Reconfiguration of a Radial Distribution System using the Harris Hawks Optimization Algorithm

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Abstract: - Recently, reducing power loss in distribution systems has become a key focus of various studies due to its influence on gross costs and voltage gradients. One solution is the optimal reconfiguration of the Radial Distribution System (RDS). This study presents an inventive tactic to reconfigure RDS by selecting the best switch combinations while considering system operating constraints, using the Harris Hawks Approach (HHA) which is a nature-inspired optimization paradigm. The primary inspiration for HHA comes from the cooperative behavior and hunting technique of Harris' hawks in the wild, regarded as the "surprise pounce". In this clever strategy, distinct hawks work together in order to pounce on their prey from multiple pathways, aiming to catch them by surprise. Harris' hawks are capable of identifying various chasing patterns, influenced by the dynamic nature of the situation and the escape tactics of the prey. The mentioned approach is examined on IEEE 33 node RDS. The effectiveness of this approach, in comparison to other established methods, is demonstrated via simulation results that assess total losses, costs, and savings. Additionally, the statistical analysis is conducted to validate the potency of the advised HHA.

Key-Words: - Radial Distribution System, Reconfiguration, HHA, Ohmic Losses, Saving, Voltage Profile.

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1 Introduction

Mitigating ohmic power losses in RDS remains a focus of numerous studies. The deployment of Distributed Generations (DGs), capacitors, and the restructuring of RDS are identified as the three primary approaches to reduce these losses. Among these, restructuring the RDS is considered the most favorable option, as it excludes the operational and installation costs associated with DG and capacitors. The restructuring process involves altering the configuration of system switches and adjusting the network's operational structure by opening or closing sectional and tie switches under specific constraints, [1], [2], [3], [4]. These switches control the feeder cases and have a significant influence on segment power transfers and overall power dissipation.

As ohmic power dissipation was a significant factor in operating charge in RDS, many studies focus on minimizing active power loss as their objective function. Neural networks were executed in [5] to select the appropriate grid topology for reducing losses in minor RDS. In [6], fuzzy was used as a solution method for restructuring RDS to attain the best voltage profiles and minimize kW dissipation. An approach for optimizing asymmetrical networks to maintain voltage profile, using the firefly approach in a fuzzy domain to address the multi-objective restructuring issue, was presented in [7]. A new cycle break approach using elementary cycles or a network adjacency matrix with a genetic approach for RDS restructuring as described in [8]. Adaptive genetics was applied in [9] to reduce real losses without incurring supplementary costs for capacitor installations, tap-changing transformers, or other switching equipment. An enhanced genetic approach was employed in [10] to address the restructuring issue, reduce power dissipation, and increase the reliability of the grid. In [11], an improved genetic was developed to manage the restructuring issue, focusing on overall voltage variation and real power dissipation. Modified particle swarm optimization was discussed in [12] and [13] for grid restructuring to strengthen voltage characteristics and reduce dissipation. The runner root approach was developed in [14] to tackle the network restructuring problem, aiming to minimize real loss and balance the load. Harmony search was introduced in [15] to find the optimal switching arrangement for loss reduction. A group search approach was utilized in [16] for RDS restructuring to minimize losses and improve voltage profiles. The Quantum firefly approach was employed in [17] for RDS restructuring, considering distinct cost functions to enhance the quality and reliability of the grid. The imperialist competitive approach, within a fuzzy framework, was applied in [18] to solve the grid restructuring issue, including the reliability pointer and power dissipation in the cost function. The cuckoo search was presented in [19] for restructuring to diminish real losses and evolve the voltage characteristic. In [20], the issue was drafted as an optimization process and clarified by adopting grey wolf optimization approach. However, these approaches may fail to guarantee an optimal solution and can become trapped in a local low point. In this work, HHA is introduced to address the restructuring issue in RDS. The target is to reduce the gross losses by optimally selecting switch combinations for RDS restructuring. HHA was constructed in [21], and [22] influenced by the hunting plans of Harris hawks. Its primary advantages include simplicity and the incorporation of a few exploratory and exploitative tools. HHA has been applied to various optimization tasks, such as variable estimation for fuel cell modules [23] and photovoltaic cell modules [24], economic dispatch [25], and others as discussed in [26], [27], and [28]. Additionally, it demonstrated significant findings compared to the existing literature. The success of HHA in addressing various tasks, along with the potential to enhance its mechanisms, serves as the primary motivation for this work.

