OPTIMAL DISTRIBUTION NETWORK RECONFIGURATION USING MULTI-OBJECTIVE CUCKOO SEARCH ALGORITHM

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ABSTRACT: In power system electricity delivery, the distribution system has the most electricity loss as the system has the highest R/X ratio and has a radial network at one time. Optimal reconfiguration of the distribution network is needed in order to reduce power losses. However, as it is also involved with multiple objectives and constraint problems such as switching frequency, voltage, and current limits, it is difficult to find the optimal solution. Hence, this paper proposes the Multi-objective Cuckoo Search (MOCS) algorithm to find the optimal reconfiguration of distribution networks by considering minimizing power losses and switch operations. Based on the simulation results on the IEEE-33 bus system, the performance of the MOCS-based scheme has been found to be significantly better than the single-objective algorithm thereby reducing approximately 33% of the power losses.

ABSTRAK Melalui sistem penghantaran jana kuasa elektrik, sistem pengagihan mempunyai pembaziran tenaga elektrik terbesar kerana sistem ini mempunyai nisbah R/X paling tinggi dan mempunyai satu rangkaian radial pada tiap-tiap satu masa. Konfigurasi semula rangkaian pengedaran yang optimum diperlukan bagi mengurangkan pembaziran tenaga. Walaubagaimanapun, oleh kerana ia melibatkan objektif dan kekangan masalah yang pelbagai seperti kadar peralihan, had voltan serta arus, adalah sukar bagi mendapatkan bacaan yang optimum. Oleh itu, kajian ini mencadangkan *Carian Cuckoo Pelbagai Objektif (MOCS)* bagi mencari konfigurasi semula yang optimum bagi sistem pengagihan tenaga dengan mengambil kira pengurangan pembaziran tenaga dan kadar peralihan. Berdasarkan keputusan simulasi pada sistem bas *IEEE-33,* pretasi *MOCS* telah menunjukkan peningkatan yang ketara berbanding algoritma objektif tunggal dan pengurangan sebanyak 33% tenaga.

KEYWORDS: *distribution network reconfiguration (DNR); multi-objective Cuckoo search (MOCS) algorithm; power loss reduction; switch operations; Pareto optimal*

1. INTRODUCTION

An efficient and high-reliability power system is crucial because global electricity demand has increased due to the rising population. Since the primary source of power around the world comes from non-renewable energy sources such as fossil fuels, coal, and natural gas, power loss in electricity delivery can be seen a contributor to global warming

[1]. The distribution system has the most power loss compared with other systems as it has a high R/X ratio. This ratio means the reactance is much higher in the system [2]. System reconfiguration can be manipulated by two methods, power line restructuring and switch opening and closing. The tie switch (normally open) and sectionalizing switch (normally closed) are used to connect and disconnect power to the load entity to reduce the power loss in the distribution network. The procedure of changing the open/closed switch status is called distribution network reconfiguration (DNR). DNR is primarily performed to minimize losses and maximize the load balancing, system reliability, and voltage profile at the network level [3]. To manually change the status of the switches requires much time and cost and consumes energy.

In the literature, two approaches have been used in optimizing this problem, which are using (i) a single-objective approach [4-8] and (ii) a multi-objective approach [9-12]. For the single-objective approach, the author in [4] has focused on minimizing the power/energy losses and network loading index using a hybrid heuristic-genetic algorithm. While authors in [5,6] have compared several heuristic algorithms for minimizing power loss and enhancing voltage profile and applied them with to various scales of the distribution networks. At the same time, [5] has considered the integration of distributed generation (DG) in the network. Other researchers have investigated the optimal placement and sizing of unified power quality conditioners (UPFC) along with DNR for real power loss reduction [7]. However, the common drawback of these approaches is that the values of variables and parameters in each objective function vary depending on the case study and type of the network. Besides, it requires a weight factor in the objective function, which needs to be tuned to get the optimal solution.

On the other hand, multi-objective optimization is a technique when two or more objectives are considered simultaneously to achieve the most desired outcome. This technique is used in many fields like economics, logistics, management, science, and engineering [13]. Unlike single-objective, this approach does not require a weight factor in the objective function. There are trade-offs among the objectives to achieve the outcome as the objectives might conflict with each other [9]. In DNR, research has been conducted using multi-objective approaches such as Multi-objective Evolutionary Algorithm [10] and Non-sorting genetic algorithm [11] for service restoration, and Bayesian learning-based evolutionary algorithm for absorption rate of wind power and voltage stability improvement [12]. However, less work has been reported on minimizing power losses and switching operations simultaneously using single-objective or multi-objective approaches.

