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Power Quality Improvement by Capacitor Placement in a Reconfigured Electric Distribution Network Using Improved Artificial Bee Colony

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Abstract: The distribution system that feeds electric power to a nuclear facility must have higher power quality and a reliable network design to carry loads. Distribution networks face significant problems, including voltage drop and power losses, which can cause malfunction for electrical nuclear instrumentation. Optimal capacitor placement and reconfiguration of the distribution network are two essential methods to solve these problems. While reconfiguration optimizes network topology, capacitor placement compensates for the reactive power, their combined implementation results in superior performance in voltage profile improvement, power loss reduction, and overall system reliability. This paper proposes an optimization technique based on an improved artificial bee colony algorithm for mathematical modelling of optimal capacitor allocation in the reconfigured distribution network problem. The proposed approach is demonstrated by using IEEE standard distribution networks to check the accuracy and reliability. Results show that considering capacitor placement and network reconfiguration simultaneously improves the voltage profile and effectively minimizes power losses.

Keywords: Electrical distribution system, nuclear facility, Feeder reconfiguration, Capacitor placement.

1 Introduction

The distribution feeder reconfiguration and the optimal capacitor placement are the most important means of reducing power losses and improving the voltage profile of the distribution network. The problem is how to obtain the optimal topology of the network and the optimal setting of capacitors. Many studies focus on obtaining the optimal network topology by reconfiguration of the distribution network, which is achieved by changing the ON/OFF status of ties and sectionalizing switches. Reconfiguration aims to optimize power flow paths by keeping radial structure, reducing active power losses, improving voltage regulation, and ensuring all loads are served. Many research works have been done in the field of distribution network reconfiguration for power loss reduction and voltage profile improvement [1-8]. Other researchers are improving the distribution network voltage profile and compensating reactive power loss by capacitor placement using different algorithms [9-23]. However, for a reliable distribution network with minimum power loss and improved voltage profile, the capacitor is placed in the reconfigured network optimally. In [24], the optimization problems for simultaneous network reconfiguration and capacitor allocations were formulated and solved using the dingo optimization algorithm. Modified Biogeography Based Optimization (MBBO) algorithm to find the optimal solution for capacitor placement in a reconfigured distribution network for power loss reduction and voltage profile improvement was presented in [25]. For simultaneous network reconfiguration and capacitor placement in a distribution network, an adaptive whale optimization algorithm is used to minimize the power losses and to improve the voltage profile [26]. In [27], capacitor placement and distribution system reconfiguration using discrete improved Grey Wolf optimization was proposed. Optimal network reconfiguration and capacitor placement for power loss reduction of the distribution system using improved binary particle swarm optimization proposed in [28]. Ant Lion optimizer (ALO) algorithm is used to solve the capacitor placement and distribution network reconfiguration problem for voltage improvement

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and losses reduction [29]. In this paper, the capacitor placement in the reconfigured distribution network problem is investigated for power loss reduction and voltage enhancement. The proposed methodology for problem solving has been applied to the IEEE standard distribution system for validation by implementation in MATLAB.

The main advantage of the proposed methodology is solving a multi-objective optimization problem for capacitor setting and feeder reconfiguration, considering variant constraints, and it applies to large-scale distribution systems with comprehensive modeling of diverse distribution components.

2 Problem Formulation

In this paper, the distribution systems will be reconfigured with capacitor placement for power loss reduction and voltage profile improvement, taking into account some constraints under specific loading conditions. The problem of the distribution network reconfiguration simultaneously with shunt capacitors installation is formulated mathematically, as follows [30]:

$$\text{Minimize} \quad \Delta P \tag{1}$$

$$\Delta P = \Delta P_{loss}^{reconfig.} + \Delta P_{loss}^{capacitor\ plac.} \tag{2}$$

Where:

$\Delta P_{loss}^{reconfig.}$ power loss in case of reconfiguration,

$\Delta P_{loss}^{capacito\ plac.}$ power loss in case of capacitor placement,

ΔP: power losses objective function.

