$

$$T_i = \left\{1, 2, \dots, T_f\right\} \tag{13}$$

3.2.2. The SLFO algorithm

Eusuff et al. (2017), developed the SLFA algorithm, a memetic meta-heuristic for generating hybrid optimization. This algorithm is a metaheuristic technique of optimization that simulates the memetic growth of a group of frogs while trying to find the optimum location which has maximum amount of food available. Memetic algorithms are adapted based on population approaches to optimization problems in heuristic searches. The word memetic has its origin in "meme" Dawkins (1976). " The Selfish Gene"., Oxford University Press, n.d.). Meme is assumed as the cultural evolution unit. The concept evolves in a way that is similar to biological evolution, the SLFA contains a population-based solution identified as memplexes which are divided into a subset. Inside each memeplex the individual frogs do hold idea of the other frogs and causes them to propagate the pattern. The SLFA algorithm progresses in the form of memestic evolution through the time loops (Eusuff and Lansey, 2004). In accomplishing this target some network parameters must be fulfilled. One can describe the problem statement as in Eq. (14)

$$\text{Objective Function} = \text{Min (TLP)} \tag{14}$$

where, $\mathrm{TLP} = \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{I}_\mathrm{i}^2\mathrm{R}_\mathrm{i}$ is the absolute loss of real power for the radial distribution syst3'em. The voltage is subject to the constraint $|\mathrm{v}_{\mathrm{imin}}| \leq |\mathrm{v}_\mathrm{i}| \leq |\mathrm{v}_{\mathrm{imax}}|$. Here, Ii is the total flowing current over the *i*th branch that is the position and size features of the DG. Ri is the branch resistance, and the number of branches in the system is denoted as n. The lower and upper limits of the *i*th bus voltages are Vimin and Vimax.

The SFL estimate joins the advantages of BPSO calculations based on inherited and social behavior. For S-dimensional variables problems, a frog i is defined below.

$$\mathrm{X}_\mathrm{i} = (\mathrm{x}_{\mathrm{i}1}, \mathrm{x}_{\mathrm{i}2}, \dots, \mathrm{x}_{\mathrm{is}}) \tag{15}$$

Afterward, the frogs are sorted in relation to their fitness in a downward order. The entire population is broken into memeplexes, each with n frogs (p = m × n). The best and worst-fit frogs are identified as x_g. Then, a method similar to BPSO is implemented in each step to boost only the worst-fit frog in every complete cycle. Consequently, the frog's location having the worst suitability is modified as follows:

The frog position deviations are defined as follows

$$(\mathrm{D}_\mathrm{i}) = rand() \times (x_b - x_w) \tag{16}$$

$$\text{New position } X_w = \text{ current position } (X_w + D_i) \tag{17}$$

The inequality that satisfies the fitness of the position is defined below

$$D_{\max \geq} D_i \geq -D_{\max}$$

where, *rand*() is defined as a random number between 0 and 1 and $D_{\max}$ is the maximum permissible change in a frog's position.

If this method developed improved the results, it takes the place of the worst frog, or else the calculations in (16) and (17) will be repeated but with respect to the best global frog (replaces). In this case, if no change is feasible, a new solution will be randomly generated to replace the frog. SFL algorithm to optimize the location and capacity of DG to minimize losses and boost voltage profile. The Stages are given in sequential order as follows: The flow chart describing the projected BPSO-SLFA is depicted in Fig. 1.