Hence, this paper proposes a solution for power loss reduction and switching minimization using the Multi-objective Cuckoo Search (MOCS) algorithm. MOCS is the extended version of the cuckoo search algorithm developed by Yang and Deb [14]. It has been tested against relevant test functions and then successfully applied to numerous problems [15-18]. This study uses MOCS to solve the DNR optimization problem focusing on power loss reduction and switching operations. The optimal model is developed in a MATLAB environment using the IEEE-33 bus test system. Then the result is compared to a single objective cuckoo search algorithm.

2. PROBLEM FORMULATION

In this paper, the DNR problem is formulated as a multi-objective and multi-constrained problem. The various objective functions and constraints considered in this work are explained as follows.

2.1 Objective Functions

The following equations express the objective functions aimed at minimizing the power loss and number of switch operations.

a) Minimization of power losses:

$$\min f_1 = \sum_{i}^{N_{br}} R_i \frac{P_i^2 + Q_i^2}{V_i^2} \tag{1}$$

where N_{br} is the total number of branches, R_i is the branch resistance i, V_i is the voltage at sending end node of *i*th branch, and P_i and Q_i are the active and reactive power at the sending end node of *i*th branch.

b) Minimization of switch operations:

$$\min f_2 = \sum_{j}^{N_s} \left|SWB_j - SWA_j\right| \tag{2}$$

where N_s is the number of operated switches, SWA_j and SWA_j are the status of *j*th operated switch in the network before and after reconfiguration.

2.2 Constraints

The followings are the constraints that secure an optimal power flow calculation and preserve the network radial condition [6].

a) Voltage Limit

$$V_{i,min} \le V_i \le V_{i,max} \tag{3}$$

where $V_{i,min}$ is 0.9 p.u and $V_{i,max}$ is 1.1 p.u which is the voltage limit at end node of *i*th branch.

b) Current Limit

$$I_i \le I_{i,max} \tag{4}$$

where I_i is the current at *i*th branch and $I_{i,max}$ is the maximum current at *i*th branch.

c) Radial Topology Constraint

In any network, the number of main loops can be calculated using the following relation:

$$N_{node} - N_{branch} = 1 \tag{5}$$

where the configuration is radial, and the system has no isolated node. The number of nodes in the system is notated as N_{node}.