The power loss in the branch connected between two nodes n, n+1 can be calculated by the following equation:

$$P_{loss} = r_m \left[\frac{P^2{}_n + Q^2{}_n}{|V_n|^2}\right] \tag{3}$$

And the total power loss, $P_{t\,loss}$ For a distribution network with "M" branches will be

$$P_{t\,loss} = \sum_{m=1}^{M} P_{loss} \tag{4}$$

Where P_n and Q_n Is the active and reactive power at bus number "n", respectively. V_n Is the bus voltage and r_m is resistance of line section "m" between two nodes n, n+1.

2.1. Power loss reduction due to reconfiguration

Reconfiguration of the distribution system is to minimize power losses and maintain voltage within specified constraints, where there are different forms of network arrangement states according to switches' position and load state. The reconfiguration problem to get the optimum connection for the electric network for power loss reduction, considering some constraints, can be represented as follows: Power loss. $P_{loss}^{"}$ For the branch between two buses, for reconfigured distribution network can be calculated by the following equation:

$$P_{loss}^{"} = r_m^{rec}\left[\frac{P^{"2}{}_n + Q^{"2}{}_n}{|V_n|^2}\right] \tag{5}$$

And the total power loss, $P_{t\,loss}^{"}$ For all branches will be:

$$P_{t\,loss}^{"} = \sum_{m=1}^{M} P_{loss}^{"} \tag{6}$$

So the net power loss reduction due to reconfiguration is the difference between total power losses before and after reconfiguration, which will be formulated as follows:

$$\Delta P_{loss}^{reconfig} = \sum_{m=1}^{M} P_{loss} - \sum_{m=1}^{M} P_{loss}^{"} \tag{7}$$

2.2. Capacitor placement for power loss reduction

The capacitors are installed at optimum locations with proper sizes for power loss reduction and voltage profile improvement, considering some constraints. As the losses due to the active component of the load currents are slightly affected by the placement of capacitors, we will focus only on the losses due to the reactive currents where capacitors inject reactive power. The total peak power loss for a distribution system with" N" nodes, "M" branches before compensation is given by [31]:

$$P_{Lo} = \underline{i}_p{}^t \underline{R}\underline{i}_p + \underline{i}_q{}^t \underline{R}\underline{i}_q \tag{8}$$

And the peak power loss after capacitors placement P_{Lc} is given by:

$$P_{Lc} = \underline{i}_p{}^t \underline{R}\underline{i}_p + [\,\underline{i}_q{}^t - \underline{i}_c{}^t\,]\,\underline{R}\,[\,\underline{i}_q - \underline{i}_c] \tag{9}$$

$$= \underline{i}_p{}^t \underline{R}\underline{i}_p + \underline{i}_q{}^t \underline{R}\underline{i}_q + \underline{i}_c{}^t \underline{R}\underline{i}_c - 2\,\underline{i}_q{}^t \underline{R}\underline{i}_c \tag{10}$$

$$P_{Lc} = P_{Lo} + \underline{i}_c{}^t \underline{R}\underline{i}_c - 2\,\underline{i}_q{}^t \underline{R}\underline{i}_c \tag{11}$$

So that the reduction in power losses in the system due to capacitor placement will be

$$\Delta P_{loss}^{capacitor\ plac.} = P_{Lo} - P_{Lc} = 2\,\underline{i}_q{}^t \underline{R}\underline{i}_c - \underline{i}_c{}^t \underline{R}\underline{i}_c \tag{12}$$

P_{Lo}: the power loss before the capacitors' placement,

$\underline{IP}$; the active component of the feeder load currents,

$\underline{IQ}$; the reactive component of the feeder load currents,

$\underline{R}$; the feeder resistance matrix ($n \times n$),

i_c; the vector of the shunt capacitors' current.

By substituting equations 7,12 into equation 2, we can get the objective function of the capacitors' placement in the reconfigured distribution network, which is the proposed mathematical model.

2.3. Objective function constraints

Radial topology: the distribution system will be radial without meshes, and the loads will be fed without interruption, and the radial configuration will be maintained during the optimization process. When all ties are closed, the number of main loops is { L = (N - M) +1}.

Node voltage limitation: The voltage at the nodes will be maintained at certain limits

$$V_{n_{min}} \leq |V_n| \leq V_{n_{max}} \quad (15)$$

Where V_n, $V_{n_{min}}$ and n_{max} are node voltage, minimum node voltage (0.95), and maximum node voltage (1.05) limits, respectively.