2 Problem Description

The cost function for restructuring the RDS aims to mitigate line losses during operation, and it can be stated like:

$$P_{Loss} = \sum_{m=1}^{N_b} I_m^2 R_m \tag{1}$$

where

m : The count of branches,

N_b : The overall count of portions,

I_m : The current of the portion m,

R_m : The resistance of the portion m,

P_{Loss} : The overall real dissipation in kW,

The yearly cost resulting from power dissipation can be obtained using formula:

$$\text{Yearly cost} = K_P * T * P_{Loss} \tag{2}$$

where

K_P : The price per kWh is 0.06 \$/kWh,

T : The duration is 8760 hours,

Several operational constraints must be maintained, and they are listed as follows:

- ***Power flow restrictions***

The Power flow restrictions are determined using relations (3), and (4) as shown below [29]:

$$P_{Slack} = P_{Loss} + \sum_{q=1}^{N} Pd(q) \tag{3}$$

$$Q_{Slack} = \sum_{m=1}^{N_b} I_m^2 X_m + \sum_{q=1}^{N} Qd(q) \tag{4}$$

where

$Pd(q)$:The required real power at point q,

$Qd(q)$:The required non-real power at point q,

P_{Slack} : The slack real power,

Q_{Slack} : The slack non-real power,

X_m : The reactance of the segment m,

- ***Radially restriction***

This indicates that the grid does not have any closed loops; therefore the branch count may be expressed by relation (5):

$$N_b = N - 1 \tag{5}$$

where

N : The number of net buses,

- ***Feasibility restriction***

This ensures all loads remain connected throughout the restructure process.

- ***Voltage restriction***

The voltage level at every bus should be regulated according to relation (6), and is set between 0.90, and 1.0 per unit, in sequence, [30].

$$V_{\min} \le |V_i| \le V_{\max} \tag{6}$$

where

$V_{\min}, V_{\max}$:The lower and higher voltage limits at bus i,

• ***Current restriction***

Relation (7) puts the level at every segment current, [29].

$$I_j < I_{j\max} \tag{7}$$

where

$I_{j\max}$: The upper limit of current in every segment,

3 The Harris Hawks Approach

In this work, the Harris Hawks Approach (HHA) is used to achieve optimal reconfiguration in RDS. The primary inspiration for HHA comes from the collaborative manner and hunting technique of Harris' hawks in the wild, known as shock strike. In this smart tactic, multiple hawks coordinate to strike on a target from various pathways, attempting to startle it, [21], [22]. Harris hawks showcase a range of hunting patterns depending on the ever-changing nature of the situation and the target's escape tactics. This study using mathematical principles simulates these ever-changing behaviors and styles to create an optimization method. Statistical analysis and comparisons demonstrate that HHA delivers promising and often competitive outcomes compared to widely recognized metaheuristic methods. The natural activities of these hawks in nature are illustrated in Figure 1.

Fig. 1: The actions of Harris's hawks

HHA is a search technique based on a population approach, consisting of three main steps, which are outlined as seen in Figure 2.