3. METHODOLOGY

3.1 Multi-objective Cuckoo Search (MOCS) Algorithm

The Cuckoo Search algorithm is based on the aggressive way that cuckoo birds use to sustain the survival of their species. The bird would lay eggs in a host nest, and the survival of the eggs depends on the probability that the host bird discovers the eggs. The host bird would either abandon the nest or throw the eggs if they are discovered. Cuckoo birds develop the way to survive by mimicking the appearance of the host bird egg or the egg hatched earlier from the host bird egg. The pseudocode and the flowchart of MOCS is shown in Fig. 1 and Fig. 2 respectively.

```
Initialize objective functions $f_1(\boldsymbol{x}), \dots, f_K(\boldsymbol{x}) \boldsymbol{x} = (x_1, \dots, x_d)^T$
Generate an initial population of $n$ host nests $\boldsymbol{x}_i$ and each with $K$ eggs
while ($t <$ MaxGeneration) or (stop criterion)
    Get a cuckoo (say $i$) randomly by Lévy flights
    Evaluate and check if it is Pareto Optimal
    Choose a nest among $n$ (say $j$) randomly
    Evaluate $K$ solutions of nest $j$
    if  new solutions of nest $j$ dominate those of nest $i$,
        Replace nest $i$ by the new solution set of nest $j$
    end
    Abandon a fraction ($p_a$) of worse nests
    Keep the best solutions (or nest with non-dominated sets)
    Sort and find the current Pareto optimal solutions
end
Postprocess results and visualization
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Fig. 1: Multi-objective Cuckoo Search Algorithm Pseudocode [14].

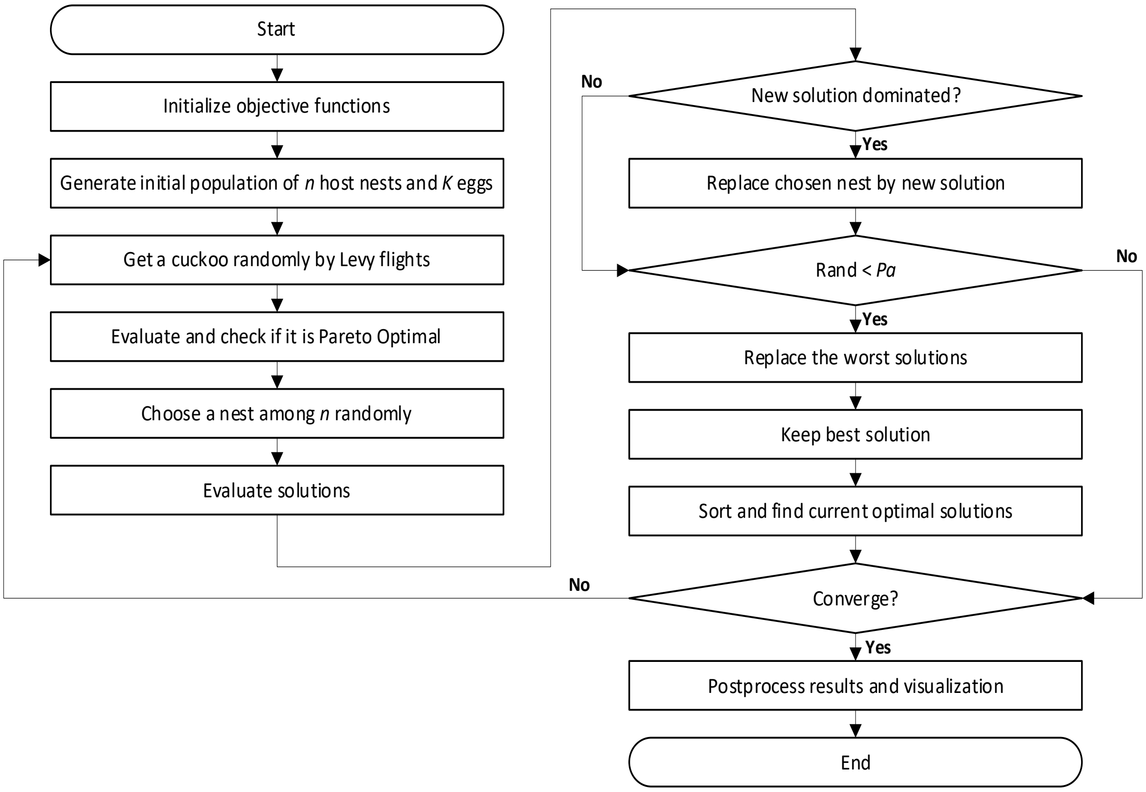


Fig. 2: Multi-objective Cuckoo Search algorithm flowchart.

Cuckoo Search algorithm has three general rules:

1) Each cuckoo bird lays one egg in only one random nest at a time;

2) The best egg would survive for the next generation;

3) The number of available host nests is the same; the probability of laid cuckoo egg to be discovered is between 0 and 1. The host bird would throw away the bird egg or abandon the nest, building a new nest [19].

In the multi-objective Cuckoo Search Algorithm, the first and third general rules are changed:

1) Each cuckoo bird lays K eggs in only one random nest at a time; K refers to the number of objectives.
2) The best egg would survive for the next generation;
3) The number of available host nests is the same. The probability of laid cuckoo K eggs to be discovered is between 0 and 1. The host bird would build a new nest with K eggs in respect of the egg differences. Diversity would happen by random mixing.

3.2 Proposed Algorithm and Pareto Optimal

The algorithm aims to obtain the Pareto Optimal with respect to some switch changes and power loss with the highest voltage stability limit. This algorithm is improved for Pareto Optimal from the MOCS algorithm in [18]. The algorithm steps are:

1. Data of the bus system (e.g. branch, bus and load number) are obtained.
2. Bus voltage and power loss (P_{loss}) are calculated by running the load flow program.