Capacitor reactive power limit: the total reactive power injected by capacitors "Q_c" must be less than the network reactive load "Q_L": $Q_c < Q_L$ (16)

Current in branches limitation: the current in branch "m" between two nodes n, n+1, within the limit:

$$|I_{n,n+1}| \leq |I_{n,n+1}|_{max} \quad (17)$$

Network serves all loads: the radial network topology at all times must serve all loads in the network. Where each load bus must be provided with the required active and reactive power. One of the switches (s_a, s_b, s_c) will be opened and the two others will be closed, and all load (L) buses served as shown in Figure 1.

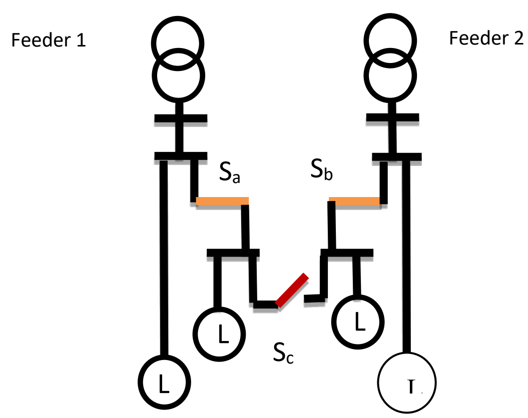

Fig.1. Network configuration serves all loads.

3 Proposed Algorithm

3.1 Artificial Bee Colony (ABC)

In the ABC algorithm, three types of bees employed, scout, and onlooker must be adjusted for food seeking and processing, where each type in the algorithm has a known function [32]. The employed bees have a task of calculating the available amount of the food source and, after that, specifying the number to each of the employed bees. Finding food sources is the main responsibility of scout bees. The onlooker bees have the task of choosing good food sources.. The employed bee will be a scout bee if the current food source collected by employed bees becomes rare and the possible solution is the food source. The quality of the solution is proportional to the food amount, which is the fitness value of the algorithm. The algorithm steps are as follows:

Random establishment for food sources:

$$X_{im} = \min X_y + \text{rand}(0,1) \times (\max X_n - \min X_n) \quad (18)$$

Where:

i: food source index number, m: random index number, X_{im}: set of solutions, min X_n: n^{th} element minimum value, max X_n: n^{th} element maximum value.

Food sources fitness value:

$$\text{if } f_i \geq 0 \rightarrow f_i = \frac{1}{(1+f_i)} \quad (19)$$

$$\text{if } f_i < 0 \rightarrow (1 + |f_i|) \quad (20)$$

Where f_i: fitness value at line i of the solution set.

New candidate food source creation:

For each of the food sources established, we can apply the following equation to get a candidate food source. After that, a comparison between the fitness values of the new food sources and the fitness values of the old food sources will be done. As a result of the comparison, if the fitness value of the new food source is greater than the old food source, the old one is replaced:

$$V_{im} = X_{im} + \varphi_{im} \times (X_{im} - X_{jm}) \quad (21)$$

Where: V_{im} new food source parameter value, X_{im} is m line selected food source value, X_{jm} is j line random neighbor food source value, j is random neighbor food source index,and φ_{im} i s two food sources distance change.

Better food sources creation:

Apply the following equation to the selected food sources:

$$o_i = \frac{f_i}{\sum_j f_j} \quad (22)$$

Where o_i On Looker Bee, a possible result solution, if selected solution sets the fitness value.$\sum_j f_j$Total solution sets fitness value. The fitness values are computed and compared with the old values. If the fitness value improved, the old food source is replaced with the new one. When the current food source cannot be enhanced, that source is canceled and starts again with a new random solution set using the first equation [33].

3.2. Modified Artificial Bee Colony

To solve any complex problem successfully and quickly than the traditional ABC algorithm, it can be modified and developed into MABC. The MABC algorithm has two additional parameters which not in the ABC algorithm, one of which attaches the scaling factor parameter and the other to the ratio [34]. In the

ABC algorithm, a single food source is updated, while in the MABC algorithm, multiple numbers of food sources are determined due to the ratio of modification. To get the modification rate, we apply the following equations.