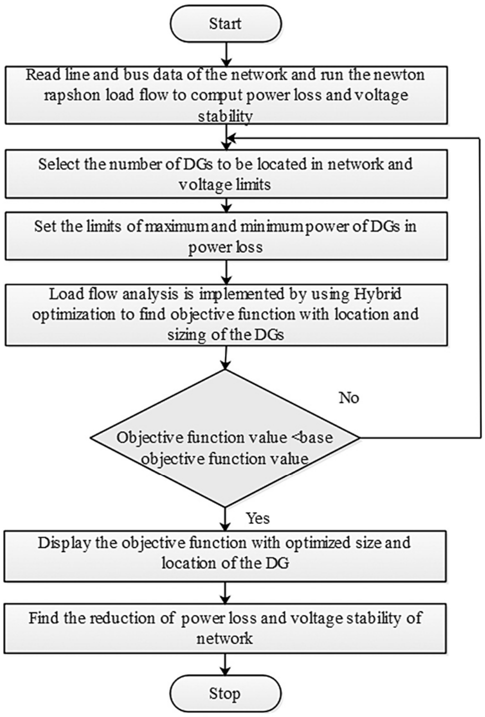


Fig. 1. A proposed flowchart for the algorithm.

```
1. Initialize to the start;
2. Generate, $p$ solutions population for the frogs in a random step;
3. For each discrete situation $i \in p$: compute the robustness (i);
4. The solution of the population $p$ is selected in downward order of robustness
5. Split the solution $p$ into m memeplexes;
6. In every memeplex;
7. The best and worst frogs' values be control;
8. Regulate the outfit location of frogs by applying Eqs. (16) and (17);
9. Repeat on a number of iterations of the defined system;
10. End;
11. integrate the develop memeplexes;
12. Sort the population into fitness in their downward order;
13. Verify if the end result is = true;
14. End;
```

Proposed Methodology of BPSO-SLFA

Fig. 1 shows the flowchart for the location and size of the DG to be detected. The techniques for identifying the optimal size and position of DGs using the proposed hybrid optimization algorithm are outlined in the steps below.

Step 1: Data of the input line and data of the bus.
Step 2: Pick the number of DG units in the network for optimal placement.
Step 3: Fix the voltage limits with real and reactive limits of power for the DGs, the DGs power factor is set according to the reactive power compensation required.
Step 4: Run the load flow analysis to compute the total active loss of power and maintain voltage stability.
Step 5: Arrange the algorithm parameters which include frequency length, pulse rate, loudness and the number of iterations.
Step 6: Iteration is achieved through an efficient and hybrid optimization algorithm with objective function.
Step 7: The spot and size of DGs are randomly selected in each iteration while updating the frequency, velocity, and position.
Step 8: The main objective function is computed as in step 6.
Step 9: If the objective function attained is less than the current best solution, then the objective function attained is considered a new optimal solution, and the loudness and pulse emission rate are modified.
Step 10: Repeat step 6 and step 9, before evaluating the full iteration.
Step 11: Fix the best fitness function between all solutions and the corresponding location, until the optimal size of the DG is determined.
Step 12: Eventually, the base case is undergoing a comparative review. The network output is determined by the loss of power and stability of the voltage.

4. Numerical simulation and results

In the previous work, the implementation of the hybrid BPSO-SLFA algorithm for optimal DG units, sizing shunt capacitor allocation problems in the distribution network was not explored. This inspires us to utilize a hybrid BPSO and SLFA algorithm approach to detect the location and size of DG units in order to reduce actual losses of power and maintain stability of voltage. The projected algorithm is realistic in resolving optimal reconfiguration of the distribution grid and optimum DG engagement with the goal of reducing power losses and boosting the voltage profile. Nevertheless, the algorithm is used to solve optimal DG placement which evaluates optimal allocation for connecting DG and is a momentary way of resolving reconfiguration performance achieved. The results obtained clearly indicates that in reducing power losses, scenario 4 (Multi DG implementation with reconfiguration of the network) in terms of reduction of losses of power are found to be more significant. The simulated results obtained are correlated with other literature reports, and are considered to be better in terms of reductions.

Scenario 1: The system with reconfiguration only

The reconfiguration process of the distribution system performed by using the optimization algorithm for handling the operation of switches. This optimization is used to overcome the concern over the selection of sectionalizing switches. The sectionalizing of switches has two states, one is open and another one is close. The open and closed states of the switches are defined by two different conditions such as 0 and 1.

Scenario 2: The system with DG units only

This scenario has a connection of multiple DG units (maximum 3 DG) in the bus system without any reconfiguration (base case scenario).