3. Voltage stability limit is calculated by the formula:
   $V_S = \frac{1}{\lambda}$, while λ is the load value.
4. A set of the initially closed switches is defined as $R_i = \left((R_i)_1^1 \quad \cdots \quad (R_i)_{n_e}^1 \right)$.
5. Parameters for the algorithm are set such as nest dimension (n_d), nests number (n), switch opened dimension (n_e), the probability to be discovered, and step size (α), lower limit and upper limit search space, and maximum iteration number (N).
6. Search space $n \times n_d$ is generated randomly. Each row represents a solution, while every element represents power loss for every connection P_c to the load.
   $$P_c = \begin{pmatrix} (P_c)_1^1 & \cdots & (P_c)_{n_d}^1 \\ \vdots & \ddots & \vdots \\ (P_c)_1^n & \cdots & (P_c)_{n_d}^n \end{pmatrix}$$
7. Search space $n \times n_e$ is generated. Each row represents a set of switches opened in the distribution network, while every element represents a switch closed for every radial network, R_c.$R_c = \begin{pmatrix} (R_c)_1^1 & \cdots & (R_c)_{n_e}^1 \\ \vdots & \ddots & \vdots \\ (R_c)_1^n & \cdots & (R_c)_{n_e}^n \end{pmatrix}$
8. Then, reactive power $(Q_{loss})'$ would be added to the bus and each P_c row, new power loss $(P_{loss})'$ and bus voltage is calculated.
   $$(Q_{loss})' = Q_{load} - P_c$$
9. Then, power loss reduction is calculated as:
   $\Delta_P = P_{loss} - (P_{loss})'$
10. Then, switch change number (j) is calculated as this conditional loop statement:
    for every element $R_i \neq R_c$
    j is incremented by 2
11. The optimal value for minimum power loss (f_1) with the lowest switch change (f_2) is obtained.
12. The bus voltage value is accepted if the bus voltage value is within the range of acceptable value.

13. Levy flight is applied to obtain a new solution.
14. Then, step 6 to 9 is repeated.
15. An unaccepted solution is abandoned, and a new solution is generated
16. Step 12 is repeated.
17. Iteration value is increased if it does not reach the maximum number from step 10.
18. Then, if the voltage stability limit is not the maximum value, the value of λ is increased, and step 3 is repeated. Otherwise, the algorithm is terminated.
19. Then, all surviving solutions of the Cuckoo Search are plotted using the Pareto optimal.

3.3 IEEE-33 Bus Test System

The effectiveness of the MOCS algorithm has been studied on the standard IEEE-33 bus model system [12] in a MATLAB environment using the MATPOWER package [20]. This test model is a power distribution system with 33 busses attached to the load points, and it is connected with 37 switches (sectionalize and tie switches), as shown in Fig. 3. Each load is identified by the number given, and in one mainline, the load number must be in sequence. Any tie switch would connect one point of the load with another point of the load of the different power lines. This tie switch would be closed to accommodate the breakdown of other sectionalizing switches to make sure every load is receiving power. The tie switch and sectionalizing switch can be alternately switched on and off to optimize power loss. This model system can be assumed to have constant base power, S_{base} = 50 MVA, and base voltage, V_{base} = 33 kV. The real power of the load is 3.715 MW, and the reactive power of the load is 2.3 MVAR. Minimum and maximum per-unit voltages are 0.95 p.u and 1.05 p.u, respectively. The initial power losses recorded in the model system is 208.46 kW.