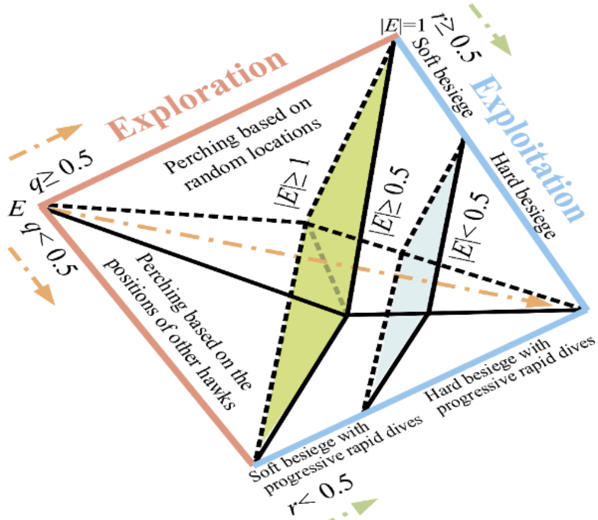

Fig. 2: Various stages of Harris hawks optimization

3.1 Exploration Stage

At this stage, the algorithm is designed to mathematically wait, search, and locate the target. The site of the Harris hawks at iteration iter+1 is represented as listed in mathematical terms:

$$X(iter+1) = \begin{cases} X_{rand}(iter) - r_1\left|X_{rand}(iter) - 2X_r(iter)\right| .if\ q \geq 0.5 \\ X_{rabit}(iter) - X_m(iter) - r_3(LB + r_4(UB - LB)) .if\ q < 0.5 \end{cases} \tag{8}$$

where

X_{rabit} represents the site of the rabbit and signifies the current iteration,

X_{rand} is the hawk randomly picked hawk from the accessible population r_i ,

$i = 1, 2, 3, \ldots, q$ represent random numbers that lie between [0, 1],

X_m displays the mean position of the hawks, and calculated as depicted below:

$$X_m(iter) = \frac{1}{N}\sum_{i=1}^{N} X_i(iter) \tag{9}$$

which X_i illustrates the site of the hawks and N symbolizes the scale of the hawk, [25].

3.2 Transition from Exploration to Exploitation

Given T as the upper number of the turns, $E_0 = \varepsilon(-1,1)$as the starting energy at every step, HHA computes the rabbit's escaping energy of rabbit (E) by Eq. (10). With respect to this amount, exploration and exploitation may be changed.

$$E = 2E_0\left(1 - \frac{iter}{T}\right) \tag{10}$$

In this context, $|E| \geq 1$ the exploration phase begins; else, the focus shifts to exploiting the neighborhood of the solutions.

3.3 Exploitation Level

Based on the prey's remaining energy, the hawks can adopt either a soft or hard siege, approaching from distinct routes. A factor, denoted as "r" is realized to quantify the prey's probability of escape, with representing a successful escape. Moreover, when HHA employs a soft encirclement, and when a hard encirclement is utilized. It is important to note that, though the hunt can escape $r < 0.5$, its winning still relies on it. The strike strategy is shaped by both the escape tactics of the prey and the pursuit tactics of the hunt and hawks sequentially. In this context, four key levels are outlined, as detailed in [21] and [22].

a) Soft siege

The rabbit retains some vigor and attempts to escape when $r \geq 0.5$ and $|E| \geq 0.5$, with a series of arbitrary, deceptive jumps, but ultimately it fails. Harris hawks swiftly resist these efforts, further exhausting the rabbit before launching a decisive surprise strike. This behavior may be modeled using the following relations.

$$X(t+1) = \Delta X(t) - E\left|JX_{rabbit}(t) - X(t)\right| \quad (11)$$

$$\Delta X(t) = X_{rabbit}(t) - X(t) \quad (12)$$

Here $\Delta X(t)$ shows the dissimilarity among the current position in iteration t, and the position vector of the rabbit, r_5 is an unspecified value in the range $(0,1)$, while $J = 2(1 - r_5)$ denotes the unpredictable diving power of the rabbit during the escape process. J modifies in each resumption to grow the activity character of the rabbit.

b) Hard siege

The sacrifice becomes exhausted and loses its capability to escape as time passes, when $r \geq 0.5$ and $|E| < 0.5$, allowing the Harris hawks to trap it and eventually implement the amazement dive. Furthermore, the updated usage of relation (13) modernized this situation.

