International Journal of Electrical and Computer Engineering (IJECE)
Vol. 13, No. 3, June 2023, pp. 2384~2395
ISSN: 2088-8708, DOI: 10.11591/ijece.v13i3.pp2384-2395

Simultaneous network reconfiguration and capacitor allocations using a novel dingo optimization algorithm

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Article Info

Article history:

Received Aug 30, 2022
Revised Sep 8, 2022
Accepted Oct 1, 2022

Keywords:

Capacitor allocation
Dingo optimization
Network reconfiguration
Power loss
Voltage magnitude

ABSTRACT

Power loss and voltage magnitude fluctuations are two major issues in distribution networks that have drawn a lot of attention. Combining two of the numerous strategies for solving these problems and dealing with them simultaneously to get more effective outcomes is essential. Therefore, this study hybridizes the network reconfiguration and capacitor allocation strategies, proposing a novel dingo optimization algorithm (DOA) to solve the optimization problems. The optimization problems for simultaneous network reconfiguration and capacitor allocations were formulated and solved using a novel DOA. To demonstrate its effectiveness, DOA's results were contrasted with those of the other optimization techniques. The methodology was validated on the IEEE 33-bus network and implemented in the MATLAB program. The results demonstrated that the best network reconfiguration was accomplished with switches 7, 11, 17, 27, and 34 open, and buses 8, 29, and 30 were the best places for capacitors with ideal sizes of 512, 714, and 495 kVAr, respectively. The network voltage profile was significantly improved as the least voltage at bus 18 was increased to 0.9530 p.u. Furthermore, the overall real power loss was significantly mitigated by 48.87%, which, when compared to the results of other methods, was superior.

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1. INTRODUCTION

The distribution network is a subsystem of the power system that is responsible for power delivery to the end users of electricity [1]–[3]. Therefore, the power quality delivered to customers strongly depends on it [4]. The two basic topologies available for the distribution network are radial and ring structures [5]. In a radial configuration, feeders radiating from the injection substation supply the loads. The key benefit of this network design is how inexpensively it can be built and maintained [6]. However, its biggest drawback is the possibility of a fault occurring in the center of the network, which might result in the loss of power to the loads located far from the feeder. Furthermore, the bus voltage magnitude decreases progressively as the loads are located away from the feeders. For ring distribution networks, the feeders continuously supply power to the loads in a ring fashion such that if there is a fault in any part of the network, the power supplied to the loads connected to the healthy sections of the network would not be interrupted. The primary downside of this design is its high cost [7]. The radial layout is preferred by power engineers because it is inexpensive to build and maintain. Furthermore, reconfiguring radial distribution networks is a simple process.

Switches used in network reconfiguration fall into two categories: tie switches and sectionalizing switches [8]–[10]. Sectionalizing switches are normally closed, whereas tie switches are normally open. Changing the status of these switches causes the network to be reconfigured. Therefore, network reconfiguration is the act of altering the state of sectionalizing and tie switches to adjust power flow to the loads to enhance the operational performance of the distribution networks. Various network reconfiguration setups are feasible [11]. However, network reconfiguration should be done in such a way that the network stays radial and no loads are cut-off from the supply after reconfiguration. One of these possible alternative configurations provides significantly lower losses and an improved voltage profile. The network reconfiguration method is inexpensive to deploy. Many optimization strategies were used to tackle the network reconfiguration problem.

For instance, to tackle a network reconfiguration problem to lower distribution system power loss, Khetrapal [12] introduced an improved harmony search algorithm (IHSA) inspired by a musician's performance. Salkuti [13] employed a crow search method to optimize network reconfiguration while keeping overall operational cost and network power loss as objectives. The problem of distribution network reconfiguration was addressed in [14] by utilizing an enhanced selective binary particle swarm optimization (IS-BPSO) method. Salau *et al.* [11] provided an excellent technique for resolving network reconfiguration issues in a distribution network to mitigate losses and boost voltage profile. A new approach was also offered to tackle this problem and offer an effective network. With diverse loading circumstances taken into account, a modified selective particle swarm optimization approach was employed for network reconfiguration of the network.

Capacitor deployment is another economical method of decreasing power losses [15]. Aside from their low cost, capacitor placement helps to mitigate power loss and boost the voltage magnitude of the networks. To obtain the greatest advantage from capacitor placements in distribution networks, however, they must be appropriately deployed (i.e., optimally sized and placed). The literature has offered several strategies for optimizing capacitor allocations in distribution networks. A flower pollination algorithm (FPA) was suggested in [16] for the allocation of capacitors in various systems. A shunt capacitor was sized and placed using a whale optimization approach in [17], [18]. A mine blast algorithm (MBA) was used in [19] to obtain the optimal locations and capacities of capacitors in various distribution networks. The utilization of the grey wolf, dragonfly, and moth-flame optimization approaches for the ideal capacitor placements in a variety of distribution networks was given in [20]. Addisu *et al.* [21] proposed a fuzzy logic optimization strategy for efficient voltage regulator positioning and capacitors in distribution systems. The method was tested on the practical Ethiopian Gondar power distribution system, which has 60 nodes. These two strategies (i.e., network reconfiguration and capacitor placements) are potent in improving the performance of radial distribution networks while being relatively affordable to implement. Hence, hybridizing the two methods and solving them simultaneously would be the most effective and beneficial.