Scenario 3: System with single DG unit reconfiguration and installation

In scenario 3, there are two different steps processed. Firstly, the reconfiguration is performed in the desired bus system and then only one DG unit is connected in the reconfigured bus system.

Scenario 4: System with Multi DG unit reconfiguration and installation

The reconfiguration is performed in the bus system. Multiple DG units (maximum 3 DG) are connected with the reconfigured with standard 33 & 69 IEEE bus system.

The planned methodology (BPSO-SLFA), is applied and tested on two standard distribution network, 33 and 69 IEEE-bus systems with base voltage as 12.66 kV.

From Table 1, it is clearly observed that base case results losses for all four cases indicate scenario 4 with multiple DG deployment

Table 1
The performance of the planned BPSO-SLFA on the IEEE 33 bus system at different case study levels.

Case 1	Before DG Installation	After DG Installation
Power loss:	202.68 kW	75.3241 kW
Reduction of loss of power:	–	62.8359%
Minimized voltage:	0.91075 pu	0.92841 pu
Case 2		
Calculated DG size = 1500.0000 kW.		
Reduction of loss of power:		
27.9855		
Case 3		
loss of power:	202.68 kW	46.6899 kW
Loss reduction in power:	–	76.9637%
Minimized voltage:	0.91075 pu	0.91981 pu
Case 4		
Power loss:	202.68 kW	31.2844 kW
Reduction of loss of power:	–	84.5646%
Minimum voltage:	0.91075 pu	0.9547 pu

Table 2
Performance of the proposed BPSO-SLFA on the IEEE 69 bus system at various level case study.

Case 1	Before DG Installation	After DG Installation
Reduction in power losses:	224.9804 kW	142.2289 kW
Power loss reduction:	–	36.7816%
Minimal voltage profile:	0.90919 pu	0.94184 pu
Case 2		
	Before DG	After DG
Tie switches:	69 70 71 72 73	69 70 71 72 73
Power loss:	224.894 kW	152.1548 kW
Power loss reduction:	–	32.3438%
DG size: 0.3296		
Optimal DG position: 8		
Case 3		
	Before DG	After DG
Tie switches:	69 70 71 72 73	62 9 63 44 7
Power loss:	224.894 kW	42.0942 kW
Power loss reduction:	–	81.2826%
DG size: 1.8147		
Optimal DG position: 19		
Case 4		
	Before DG	After DG
Tie switches:	69 70 71 72 73	15 40 46 19 18
Power loss:	224.894 kW	67.841kW
Power loss reduction:	–	69.8342%
DG size: 1.9246, 1.1350, 1.7587		
Optimal DG position: 13, 10, 30		

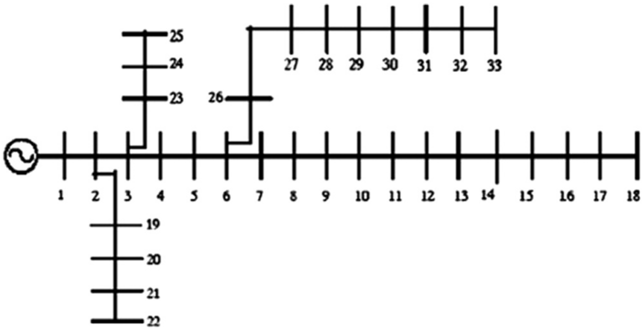


Fig. 2. IEEE standard 33 bus radial distribution system single line diagram (Baran and Wu, 1989).

with reconfiguration option is found to be more effective in decreasing losses of power from 202.68 kW to 31.2844 kW. The internal parameters of the proposed algorithm modified for the MATLAB simulations are shown in Table 4.