$$X(t+1) = X_{rabbit}(t) - E\left|\Delta X(t)\right| \quad (13)$$

c) Soft siege

With progressive rapid dives, the rabbit retains enough strength to escape powerfully when $|E| \geq 0.5$ but $r < 0.5$ before the unexpected dive, a gentle siege is formed. This technique is more intelligent than mere mimicry. In the HHA, the concept of levy flight is performed to strictly grow the victim's escape patterns and the leapfrog movement. According to the rule in relation (14) it is assumed that the hawks may administer their subsequent actions to carry out a soft siege.

$$Y = X_{rabbit}(t) - E\left|JX_{rabbit}(t) - X(t)\right| \quad (14)$$

They estimate the likely result of the previous jump to comprehend whether it is favorable. If it is not deemed effective, they start to perform abrupt, erratic, and rapid dives as they approach the rabbit. It is believed that LF-based styles are employed according to the following relation:

$$Z = Y + S \times LF(D) \quad (15)$$

The Levy flight function is LF and S is an spontaneous size $1 \times D$ and D is the size of the issue. Relation (14) can identify the positions of hawks in the soft besiege level.

$$X(t+1) = \begin{cases} Y & if\ F(Y) < F(X(t)) \\ Z & if\ F(Z) < F(X(t)) \end{cases} \quad (16)$$

d) Hard siege

Through progressively rapid dives, the rabbit no longer has enough strength to escape, and a hard siege is carried out before the surprise dive to capture the prey. When $|E| < 0.5$ and $r < 0.5$, the victim's situation resembles that of a soft siege. However, at the point, the exhausted victim has decreased the average distance from the hawks. As a result, the hard siege condition is modeled by relation (16).

Here relations (14) and (15) retrieve Y and Z.

4 Results and Discussion

To demonstrate the significance of the proposed HHA, the outcomes for the IEEE 33-point network are discussed below. The 33-bus system, as described in [31], consists of thirty-seven segments, normally thirty-two closed breakers, and five open breakers, as shown in Figure 3. The primary tie switches are numbered from thirty-three to thirty-seven, and closing these five ties creates five loops.

The HHA's Efficiency in identifying the optimal open switches, compared to those in [6], [15], [16], [19], [32], [33], [34], [35], [36] and [37], is demonstrated. The HHA selects breakers S4, S14, S15, S22, and S33 as the best resolution. Figure 4 shows the restructured grid. The overall active power losses are reduced from 202.66 to 102.55 kW, resulting in a savings of 100.11 kW and a 49.4% reduction in ohmic losses. Additionally, the total cost is minimized to $53,900.2, as shown in Table 1, yielding a net savings of $52,617.9, the highest among the compared cases. Furthermore, the minimum voltage increases to 0.9191 p.u., as indicated by the improved voltage gradient in Figure 5 due to the proposed reconfiguration. Finally, the statistical analysis of the proposed HHA, detailed in Table 2, confirms its superiority over the methods in [12], [38], [39] and [40] based on the minimum, mean, standard deviations values, as well as the count of iterations and computation time.