There are very few works in the literature that employ simultaneous network reconfiguration and capacitor placements to mitigate losses and boost the distribution network voltage magnitudes. The expenses of real power losses and shunt capacitor installation, as well as enhancing the harmonic state of the network, were modeled as multi-objective problems in [22]. A fuzzy harmony search technique was devised to find the best solution point for multi-objective problems. The presented model was tested on two common distribution systems: the IEEE 33-bus standard system and Taiwan Power Company's 83-bus distribution network. While operational and power quality restrictions were present, Esmaeilian and Fadaeinedjad [23] employed simultaneous reconfiguration and capacitor installation to decrease power loss and increase system dependability. Because the optimization problem was discrete and non-linear, a binary gravitational search algorithm was used to efficiently tackle the fuzzy multi-objective problems. The quick harmonic analysis approach was adopted to execute harmonic power flow in the presence of capacitors and non-linear loads. To evaluate the dependability of various system configurations, the state enumeration approach which depends on the Weibull-Markov stochastic model was utilized. Furthermore, a novel encoding approach was presented to improve the network reconfiguration procedure's performance. To test and validate the suggested technique, the IEEE 33 and 83-bus system of Taiwan Power Company with a variety of harmonic producing loads were used.

Namachivayam *et al.* [24] suggested a combined technique for network reconfiguration and appropriate placement of capacitor banks in radial distribution networks to decrease real power loss and increase bus voltages. Prior to the optimization procedure, suitable tie-switch combinations were constructed using a graph theory-based technique to maintain radial organization and prevent node islanding. The optimization issue was addressed with the help of a modified flower pollination algorithm and a dynamic switching probability technique. The approach's performance was evaluated utilizing conventional 33-bus, 69-bus, and 118-bus distribution networks.

Babu *et al.* [25] presented simultaneous network reconfiguration and capacitor deployment in the distribution system to reduce losses, operational costs, and enhance voltages. During network reconfiguration, the Johnson's technique was employed to determine the smallest spanning tree, and an adaptive whale optimization algorithm was utilized to address the problem. On IEEE 33-bus and 69-bus networks, the suggested technique was validated. Sedighizadeh *et al.* [26] suggested a strategy and a optimization technique for minimizing loss in distribution systems by simultaneous network reconfiguration and capacitor allocation using improved binary PSO. The status of the network switches and capacitors was represented by binary strings in the model. The technique was deployed and evaluated on IEEE 16-bus and 33-bus networks to determine the best network design in terms of losses. Using Johnson's and modified Whale's algorithms, Anitha [27] performed simultaneous reconfiguration and capacitor allocation in distribution networks to mitigate loss and operational cost. The proposed technique was tested on the IEEE 33-bus and 69-bus systems.

The optimization methods utilized to tackle simultaneous network reconfiguration and capacitor allocations in the literature reviewed so far are usually trapped in local minimum points, which affects their efficacy. Besides, better results could be obtained by using a powerful novel optimization technique. Therefore, this paper proposes simultaneous network reconfiguration and capacitor allocation using a novel dingo optimization algorithm (DOA) proposed by [28] to tackle the optimization problems, which is the novelty of this research. The proposed technique was coded in MATLAB and tested on the IEEE 33-bus network. This study's primary contribution is the application of a powerful novel optimization technique to optimally address the simultaneous network reconfiguration and capacitor allocation problems efficiently. The rest of the paper is structured as follows: The second section describes the methodology utilized in this study. The simulation results are presented in the third section, and the study is concluded in the fourth section.

2. METHOD

2.1. Objective function

The objective of network reconfiguration and capacitor allocations is to minimize overall real power loss. As a result, this is regarded as the research's objective function. The overall network real power loss was calculated as the summation of the losses in the line segments.

$$OF_{min} = \sum_{i}^{n_b} |I_i|^2 R_i \tag{1}$$

where, n_b: total number of branches, R_i=i^{th} branch resistance and $|I_i|$=i^{th} branch current magnitude.

2.2. Constraints

The objective function is restricted by some constraints. These constraints are divided into two categories: equality constraints and inequality constraints. The mathematical expressions of these constraints are given in the following sub-sections.