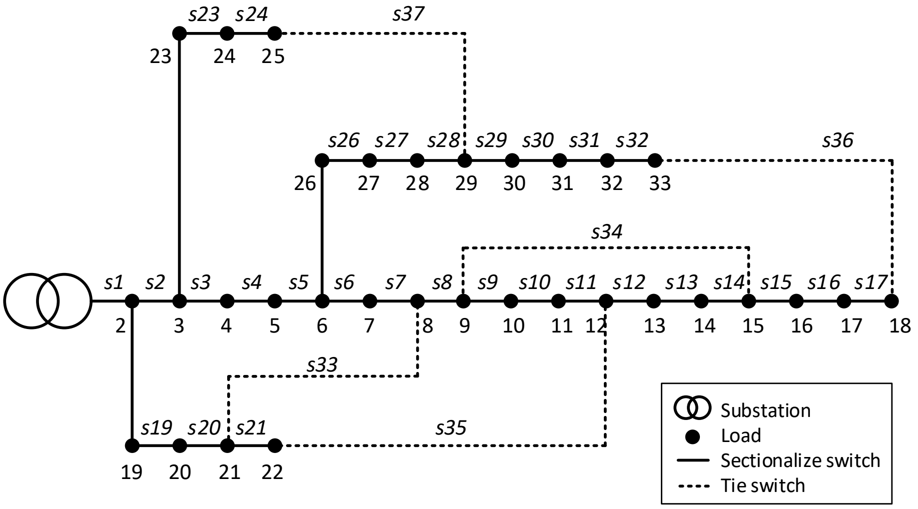


Fig. 3: The initial state of the IEEE-33 bus system [12].

4. RESULTS AND DISCUSSION

In this paper, the MOCS algorithm is used to obtain the optimal DNR for minimizing the power losses and switch operation simultaneously. The result is analyzed using the Pareto optimal front, and the voltage profile for all solutions are presented. Then, it is compared to a single objective approach cuckoo search algorithm. Finally, the performance of MOCS is analyzed using the convergence rate in terms of generalized distance [14] and validated against the multi-objective genetic algorithm (MOGA) [21].

4.1 Pareto Optimal Front

The Pareto front generated by four non-dominated solutions after 50 iterations is presented in Fig. 4. The graph is aligned with Pareto optimal as it shows that the higher number of switch changes, the lower the power loss in the distribution network. The number of operated switches ranges between two and eight, contrary to the broadest possible range between zero and ten. At the same time, the power losses ranged from 138 kW to 156 kW. The detailed result for each Pareto point is tabulated in

Table 1. From the table, all solutions show a significant reduction in power losses after obtaining optimal reconfiguration using MOCS. The lowest power loss is obtained by solution 1, which decreased from 208.46 kW to 138.93 kW, bringing approximately 33% reduction. It requires eight switches to be operated, which are number 7, 9, 14, 32, 33, 34, 35, and 36. On the other hand, the lowest number of operated switches is recorded by solution 4, which only changed switches number 7 and 35. However, the power losses decreased to 155.80 kW, equivalent to a 25% reduction, which is slightly lower.

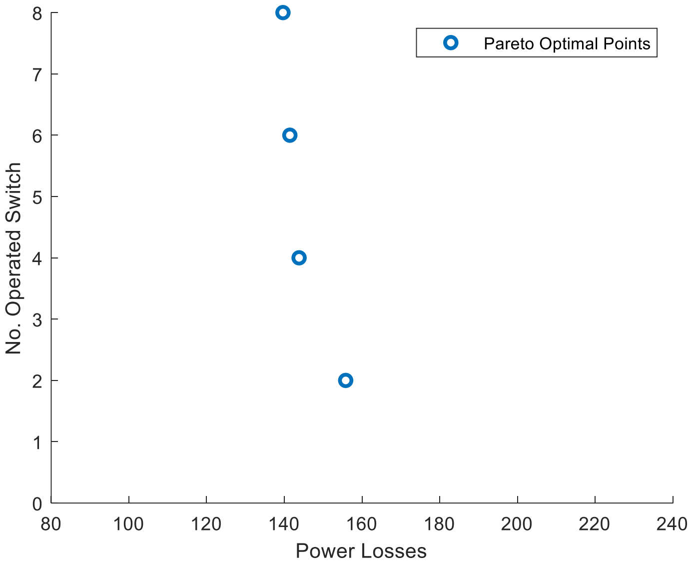


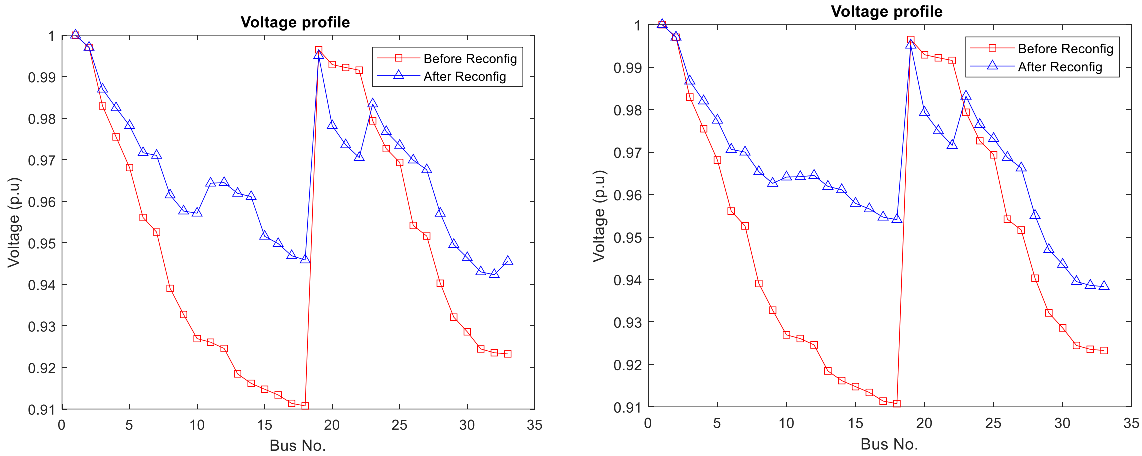
Fig. 4. Pareto Optimal Multi-Objective Cuckoo Search Algorithm.

Table 1: Simulation before and after reconfiguration using MOCS

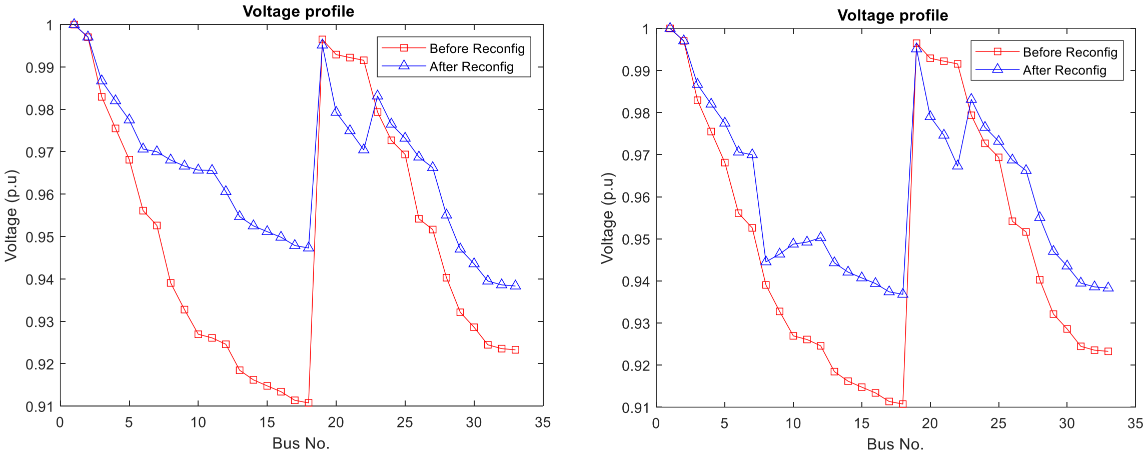
	Before Reconfiguration	**After Reconfiguration**			
		Solution 1	**Solution 2**	**Solution 3**	**Solution 4**
Tie Switch	33 34 35 36 37	7 9 14 32 37	7 9 14 36 37	7 11 34 36 37	7 33 34 36 37
Power Loss	208.46 kW	138.93 kW	141.43 kW	143.80 kW	155.80 kW
Power Loss Reduction	-	33.36 %	32.15 %	31.02 %	25.26 %
No. of Operated Switch	-	8	6	4	2
Minimum Voltage	0.911 p.u	0.942 p.u	0.938 p.u	0.938 p.u	0.937 p.u

4.2 Voltage Profile