4.1. Radial distribution systems of IEEE 33

The IEEE-33 bus system is a radial distribution system (RDS) with a total load of 3.72 MW, 2.3 MVar, 33 buses and 32 branches as shown in Fig. 2. The line loading system and line data are obtained from Baran and Wu (1989). Table 1, describes the performance of the proposed BPSO-SLFA for all the four cases scenario. The line losses and voltage profiles of the IEEE 33 bus systems with network reconfiguration before and after DG for all the cases are shown in Fig. 5. It is clearly observed from the results, that the voltages have better-quality with multiple installations of DGs and reconfiguration as shown from Fig. 1C.

4.2. IEEE 69 radial distribution systems results

As shown in Fig. 3, the IEEE-69 bus system is a radial distribution system (RDS) with a total real and reactive power load of

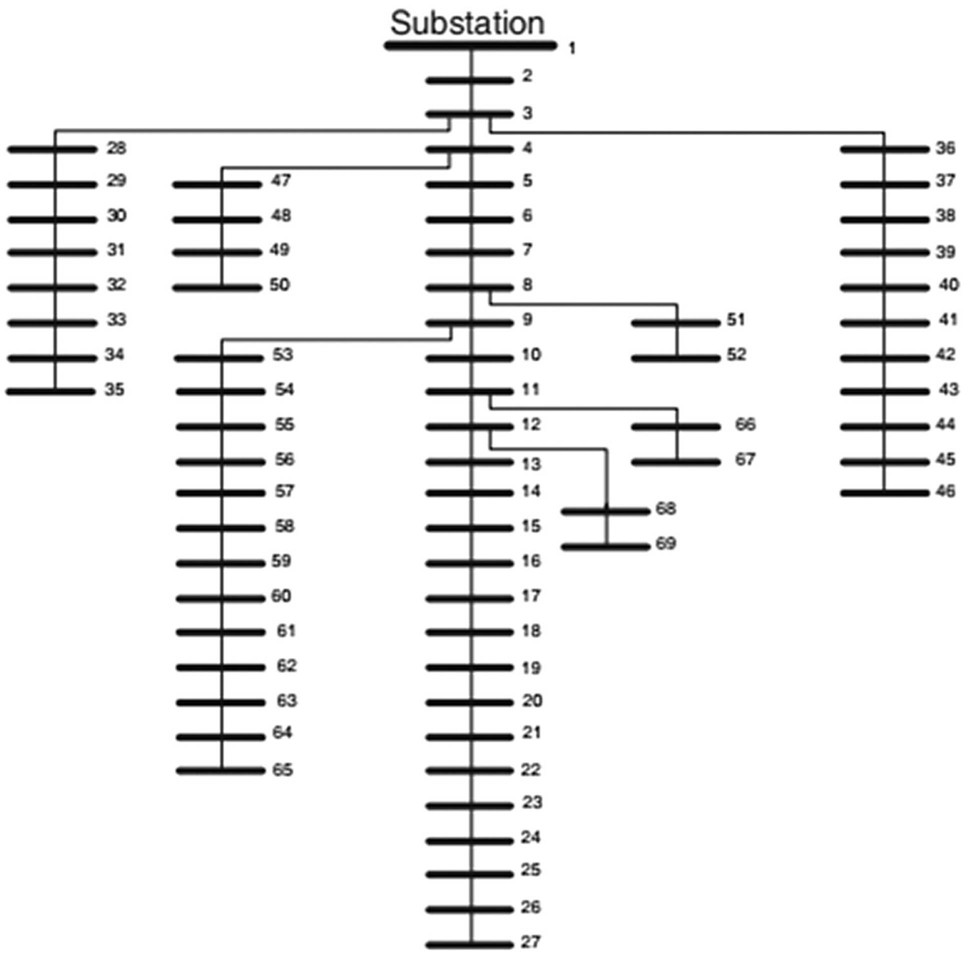


Fig. 3. The IEEE 69 bus-radial network single line diagram (Sahoo and Prasad, 2006).

Table 3
Compares the results of the various methods for the test systems of the allocation of multiple DG units.