2.2.1. Power flow equations

During the optimization process, the power flow problems were solved utilizing the Newton-Raphson approach. These equations are as (2) and (3):

$$P_{gi} = P_{Di} + \sum_{j=1}^{n_b} |V_i| \left|V_j\right| \left[G_{ij} \cos\theta_{ij} + B_{ij}\ \sin\theta_{ij}\right] \tag{2}$$

$$Q_{gi} = Q_{Di} + \sum_{j=1}^{n_b} |V_i| \left|V_j\right| \left[G_{ij} \sin\theta_{ij} - B_{ij}\ \cos\theta_{ij}\right] \tag{3}$$

where V_i, V_j: bus voltages at buses i and j; P_{gi} and P_{Di}: active power generated and power demanded at bus i; Q_{gi} and Q_{Di}: reactive power generated and demanded at bus i; and θ_{ij}: voltage angle between buses i and j.

2.2.2. Voltage constraints

The voltage magnitudes must be within permissible limits for the distribution network.

$$V_{min} \leq V_i \leq V_{max} \quad (4)$$

where $V_{\min}$ and $V_{\max}$: least and maximum voltages (0.95 and 1.05 p.u.), and V_i: voltage magnitudes.

2.2.3. Reactive power constraint on the capacitors

The size of each of the installed shunt capacitors is constrained within the limits given by (5).

$$Q_{SC(min)} \leq Q_{SC} \leq Q_{SC(max)} \quad (5)$$

where $Q_{SC(\min)}$=100 kVAr and $Q_{SC(\max)}$ is 75% of the overall network reactive power demand [29].

2.2.4. Radial topology constraint

Without meshes, the distribution scheme should be radial. All loads are typically serviced without interruption. The overall number of main loops created once all ties are closed is given by (6).

$$N_{\text{main loops}} = (N_b - N_R) + 1 \quad (6)$$

The total number of sectionalizing switches

$$N_R = N_b - 1 \quad (7)$$

where N_b: total bus number, N_R: total branch number.

A radial configuration check was carried out before starting the load flow and at different points during the optimization process of the proposed method to ensure that the developed solutions satisfy the radial configuration criteria. Each configuration involves the calculation of the incidence matrix C. After that, the first column related to the slack bus is deleted, leaving a square matrix C. If the configuration is radial, the square matrix C's determinant is equal to 1 or -1; if not, the configuration is non radial [30].

2.3. Dingo optimizer

In 2021, Bairwa [28] suggested the DOA, taking cues from the social organization and expert collective hunting behavior of dingoes. They live in groups of 12-15 individuals, are intelligent, and have effective communication abilities. Their social structure is well organized. The strongest member of the group, or the alpha, is in charge of making decisions that will have an impact on every other member of the group. Beta dingoes serve as the group's second in command, enforce group rules, and serve as a liaison between the alpha and the other dingoes. The alphas and betas are assisted in their quest for prey and food for the pack by all the other dingoes.

2.3.1. Encircling

Dingoes are naturally good at finding their prey. The pack of dingoes surrounds the prey after spotting its location. The mathematical model for this behavior is (8)–(12).

$$\overrightarrow{D_d} = \left|\vec{A} \cdot \overrightarrow{P_p}(x) - \vec{P}(i)\right| \quad (8)$$

$$\vec{P}(i+1) = \vec{P}_p(i) - \vec{B} \cdot \vec{D}(d) \quad (9)$$

$$\vec{A} = 2 \cdot \vec{a}_1 \quad (10)$$

$$\vec{B} = 2\vec{b} \cdot \vec{a}_2 - \vec{b} \quad (11)$$

$$\vec{b} = 3 - \left(I * \left(\frac{3}{I_{max}}\right)\right) \quad (12)$$

where $\vec{D}_a$: the distance between the dingo and prey; $\vec{P}_p$: prey's position vector; $\vec{P}$: dingo's position vector; $\vec{A}$ and $\vec{B}$: coefficient vectors; $\vec{a}_1$ and $\vec{a}_2$: random vector in [0, 1], $\vec{b}$ linearly decreases from 3 to 0 at each iteration. Dingoes change their location within the search space around the prey at random.

2.3.2. Hunting

The mathematical modeling of dingoes assumes that the pack is aware of potential locations for prey. The beta dingo occasionally assists the alpha dingo in the hunting process. Using (13)–(18), the dingoes' where abouts are updated [28].

$$\vec{D}_\alpha = \left|\vec{A}_1 \cdot \vec{P}_\alpha - \vec{P}\right| \quad (13)$$

$$\vec{D}_\beta = \left|\vec{A}_2 \cdot \vec{P}_\beta - \vec{P}\right| \quad (14)$$

$$\vec{D}_o = \left|\vec{A}_3 \cdot \vec{P}_o - \vec{P}\right| \quad (15)$$

$$\vec{P}_1 = \left|\overrightarrow{P_\alpha} - \vec{B} \cdot \vec{D}_\alpha\right| \quad (16)$$

$$\vec{P}_2 = \left|\overrightarrow{P_\beta} - \vec{B} \cdot \vec{D}_\beta\right| \quad (17)$$

$$\vec{P}_3 = \left|\overrightarrow{P_o} - \vec{B} \cdot \vec{D}_o\right| \quad (18)$$