Fig. 5 presents the voltage profile of IEEE-33 bus system for each solution obtained by MOCS. The graphs show that the voltage profiles are significantly improved after the network is reconfigured across all solutions. Besides, the minimum voltages are also increased by approximately 3% compared to before reconfiguration.



(i) Solution 1 (ii) Solution 2



(iii) Solution 3 (iv) Solution 4

Fig. 5: Voltage profile of the network before and after reconfiguration for each solution.

4.3 Comparison with Single-objective Algorithm

In order to see the effectiveness of the multi-objective technique, the above results are compared with the single-objective approach [22] demonstrated in **Error! Reference source not found.**. It is apparent that the power loss obtained by the single-objective is 157.65 kW which is almost 1% lower power loss reduction compared to the solution 4 recorded by MOCS in

Table 1. Furthermore, in terms of switch operations, both single-objective and multi-objective approaches were at the same level. Overall, MOCS shows better effectiveness compared to the single-objective algorithm. Besides, it provides multiple solutions to be chosen and does not require a weighting factor as a single-objective method.

Table 2: Simulation Result of single objective Cuckoo Search Algorithm

	Before Reconfiguration	**After Reconfiguration**
Tie Switch	33 34 35 36 37	7 34 35 36 37
Power Loss	208.46 kW	157.65 kW
Power Loss Reduction	-	24.38 %
No. of Operated Switch	-	2
Minimum Voltage	0.911 p.u.	0.930 p.u.

4.4 Generational Distance (GD) Measurement

Furthermore, in order to see the proposed MOCS performance, we also tested the same problems using a similar multi-objective technique, which is MOGA [21]. The performance is measured in terms of generational distance (GD)[14]. GD is designed to measure the sum of adjacent distances of solutions sets obtained by different algorithms, especially multi-objective evolutionary algorithms. The comparison of the convergence rates between proposed MOCS and MOGA is plotted in Fig. 6. This figure shows that MOCS converged slightly faster than MOGA even though there were opposite patterns shown at early iterations, which could be neglectable. Nevertheless, overall, MOCS delivers better performance than MOGA.

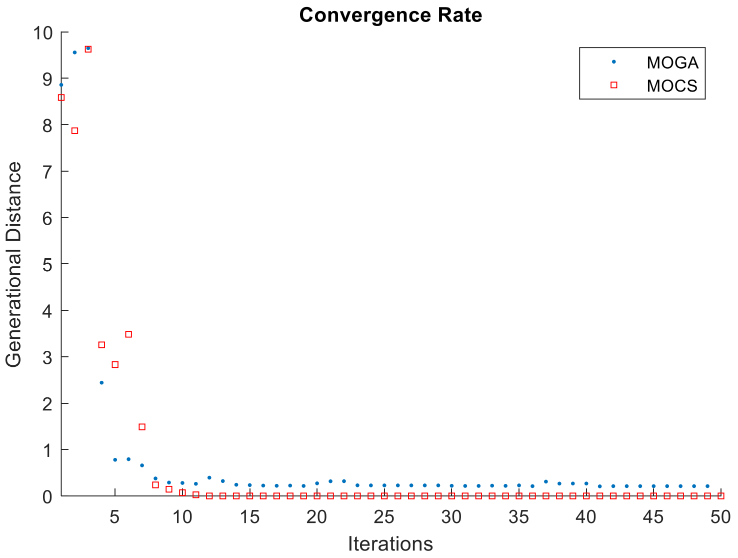


Fig. 6: Convergence comparison between MOCS and MOGA.

5. CONCLUSION

Power losses are critical in electrical power systems due to their impact on system reliability. Thus, distribution network reconfiguration (DNR) is introduced to minimize power losses and switch operations. In this study, a multi-objective Cuckoo Search (MOCS) algorithm for finding the optimal reconfiguration is presented. The simulation result is validated on the standard IEEE-33 bus test system in the MATLAB environment, and MATPOWER package is used for power flow calculation. The results show that MOCS obtained approximately 25% to 33% reduction results of power losses where two to eight switches were operated. Compared to the single-objective approach, MOCS recorded slightly better losses reduction and was on par in terms of switch operations. Besides, the convergence comparison with a similar multi-objective technique, MOGA, indicates the superiority of MOCS to obtain better optimal reconfiguration. Hence, the objectives of this paper to minimize the power losses and switch operations is achieved.