Case	Approach	Installed DG	Power loss (kW)	Loss reduction (%)
3 DG	Hybrid (Kansal et al., 2016).	13, 0.79	81.050	61.62
3 DG	Hybrid* proposed	13, 10, 30	31.2844	84.5646
3 DG	Hybrid (HGWO) (Sanjay et al., 2017).	30,24,13	2946	72.884
3 DG	Hybrid Big bang big crunch (Sedighizadeh et al., 2014).	7,9,14,28,32	139.53	78.73

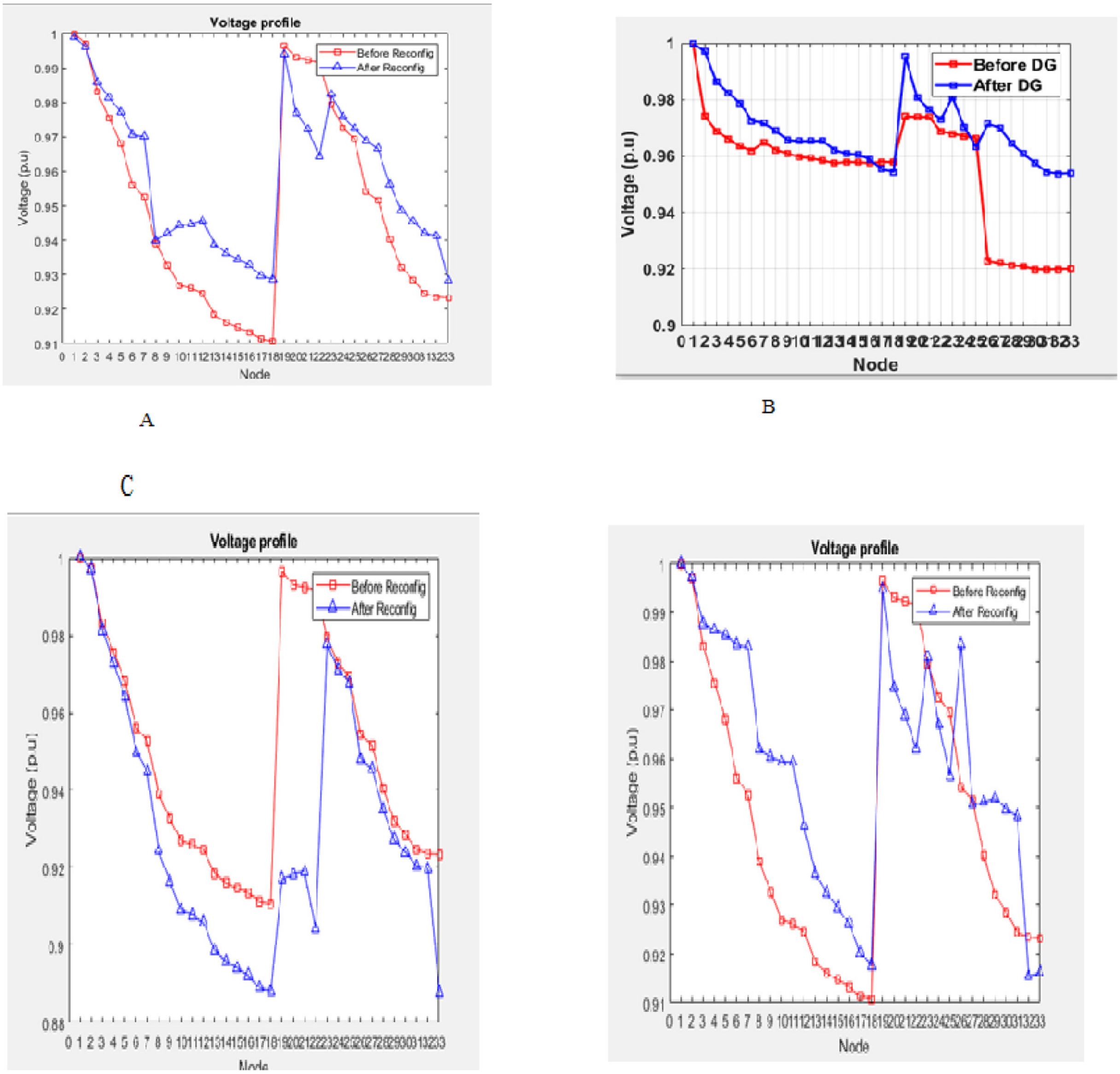
Note: Hybrid* is the proposed new algorithm.