The (19) to (21) are used to estimate the intensity of each dingo.

$$\vec{I}_\alpha = log\left(\frac{1}{F_\alpha-(1E-100)} + 1\right) \quad (19)$$

$$\vec{I}_\beta = log\left(\frac{1}{F_\beta-(1E-100)} + 1\right) \quad (20)$$

$$\vec{I}_o = log\left(\frac{1}{F_o-(1E-100)} + 1\right) \quad (21)$$

2.3.3. Attacking prey

A dingo assault on the prey has occurred when there is no update. The value of $\vec{b}$ is decreased linearly to model this strategy. It should be noted that the change range of $\vec{D}_\alpha$ is likewise reduced by $\vec{b}$. $\vec{D}_\alpha$ is a random variable in the [-3b, 3b] interval where $\vec{b}$ is lowered from 3 to 0 between iterations. When $\vec{D}_\alpha$ has random values between [1, 1], a search agent's next position could be anywhere between its current and the prey's.

2.3.4. Searching

Dingoes constantly move forward to pursue and pounce on their prey [28]. The dingo is retreating from the prey when $\vec{B}$ is less than 1, and toward the prey when it is greater than 1. Anytime the conditions for termination are satisfied, DOA terminates itself.

2.4. Application of dingo optimization algorithm

The DOA approach was used to solve the problems with capacitor allocation and network reconfiguration as:

Step 1: Input the network line and load data including the tie switches, and DOA data.

Step 2: Initialization.

A dingo is a hypothetical solution consisting of radial arrangement, capacitor placements, and sizes when using the DOA approach. A swarm of *n* dingoes is denoted by

$$D = \begin{bmatrix} D_1 \\ D_2 \\ \vdots \\ D_n \end{bmatrix} = \begin{bmatrix} TS_1^1, \dots, TS_{NTL}^1 & bus\_Cap_1^1, \dots, bus\_Cap_m^1 & size\_Cap_1^1, \dots, size\_Cap_m^1 \\ TS_1^2, \dots, TS_{NTL}^2 & bus\_Cap_1^2, \dots, bus\_Cap_m^2 & size\_Cap_1^2, \dots, size\_Cap_m^2 \\ \vdots & \vdots & \vdots \\ TS_1^n, \dots, TS_{NTL}^n & bus\_Cap_1^n, \dots, bus\_Cap_m^n & size\_Cap_1^n, \dots, size\_Cap_m^n \end{bmatrix} \quad (22)$$

A dingo in the population may be described by (23).

$$D_i = [TS_1^i, \dots, TS_{NTL}^i \quad bus\_Cap_1^i, \dots, bus\_Cap_m^i \quad size\_Cap_1^i, \dots, size\_Cap_m^i] \quad (23)$$

In (23) demonstrates that each dingo's solution vector is made up of three parts. The first component reflects the quantity of network tie switches (open branches); the second component, the number of buses selected for the placement of capacitors; and the third component, the number of capacitor capacities.

In the equations, TS_1, TS_2, ..., TS_{NTL} are the tie switches in the fundamental loops; bus_Cap_1, bus_Cap_2, ..., bus_Cap_m are the buses chosen for the placement of capacitors; $size\_Cap_1$, $size\_Cap_2$, ..., $size\_Cap_m$ are the sizes of the capacitors in kVAr to be installed on the buses respectively.

Each dingo in the DOA may be seen as a solution that is generated at random at initialization. As a consequence, each dingo, D_i in the population has the following random initialization:

$$TS_i = round\left[TS^i_{lower,r1} + rand \times (TS^i_{upper,r1} - TS^i_{lower,r1})\right] \tag{24}$$

$$bus\_Cap_i = round\left[bus^i_{lower,r2} + rand \times (bus^i_{upper,r2} - bus^i_{lower,r2})\right] \tag{25}$$

$$size\_Cap_i = round\left[size^i_{lower,r3} + rand \times (size^i_{upper,r3} - size^i_{lower,r3})\right] \tag{26}$$

where r_1=1, 2, ... NTL, r_2=1, 2, ... m and $r3$=1, 2 ... m. $TS_{lower,\ r1}$ and $TS_{upper,\ r1}$ are the least tie switch and maximum tie switch which are encoded in the fundamental loop r_1. Capacitors are placed on any bus of the network apart from the slack bus which represent the first bus. Hence, the lower limit ($size_{lower,\ r2}$) and upper limit ($size_{upper,\ r2}$) of the placement of the capacitor is from bus 2 to the last bus and the sizes of each capacitor is from 150 kVAr to maximum power of capacitor as given in the inequality constraint of (5).