If R_{im}< MR then $V_{im}=X_{im}+\varphi_{im}\times(X_{im}-X_{jm})$ (23)
Where R_{im} is a randomly produced value, the MR modification rate

Else $V_{im} = X_{im}$ (24)

In the MABC, the value range produced related to the Scalar Factor (SF) parameter changes will be in the range of [-SF, SF]. Where the number is randomly produced for the ABC algorithm in the range of [-1,1] [35]. The algorithm steps will be:

Step 1: Load all feeder data.
Step 2: Run load flow for base case.
Step 3: Initialize variables, limits, number of cycles, and algorithm parameters.
Step 4: Evaluate objective function (initial solution equation 21.
Step 5: Evaluate the objective function by position modification using equation 23.
Step 6: Evaluate solution probability value by equation 22.
Step 7: Allocate onlooker bees and get the modified solution using equation 23.
Step 8: Compare solutions with old and new solutions, memorize the best.
Step 9: Is the solution improved?
Step 10: Yes, display optimal solution.
Step 11: No, Scout, search for a better solution, go to step 4

4 Results and Discussion

To determine the optimal locations and size of capacitors in a reconfigured distribution system, the proposed MABC algorithm and solution methodology are tested on IEEE –16, IEEE-33 buses radial distribution network with tie lines, where data loads are given in. For each tested network, three scenarios are studied to clarify the reliability of the proposed algorithm:

Scenario 1: Considering reconfiguration only.
Scenario 2: Capacitor placement only.
Scenario 3: Reconfigured distribution system with capacitor placement simultaneously.

4.1. Algorithm implementation on 16-bus network

The system consists of three feeders, 16 buses, three tie switches, and 13 sectionalizing switches. The switches for tying are (s26, s21, and s15), which will be opened, and the switches for sectionalizing are the remaining switches as shown in Figure 2, which will be closed [36]. The simulation results for applying the proposed MABC algorithm on a 16-node test system for the three scenarios are shown in Table 1 and the voltage profile in Figure 3.

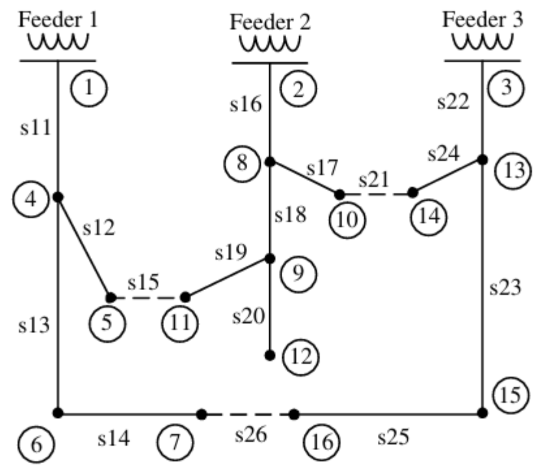

Fig. 2. Base configuration of a 16-bus network.

In the initial case, there are three open switches of 15-21-26 with a minimum voltage of 0.9639 p.u. and 514.4 kW power losses. In scenario 1, with optimal reconfiguration with the proposed MABC algorithm, the power loss was reduced to 439.5 with 14.5 % loss reduction, and the minimum node voltage improved to 0.979 p.u. In case of capacitor placement only (scenario 2), the power loss reduced to 411.2 with 20 % loss reduction, and the minimum node voltage improved to 0.983 p.u. When the capacitor is installed simultaneously with feeder reconfiguration (scenario 3), the power loss is reduced to 390.7 with 24 % loss reduction, and the minimum node voltage improves to 0.987 p.u., where the power loss reduction for scenario 3 in [37] is 11.69%.