Furthermore, the obtained Pareto optimal front shows the trade-offs between two objectives in solving the DNR problem. In this case, the system operator can benefit from the results of the MOCS application to decide the priority between power losses and numbers of switch operations based on actual circumstances. As a way forward, this research may be extended to the large-scale networks such as IEEE-69 and IEEE-129 bus system models with the integration of renewable energy sources.

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REFERENCES

[1] Surana K, Jordaan SM. (2019) The climate mitigation opportunity behind global power transmission and distribution. Nature Climate Change, 9(9): 660-665. https://doi.org/10.1038/s41558-019-0544-3

[2] Singh B, Chauhan S, Reddy CC. (2017) Power loss minimization in electrical power distribution networks by use of hybrid reconfiguration method. 3rd International Conference on Condition Assessment Techniques in Electrical Systems (CATCON), IEEE. pp. 349-354. https://doi.org/10.1109/CATCON.2017.8280243

[3] Thakar S, Vijay AS, Doolla S. (2019) System reconfiguration in microgrids. Sustainable Energy, Grids and Networks, 17100191. https://doi.org/10.1016/j.segan.2019.100191

[4] Jakus D, Čađenović R, Vasilj J, Sarajčev P. (2020) Optimal Reconfiguration of Distribution Networks Using Hybrid Heuristic-Genetic Algorithm. Energies, 13(7): 1544. https://doi.org/10.3390/en13071544

[5] Nguyen HD, Valeev IM. (2019) Improvement methods for solving the distribution network reconfiguration problem. Energetika, 64(4): 174-185. https://doi.org/10.6001/energetika.v64i4.3892

[6] Landero A, Koziel S, Abdel-Fattah MF. (2019) Distribution network reconfiguration using feasibility-preserving evolutionary optimization. Journal of Modern Power Systems and Clean Energy, 7(3): 589-598. https://doi.org/10.1007/s40565-018-0480-7

[7] Gholami K, Karimi S, Dehnavi E. (2019) Optimal unified power quality conditioner placement and sizing in distribution systems considering network reconfiguration. International Journal of Numerical Modelling: Electronic Networks, Devices and Fields, 32(1): e2467. https://doi.org/10.1002/jnm.2467

[8] Samadaei E, Khosravi A, Sheikholeslami A. (2017) Optimal Allocation of Active Power Filter On real distribution network for improvement of power quality by use of BBO: A case study. IIUM Engineering Journal, 18(1): 85-99. https://doi.org/10.31436/iiumej.v18i1.688

[9] Gunantara N. (2018) A review of multi-objective optimization: Methods and its applications. Ai Q, editor. Cogent Engineering, 5(1): 1502242. https://doi.org/10.1080/23311916.2018.1502242