Step 3: Evaluation each dingo’s fitness

A radial configuration check is performed for the dingo population. The fitness function of a non-radial configuration is set to infinity. The fitness function, which is employed in this work as the power loss, is obtained by conducting the load flow for each dingo using the Newton-Raphson technique. Depending on the parameters of the fitness function (power loss), the following outcomes are attained: i) the dingo with the best search (D_a), ii) the dingo with the second-best search (D_b); and the Dingo search results after words (D_c).

Step 4: Updating the dingoes status

For i=1: D_n utilize the set of (13)–(18) to update the most recent search agent status.

Step 5: Estimation of the fitness of updated dingoes

A radial configuration check is conducted for the upgraded dingoes. A non-radial configuration's fitness function is set to infinity. The loss is computed by performing a power flow on the dingoes (objective function and fitness function).

Step 6: Determination of the fitness value of dingoes

Keep track of the values of S_a, S_b and S_c and Keep track of the values of $\vec{b}$, $\vec{A}$, and $\vec{B}$.

Step 7: Termination criterion

As the iteration number approaches the maximum, the dingoes' status is updated continuously. The IEEE 33-bus network depicted in Figure 1 was used as the basis for applying the DOA method, with continuous lines denoting sectionalizing switches and broken lines denoting tie switches. This network's line and load data were taken from [31].

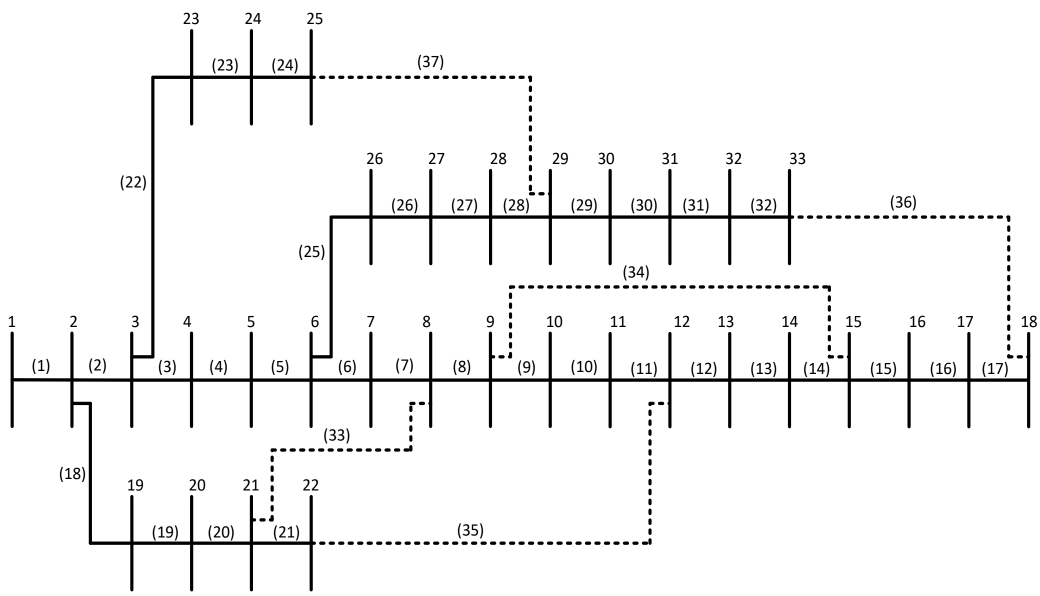

Figure 1. IEEE 33-bus network

3. RESULTS AND DISCUSSION

The simulations were done with a precision of 1e-10 across a total of 20 iterations. The simulation findings for the simultaneous network reconfiguration and capacitor allocations are summarized in Table 1. The results shown in Table 1 indicate that opening switches 7, 11, 17, 27, and 34 resulted in optimal network reconfiguration. The network's radiality was preserved after reconfiguration, and no load was disconnected from the supply. Similarly, as shown in Table 1, the optimal capacitor positions were buses 8, 29, and 30, with optimal capacitor capacities of 512, 714, and 495 kVAr, respectively. Figure 2 depicts the optimal reconfigured network for visual inspection. The following subsections go through the remaining simulation findings and the comparison of the results of the proposed DOA technique with those of other optimization techniques.

Table 1. Simulation results

Base case tie switches	33, 34, 35, 36, 37
Tie switches after reconf. + cap.	7, 11, 17, 27, 34
Location/Capacitor size (kVAr)	8/512, 29/714, 30/495