Table 1. Simulation results for 16- 16-bus system in all scenarios

Item	Opened switches	Power loss (kW)	Min, voltage	Capacitor size kVAR (bus)	Power loss reduction. (%)
Base Case	15,21,26	514.4	0.96393	----	---
Scenario 1	17-19-26	439.5	0.979	-----	14.5
Scenario 2	15,21,26	411.2	0.983	1800 (4), 2100 (8)	20
Scenario 3	17-19-26	390.7	0.987	1800 (4), 900 (13), 2100 (8)	24

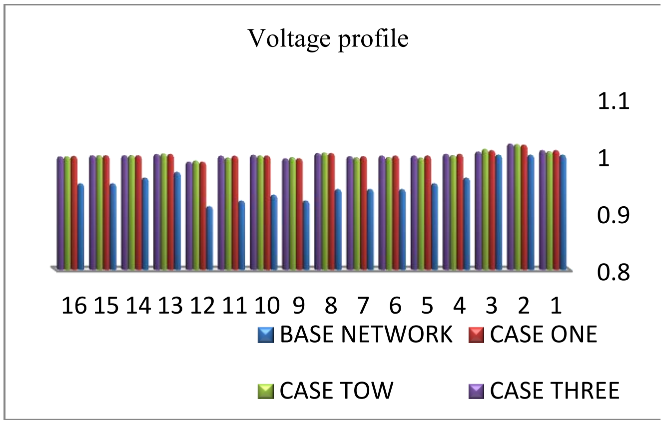

Fig. 3. Voltage profile for the 16-bus network, all scenarios.

4.2. Algorithm implementation on 33 bus networks

The 33-node 12.66 kV radial feeder in Figure 4 has 33 nodes, 37 branches, 3.72 + j2.3 MVA total loads [38]. The simulation results for applying the proposed MABC algorithm on33-node test system for the three scenarios are shown in Table 2 and the voltage profile in Figure 5. In initial configuration (base case), there are five open switches of 33-34-35-36-37 and 32 normally closed switches with a minimum voltage of 0.9138 p.u. at bus 18- and 202.68-kW power loss. In scenario 1, with optimal reconfiguration with the proposed MABC algorithm, the power loss was reduced to 130.27 with a 35.5 % loss reduction, and the minimum node voltage improved to 0.945 p.u. In case of capacitors placement only (scenario 2), the power loss reduced to 131.5 with 35 % loss reduction, and the minimum node voltage improved to 0.935 p.u. For scenario 3, where capacitors are installed simultaneously with feeder reconfiguration, the power loss is reduced to 100.7 with 50 % loss reduction, and the minimum node voltage is improved to 0.957 p.u.

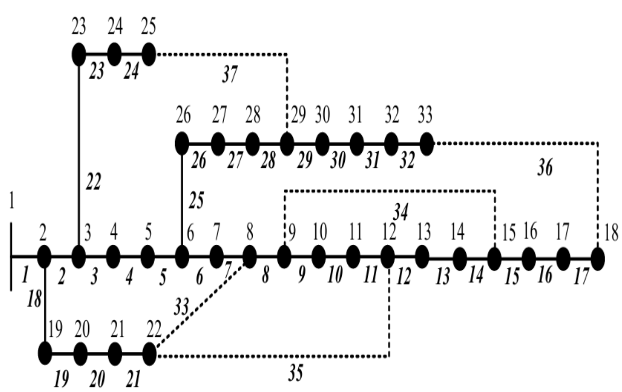

Fig. 2. Base configuration of a 33-bus network.

Table 1. Simulation results for 33- 33-bus system in all scenarios

Item	Opened switch	Power loss (kW)	Min. voltage	Capacitor size kVAR (bus)	P.L. R. (%)
Base case	33-34-35-36-37	202.68	0.9138	----	---
Sce. 1	7-10-12-32-37	130,27	0.945	-----	35.5
Sce. 2	33-34-35-36-37	131.5	0.935	900 (7), 300 (28), 600 (29), 300 (30)	35
Sce. 3	7-8-17-31-34	100.7	0.957	600 (6), 300 (12), 600 (25), 600 (30)	50

In Table 3, a comparison with the proposed methodology with other works with variant algorithms such as SA [39], HAS [39], IBPSO [28], and MFPA [40] is presented. In the base case, the results are the same for all algorithms, and scenario 3is the best result for power loss 100.7 kW and minimum voltage 0.957 p. u. is presented by the proposed MABC algorithm.