[10] Sanches DS, London Junior JBA, Delbem ACB. (2014) Multi-Objective Evolutionary Algorithm for single and multiple fault service restoration in large-scale distribution systems. Electric Power Systems Research, 110: 144-153. https://doi.org/10.1016/j.epsr.2014.01.017

[11] Shahrin M, Aoki H. (2016) Application of Multi-Objective Optimization for Service Restoration Problem in Distribution Systems. IEEJ Transactions on Power and Energy, 136(3): 275-283. https://doi.org/10.1541/ieejpes.136.275

[12] Zhong T, Zhang H-T, Li Y, Liu L, Lu R. (2020) Bayesian Learning-Based Multi-Objective Distribution Power Network Reconfiguration. IEEE Transactions on Smart Grid, 12(2): 1174-1184. https://doi.org/10.1109/TSG.2020.3027290

[13] Khan MR, Badran M, Toha SF, Zainal Abidin Z. (2021) Multi-Objective Optimization of Snake Robot in Serpentine Locomotion. IIUM Engineering Journal, 22(2): 364-383. https://doi.org/10.31436/iiumej.v22i2.1691

[14] Yang X-S, Deb S. (2013) Multiobjective cuckoo search for design optimization. Computers & Operations Research, 40(6): 1616-1624. https://doi.org/10.1016/j.cor.2011.09.026

[15] Zainal MI, Yasin ZM, Zakaria Z. (2021) Optimizing Voltage Profile and Loss Minimization using Multi Objective Cuckoo Search Algorithm. 2021 IEEE 11th IEEE Symposium on Computer Applications & Industrial Electronics (ISCAIE), IEEE. pp. 116-122. https://doi.org/10.1109/ISCAIE51753.2021.9431835

[16] Yasin ZM, Aziz NFA, Salim NA, Wahab NA, Rahmat NA. (2018) Optimal Economic Load Dispatch using Multiobjective Cuckoo Search Algorithm. Indonesian J. Electrical Engin. Comp Sci, 12(1): 168. https://doi.org/10.11591/ijeecs.v12.i1.pp168-174

[17] Zhou X, Liu Y, Li B, Li H. (2017) A multiobjective discrete cuckoo search algorithm for community detection in dynamic networks. Soft Computing, 21(22): 6641-6652. https://doi.org/10.1007/s00500-016-2213-z

[18] Rao NT, Sankar MM, Rao SP, Rao BS. (2021) Comparative study of Pareto optimal multi objective cuckoo search algorithm and multi objective particle swarm optimization for power loss minimization incorporating UPFC. Journal of Ambient Intelligence and Humanized Computing, 12(1): 1069-1080. https://doi.org/10.1007/s12652-020-02142-4

[19] Yang X-S, Deb S. (2009) Cuckoo Search via Lévy flights. 2009 World Congress on Nature & Biologically Inspired Computing (NaBIC), IEEE. pp. 210-214. https://doi.org/10.1109/NABIC.2009.5393690

[20] Zimmerman RD, Murillo-Sanchez CE, Thomas RJ. (2011) MATPOWER: Steady-State Operations, Planning, and Analysis Tools for Power Systems Research and Education. IEEE Trans Power Sys, 26(1): 12-19. https://doi.org/10.1109/TPWRS.2010.2051168

[21] Bevilacqua V, Pacelli V, Saladino S. (2011) A Novel Multi Objective Genetic Algorithm for the Portfolio Optimization. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), pp. 186-193. https://doi.org/10.1007/978-3-642-24728-6_25

[22] Fuad NAA, Azlin AAN, Zahari MFD, Hanifah MSA. (2018) Power Distribution Loss Reduction Using Cuckoo Search. 2018 7th International Conference on Computer and Communication Engineering (ICCCE), IEEE. pp. 333-337. https://doi.org/10.1109/ICCCE.2018.8539252