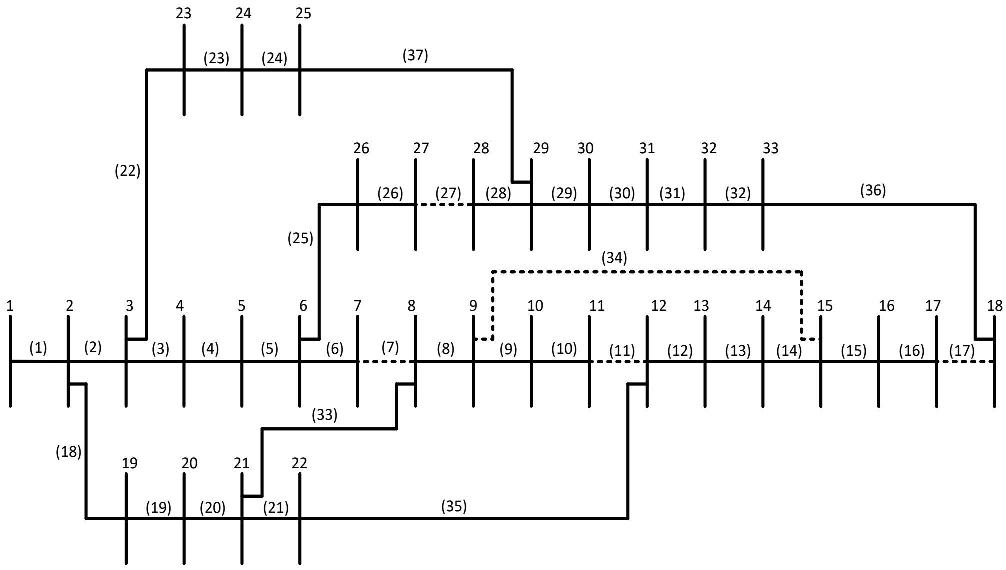

Figure 2. The optimal network configuration after simultaneous network reconfiguration and capacitor allocations

3.1. Voltage profile

Figure 3 compares the network voltage profile before and after concurrent network reconfiguration and capacitor allocations. When Figure 3 was visualized, the voltage magnitudes of buses 6 through 18, as well as buses 26 through 33, were not sufficient because they were below the acceptable lower voltage limit, with bus 18 having the least voltage value of 0.9131 p.u. In other words, the network's voltage profile was quite subpar. Additionally, it is evident from Figure 3 that the network's overall voltage profile had greatly enhanced, as the buses whose voltage magnitudes were below the acceptable lower voltage limit had their voltage magnitudes significantly improved, with the least voltage magnitude at bus 18 now increased to 0.9530 p.u. following simultaneous network reconfiguration and capacitor allocations. The voltage profile was generally remarkedly elevated, proving the viability of the proposed DOA technique in solving the optimization problems of simultaneous network reconfiguration and capacitor allocations to upgrade the network voltage profile and boost the network operational efficiency.

3.2. Real and reactive power losses

Figure 4 gives a quick overview of the real and reactive power losses in each branch of the distribution networks. The network was found to have significant real and reactive power losses. However, these losses were dramatically decreased following the optimal simultaneous network reconfiguration and capacitor allocations. Figures 5 and 6 compare the network's real and reactive power losses at a glance before and after simultaneous network reconfiguration and capacitor allocations for better understanding. As indicated in Figure 5, the greatest real power loss at branch 2-3 was reduced from 51.8 to 20.88 kW, representing a loss reduction of 59.69%. Similar to this, branch 5-6, which had the most reactive power loss, experienced a large loss reduction as the loss was dramatically decreased from 33.1 to 0.9169 kVAr, equating to a 97.23% minimization, as seen in Figure 6.

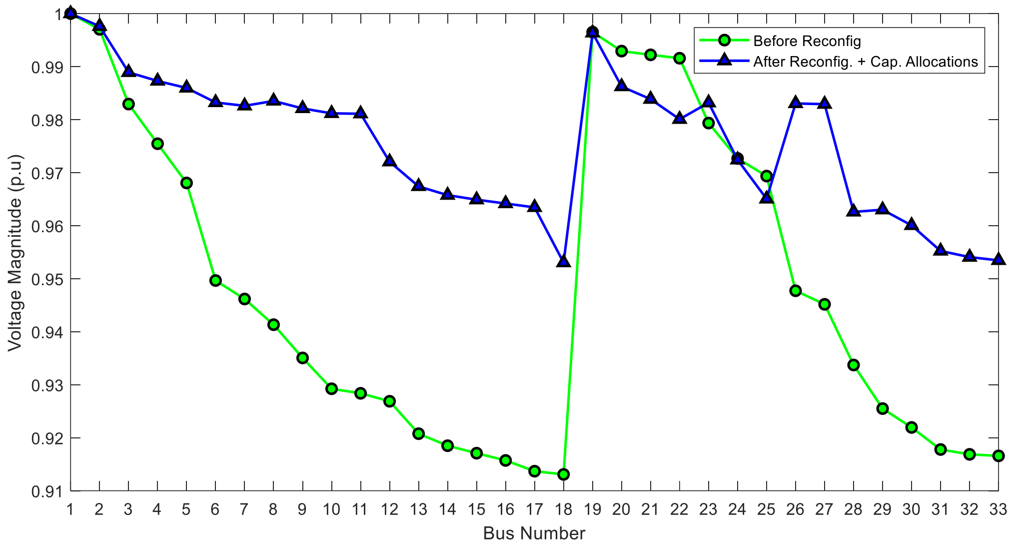

Figure 3. Voltage profile of the network before and after simultaneous network reconfiguration and capacitor allocations