Table 3. Comparison results for the 33-bus network

Item	Scenarios	SA [39]	IBPSO [28]	MFPA [40]	HSA [39]	Proposed MABC
Power loss Kw	Base	202.7	202.7	202.7	202.7	202.7
	1	142.6	139.6	139.5	137.8	130.27
	2	136.11	140.40	139.57	135.16	131.5
	3	124.3	103.1	101.8	119.7	100.7
Min. Voltage	Base	0.914	0.914	0.914	0.914	0.914
	1	0.929	0.938	0.94	0.93	0.945
	2	0.931	0.941	0.93	0.94	0.935
	3	0.94	0.957	0.954	0.943	0.957

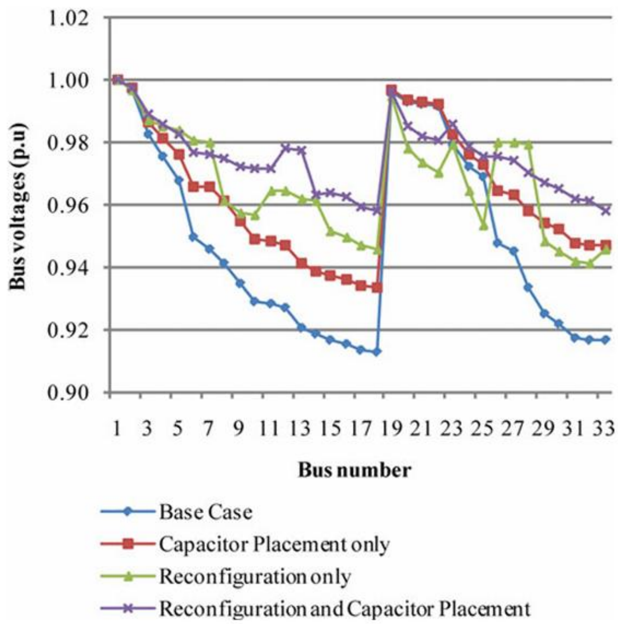

Fig.3. Voltage profile for the 33-bus network, all scenarios.

5 Conclusions

In this paper, a mathematical model for the capacitor in the reconfigured network problem and an optimization technique based on MABC were proposed to reduce the electric network power losses and improve the network voltage profile. To determine the optimal locations and size of capacitors in a reconfigured distribution system, the proposed MABC algorithm and solution methodology are tested on IEEE- 16, IEEE- 33 buses radial distribution network. For each tested network, three scenarios are studied: the Distribution system base case, the reconfigured distribution system only, the Distribution system with capacitors only, and the reconfigured distribution system with capacitors placement simultaneously. The results obtained and analysis for the two tested feeders show that the optimal solution of the problem is achieved by simultaneous capacitor placement with electrical network reconfiguration. By the proposed MABC algorithm, the optimum solutions when implemented on the IEEE–16, IEEE-33 (scenario 3) are: simultaneous capacitors 1800 kVAR (node 4), 900 kVAR (node 13), 2100 kVAR (node 8) placement with electrical network reconfiguration (open switches 17-19-26) and simultaneous capacitors 600 kVAR(node 6), 300 kVAR (node 12),600 kVAR (node 25), 600 kVAR (node 30) placement with electrical network reconfiguration (open switches 7-8-17-31-34) respectively. By comparison with SA, MFPA, IBPSO, and HSA algorithms in other works, the solution with the proposed MABC algorithm is the optimum solution considering voltage profile improvement and power loss reduction.

References

[1] Hemmati, M., Mohammadi, B., Abapour, M. & Anvar, A., Optimal chance-constrained scheduling of reconfigurable microgrids considering islanding operation constraints. *IEEE Syst. J.,* vol. 14, no. 4, pp. 5340–5349, 2020.

[2] Gao, Y., Wang, W., Shi, J. & Yu, N., Batch-constrained reinforcement learning for dynamic distribution network reconfiguration. *IEEE Trans. Smart Grid*, vol. 11, no. 6, pp. 5357–5369, 2020.

[3] Ehsan, K. R., Mohammad, S. S., Fast heuristic methods for harmonic minimization using distribution system reconfiguration. *Electr. Power Syst. Res.,*181, 106185, 2020.

[4] Yinpeng Qu, C. C. et al., A global optimum flow pattern for feeder reconfiguration to minimize power losses of unbalanced distribution systems. *Int. J. Electr. Power Energy Syst*.,131, 107071, 2021.