3.80 MW, 2.69 MVar, 69 buses and 68 branches. The system load line and line data are taken from Sahoo and Prasad (2006). The performance of the proposed BPSO-SLFA for all the four (4) cases scenario are presented in Table 2. The line losses and Voltage profiles of the standard IEEE-69 bus systems with reconfiguration before and after DG for all the cases are shown in Fig. 4. From Fig. 4D it is observed that the voltage profile has improved with multiple installations of DGs with reconfiguration and comparison was given in Table 3, and shows the effectiveness of the new algorithms against existing ones. Figs. 4 and 5 shows the voltage profiles and line losses of IEEE-33 and 69 bus systems with and without DG reconfiguration. From Figs. 4 and 5, it is clearly observed that the minimized voltage profile has improved after installation of multiple DG reconfiguration network. This shows the effectiveness of the proposed algorithm. Table 2 illustrates the optimal network reconfiguration of all the cases under the study structure of the IEEE 69 bus system after the instantaneous reconfiguration of multiple DGs using the proposed technique.

Table 4
Parameters of the proposed algorithm for the test systems under assessment.

Test system
Balanced 33 &66 bus N = 20, dimension of search = 5, Maximum weight (wmax) = 0.9, Minimum weight (wmin) = 0.4 Minimum average weight (wavg) kW = 00.31 × 10^3, Maximum average weight (wavg) kW = 00.015 × 10^3 population size (pop size) = 10 bMVA = 100, bkV = 12.66 nbb = 33 & p.f = 1

From Table 2, it is noticed that the Tie switches at 15, 40, 46, 19 and 18 are open at a suitable location and the size of the DG is given as 1.9246, 1.1350 and 1.7587 with precise optimal position of 13, 10 and 30 respectively. The quality, power loss reduction and improvement in voltage profile for the cases are observed in CASE 4, which demonstrate the preeminence of the proposed BPSO-SLFA.



A

B

C

C

D

Fig. 4. (A–D) Voltage profile improvement before reconfiguration and after reconfiguration for all the four cases.

5. Conclusion

In this study, the authors have utilized BPSO-SLFA algorithm to assign DG of optimum size DG in power network distribution. It is clearly observed that the technical goal of hybrid DG installation and reconfiguration in scenario 4 was achieved. The proposed study was investigated on IEEE33 and 69-bus power network system by DG installation at the 13th, 10th and 30th bus and succeeding in terms of reduction in network power losses and improvement in voltage profile. The obtained result shows that BPSO-SLFA algorithm has the best result in power loss reduction, voltage profile improvement and enhancing reliability versus Hybrid GWO and Hybrid big bang big crunch for both test results. Hence, the proposed methodology can be used as a reliable method in DG setting and sizing in distribution network system bestowing to good enactment and the preeminent results rather than Hybrid GWO and Hybrid big bang big crunch.

1. More benefits of the recommended (PBSO-SLFA) algorithms have been achieved compared with other optimization algorithm, to solve optimal sizing and placement problem.
2. The power losses associated with the system, have significantly reduced up to 31.8244 kW, using multi-DGs reconfiguration placement which is expected as part of the objective of the research work.
3. Significant improvement in voltage profile and Voltage stability boosted with reconfiguration and installation of multiple DG units has been achieved using controlled power factor.