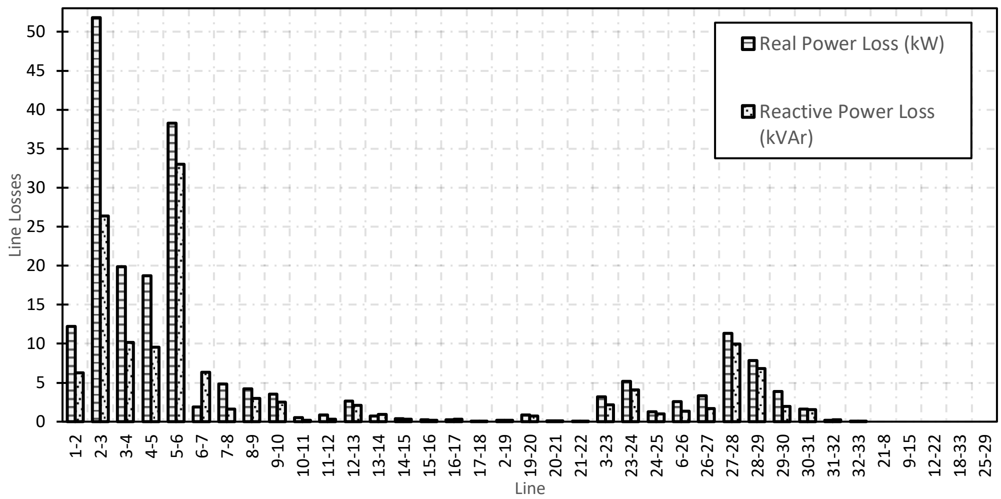

Figure 4. Base case real and reactive power losses

All of the network's branches had general reductions in real and reactive power losses, except for branches 2-19, 19-20, 20-21, 21-22, 3-23, 23-24, 24-25, 30-31, 31-32, 21-8, 12-22, and 25-29, where there were modest rises. This came about as a result of the real and reactive power being redistributed along the system branches to enhance the overall network performance. Additionally, the total real and reactive power losses, which were formerly 202.60 kW and 135 kVAr, respectively, were dramatically decreased to 103.65 kW and 77.53 kVAr, or 48.87 and 42.57%, respectively. The simulation findings show that the proposed DOA is efficient in addressing the simultaneous network reconfiguration and capacitor allocation optimization problems by reducing the network power losses and thus enhancing network performance.

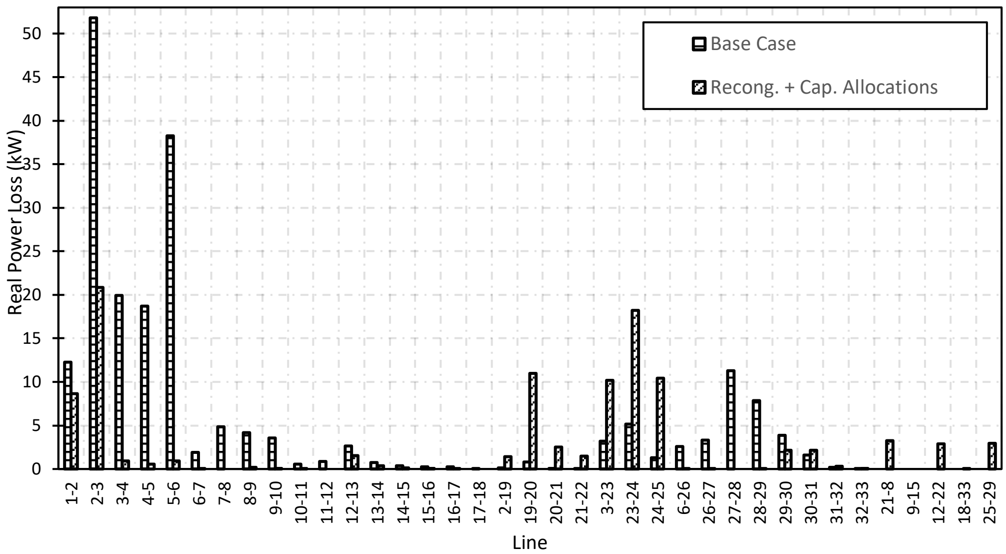

Figure 5. Real power loss before and after simultaneous network reconfiguration and capacitor allocations