[5] Mahdavi, M., Alhelou, H. H. & Hesamzadeh, M. R., An efficient stochastic reconfiguration model for distribution systems with uncertain loads. *IEEE Access*,10, 10640–10652, 2022.

[6] Karimianfard, H. & Haghighat, H., An initial-point strategy for optimizing distribution system reconfiguration. *Electr. Power Syst. Res.*,176,105943,2019.

[7] Qingxin Shi, F. et al., Co-optimization of repairs and dynamic network reconfiguration for improved distribution system resilience. *Appl. Energy,* 318, 2022.

[8] Razavi, S. M., Momeni, H. R., Haghifam, M. R. & Bolouki, S., Multi-objective optimization of distribution networks via daily reconfiguration. *IEEE Trans. Power Delivery,*37 (2), 775–785, 2022.

[9] Mehrdad, A. K., Raymond, G., Mahmoud, A. A., Mohamed, H., Mohanad, A., Shawkat, A., Ilhami, C.& Ahmed, S., Optimizing capacitor bank placement in distribution networks using a multi-objective particle swarm optimization approach for energy efficiency and cost reduction. *Scientific Reports*, 15, 12332, 2025.

[10] Akbari, E., Optimal placement and scheduling of switched capacitor banks using multi-objective hybrid optimization algorithms under load uncertainty conditions. *Int. J. Smart Electr. Eng.*, 12 (02), 79–87,2023.

[11] Jawad, A., Ahmed, K. T., Islam, S. R. & Islam, M. A., Optimal capacitor placement in Northern region of Bangladesh transmission network for voltage profile improvement. *Energy Rep.*, 9, 1896–1909,2023.

[12] Osama, A., Zeineldin, H. H., HM, E. F. T. & El-Saadany, E. F., Optimal placement and sizing of capacitor banks in radial distribution systems using the whale optimization algorithm. *IEEE Conference - Middle East (ISGT),* 1–5, 2023.

[13] Maghami, M. R. & Mutambara, A. G. O., Optimum power flow concerning the capacitor location and size in distribution network. *Processes,* 10 (12), 2590, 2022.

[14] Mondal, S. & De, M., Optimal capacitor placement for unbalanced distribution system using graph theory. *IETE J. Res.*, 69 (9), 6512–6519, 2023.

[15] Rofandy, M. Y., Hasibuan, A. & Rosdiana, R., Analysis of the effect of bank capacitor placement on voltage drop increase in distribution network. *Int. J. Appl. Sci. Eng. Technol.*, 2 (1), 11–24,2022.

[16] Montoya, O. D., Moya, F. D. & Rajagopalan, A., Annual operating costs minimization in electrical distribution networks via the optimal selection and location of fixed-step capacitor banks using hybrid mathematical formulation. *Mathematics*, 10 (9), 160, 2022.

[17] Ghadimi, M., Khameneh, M. & Khodadadi, M., Hybrid algorithms for reactive power compensation in renewable-integrated grids. *Renew. Energy*,187, 508–522, 2023.

[18] Kumar, S., Sharma, M. & Singh, R. Optimal capacitor placement in distribution networks using multi-objective particle swarm optimization. *IEEE Trans. Power Syst.*, 38 (3), 2345–2354, 2023.

[19] Hassan, M., Raza, T. & Ahmad, F., Application of genetic algorithm for optimal capacitor placement in radial distribution networks. *IEEE Access*, 11, 72912–72925, 2023.

[20] Huang, N., Zhou, Q. & Lin, Y., Multi-objective capacitor placement in distribution networks using modified particle swarm optimization. *Int. J. Electr. Power Energy Syst.*, 160, 109240, 2024.

[21] Lee, C., Park, K. & Kim, T., Hybrid particle swarm optimization and simulated annealing for capacitor placement in distribution systems. *IEEE J. Emerg. Sel. Top. Power Electron,* 11 (1), 223–234,2024.

[22] Qureshi, A., Khan, S. & Rafi, M., M., Multi-objective particle swarm optimization for optimal capacitor placement in distribution systems. *IEEE Trans. Ind. Appl.*, 60 (3), 2256–2265, 2024.