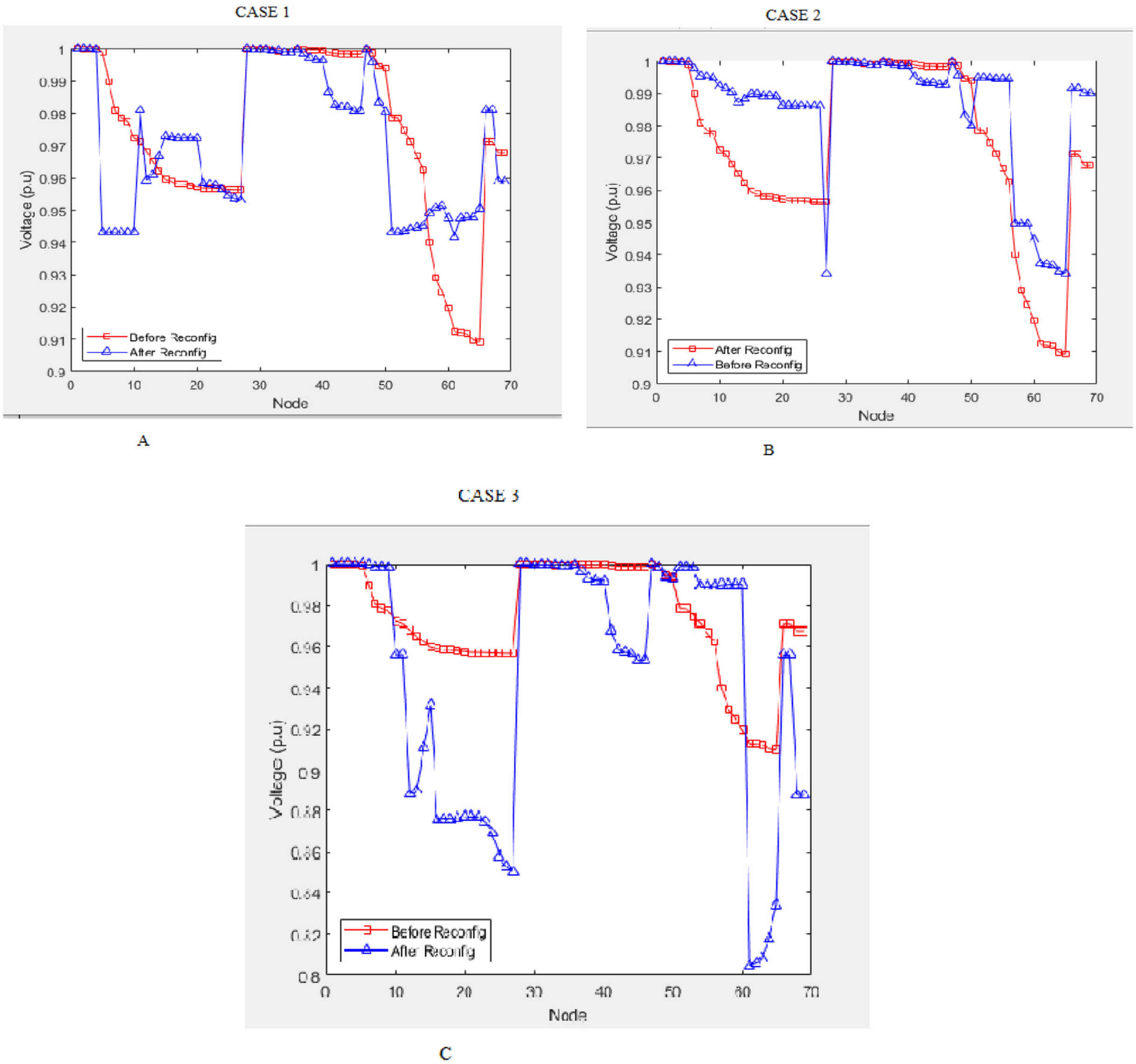


Fig. 5. (A–C) Voltage profile improvement before reconfiguration and after reconfiguration for all the cases.

CRediT authorship contribution statement

Abdurrahman Shuaibu Hassan: Investigation, Writting, Review, Methodology and Editing. **Yanxia Sun**: Supervision, Visualization and Editing. **Zenghui Wang**: Supervision, Validation, Checking codes and Proofreading.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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