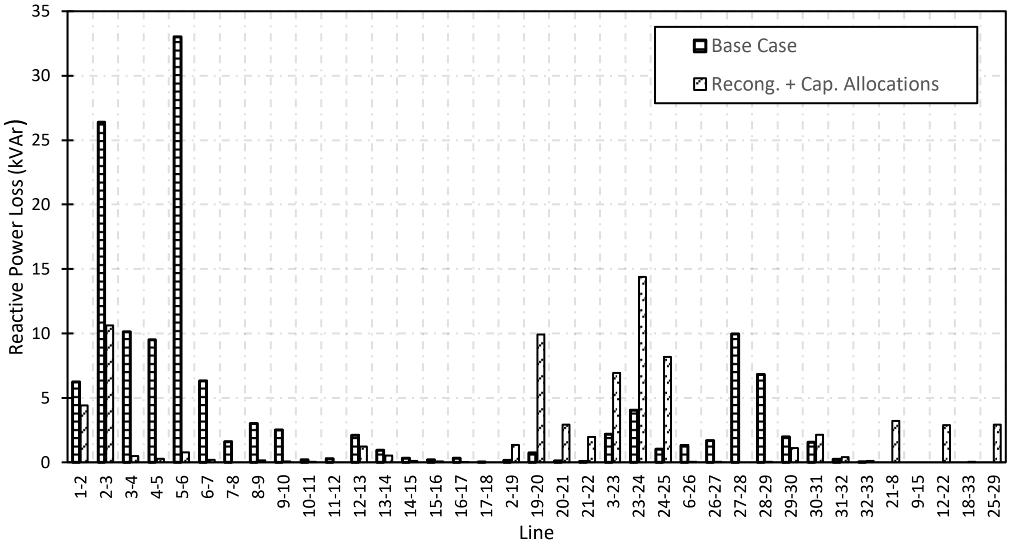

Figure 6. Reactive power loss before and after simultaneous network reconfiguration and capacitor allocations

3.3. Comparison of DOA results with those of other optimization methods in the literature

The findings were compared to those of the modified flower pollination algorithm (MFPA), binary gravitational search algorithm (BGSA), the adaptive whale optimization algorithm (AWOA), improved binary particle swarm optimization (IBPSO), fuzzy harmony search (Fuzzy-HS), and modified whale algorithm (MWA) in the literature to confirm the applicability of the proposed DOA approach. Table 2 provides documentation of the comparison of the DOA solutions with those of other optimization methods. Column two of Table 2 lists the switches that were opened (i.e., tie switches) following simultaneous network reconfiguration and capacitor allocations. Table 2's third column contains the capacitor locations and sizes, whereas column four contains the percentage decrease in real power loss for each method as well as for the proposed DOA technique.

The proposed DOA optimization approach demonstrated superiority over existing optimization strategies in the literature, with a real power loss reduction percentage of 48.87%, as shown in Table 2. The percentage real power reductions obtained by other optimization methods, as indicated in Table 2, were not as high as that of the proposed DOA technique. Also, it can be seen that the IBPSO and MFPA techniques have the least power loss reduction of 31.14%, closely followed by MWA at 32.68%, BGSA at 37.42%, AWOA at 42.68%, and Fuzzy-HS at 44.49%. So, the simultaneous network reconfiguration and capacitor allocation optimization challenges were better addressed by the proposed DOA approach, as Table 2 clearly shows.

Table 2. Proposed DOA's performance summary against other existing optimization techniques

Algorithm	Ties Switches	Capacitor size in kVAr (Location)	% Reduction
BGSA [21]	10, 14, 28, 32, 33	450 (6), 300 (12), 900 (30), 600 (29)	37.42
MFPA [22]	7, 14, 9, 32, 37	750 (6), 150 (28), 850 (29)	31.14
AWOA [23]	33, 34, 35, 36, 25	400 (24), 250 (25), 150 (30)	42.68
IBPSO [24]	7, 14, 9, 32, 37	900 (2), 300 (4), 300 (15), 300 (23), 300 (25), 600 (31), 600 (32)	31.14
Fuzzy-HS [20]	6, 9, 32, 34, 37	450 (11), 900 (5), 150 (19), 150 (29), 150 (23)	44.49
MWA [25]	33, 34, 35, 36, 25	400 (24), 250 (25), 150 (30)	32.68
Proposed DOA	7, 11, 17, 27, 34	512 (8), 714 (29), 495 (30)	48.87

4. CONCLUSION

The IEEE 33 bus network's simultaneous network reconfiguration and capacitor allocation optimization problems were resolved by employing a novel DOA optimization approach. With the help of the proposed technique, the optimization problem posed by simultaneous network reconfiguration and capacitor allocations was adequately addressed, and the overall network voltage profile was greatly enhanced as the minimum voltage magnitude was increased to 0.9530 p.u. Also, significant improvements were made in the network's overall real and reactive power losses as the total real and reactive power losses decreased by 48.87 and 42.57%, respectively. According to the comparison findings, the proposed method's outcomes were noticeably superior to those of other optimization approaches in the literature. The simultaneous solution of network reconfiguration and capacitor allocation may be achieved using DOA, a powerful optimization approach.

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