[[23] El-Saeed, M. A. E. S. M., Abdel-Gwaad, A. F. & Farahat, M. A. F., Solving the capacitor placement problem in radial distribution networks. *Results Eng.*, 17, 100870, 2023.

[24] Samson, O., Ayanlade, A. J., Emmanuel, I. O., Abdullahi, A., Abdulsamad, B. J. & Dolapo, E. O., Simultaneous network reconfiguration and capacitor allocations using a novel dingo optimization algorithm. *International Journal of Electrical and Computer Engineering*, (13),3,2384-2395,2023.

[25] Haider, F., Ali, N. H., Waleed, K. S., Dual technique of reconfiguration and capacitor placement for distribution system. *International Journal of Electrical and Computer Engineering*, (10),1,80-90, 2020.

[26] Ramesh Babu, M., Venkatesh Kumar, C. & Anitha, S., Simultaneous Reconfiguration and Optimal Capacitor Placement Using Adaptive Whale Optimization Algorithm for Radial Distribution System. *Journal of Electrical Engineering & Technology,*16:181 190, 2021.

[27] Prasad, P. S. & Sushama, M., Distribution network reconfiguration and capacitor allocation in distribution system using discrete improved Grey Wolf optimization. *Innovations in Electrical and Electronic Engineering, ICEEE*, vol 894, 2022.

[28] Sedighizadeh, M., Dakhem, M., Sarvi, M.& Kordkheili, H. H., Optimal reconfiguration and capacitor placement for power loss reduction of distribution system using improved binary particle swarm optimization. *Int J Energy Environ Eng*., 5(73):1–11, 2014.

[29] Maryam, S., Shahrokh, S. & Mehri, L., Reconfiguration and Capacitor Allocation in Distribution Systems to Reduce Losses and Improve Voltage Profiles using Ant Lion Algorithm. *International Journal of Digital Application & Contemporary Research,* Volume 5, Issue 12, 2017.

[30] Vo Ngoc, D., & Tran Anh, N., Distribution network reconfiguration for power loss reduction and voltage profile improvement using chaotic stochastic fractal search algorithm. *Complexity*, 2020.

[31] Alaa A. Saleh, & Ahmed S. Adail, Iimprovingof electric network feeding a nuclear facility based on multiple types of DGs placement. *Kerntechnik ,* 88 (1), 13-20, 2022.

[32] Karaboga, D. & Basturk, A. A powerful and efficient algorithm for numerical function optimization: artificial bee colony (ABC) algorithm. *Journal of Global Optimization*, 39,459-471,2007.

[33] Korkmaz, R. & Bora, S., Parameter tuning of complex systems modeled in agent-based modeling and simulation. *World Academy of Science, Engineering and Technology*, 2017.

[34] Akay, B. & Karaboga, D. A., Modified artificial bee colony algorithm for real-parameter optimization. *Information Sciences*,192,120-142, 2010.

[35] Tan, R. S. & Bora, S., Adaptive modified artificial bee colony algorithm for optimization of complex systems. *Turkish Journal of Electrical Engineering & Computer Sciences*,28,5, 2602-2629,2020.

[36] Civanlar, S., Grainger, J. J., Yin, H. & Lee, S. H., Distribution feeder reconfiguration for loss reduction. *IEEE Trans. Power Delivery*, Vol. 3 No 3, pp. 1217-1222, 1988.

[37] Su, C. T. & Lee, C. S., Feeder reconfiguration and capacitor setting for loss reduction of distribution systems. *Electric Power System Research*, Vol. 58, No. 2, pp. 97-102, 2001.

[38] Baran, M. E. & Wu, F. F., Network reconfiguration in distribution systems for loss reduction and load balancing. *IEEE Transactions on Power Delivery*, vol.. 4, no. 2. pp. 1401–1407,1989.

[39] Rao, R. S., A hybrid approach for loss reduction in distribution systems using harmony search algorithm. *Int. J. Electr. Electron. Eng*., Vol. 4, No. 7, pp. 461–467,2010.

[40] Gnanasekaran, N., Chandramohan, S., Sathish, K. P. & Sudhakar, T. D., Reconfiguration and Capacitor Placement of Radial Distribution Systems by Modified Flower Pollination Algorithm. Electric Power *Components and Systems*, 00(00):1–11, 2016.