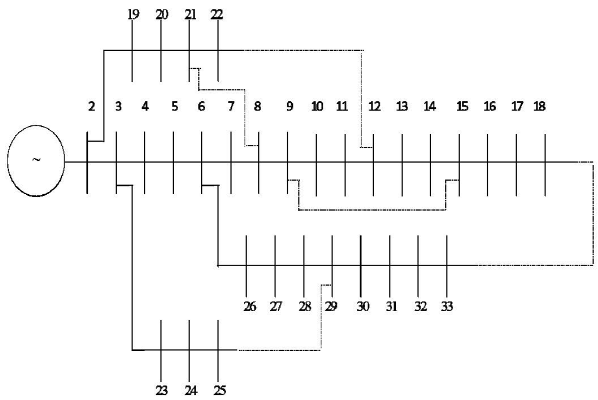

Fig. 3: 33 bus base system

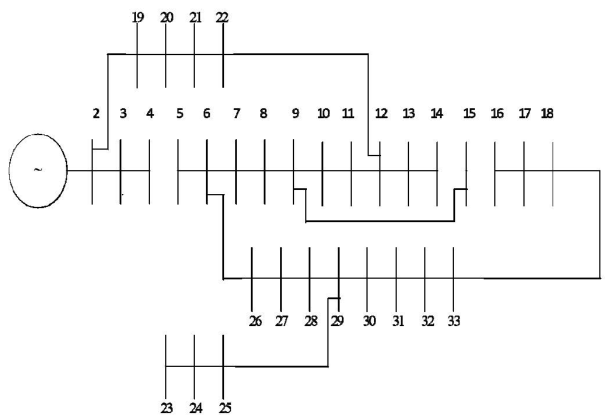

Fig. 4: 33 bus system post reconfiguration

Table 1. Outcomes of the tested system

Paper	Opened Switches	active losses (kW)	% Reduction	Cost ($)	Saving ($)
Base	33,34,35,36,37	202.66	-	106518.1	------
[33]	7,10,14, 32, 37	141.54	30.16	74393.424	32124.67
[34]	7, 9, 14, 32, 37	139.55	31.15	73347.48	33170.62
[35]					
[36]					
[19]					
[37]	7, 9, 14, 32, 37	138.92	31.45	73016.35	33501.75
[16]	7, 9, 14, 28, 32	139.26	31.28	73195.056	33323.04
[6]	7, 9, 14, 28, 32	139.83	31	73494.65	33023.45
[15]	7, 9, 14, 36, 37	145.11	28.4	76269.82	30248.28
[15]	7, 10, 14, 36, 37	146.39	27.77	76942.58	29575.52
[32]	7, 9, 14, 28, 32	134.26	33.75	70567	35951.1
HHA	**4, 14, 15, 22, 33**	**102.55**	**49.4**	**53900.2**	**52617.9**

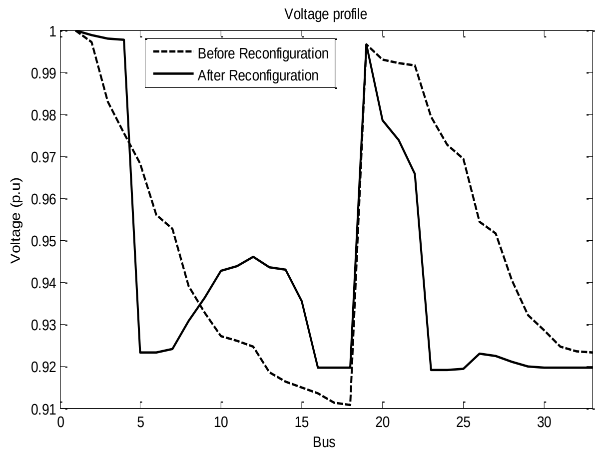

Fig. 5: Reconfiguration's effect on voltage profiles

Table 2. Statistical analysis for 33 bus networks

Paper	Min loss kW	Iteration count	Mean kW	SD kW	CPU time in sec
[12]	139.50	-	-	-	-
[38]	139.55	16	157.5	68.87	100.225
[39]	139.981	17	170.9	71.94	106.489
[40]	102.55	5	112.1	63.13	29.97
HHA	102.55	5	112	63.11	28.48

5 Conclusions

In this study, HHA has been efficiently applied to address the reconfiguration issue of RDS. The optimal reconfiguration of RDS is framed as an objective optimization process aimed at minimizing active power dissipation. The primary findings of this work are mentioned below:

1. HHA is created to determine the optimal combination of switches while adhering to system working restrictions.
2. The effectiveness of HHA is highlighted by its successful application to the IEEE system.

3. A 49.4% reduction in ohmic losses in the IEEE 33-bus grid, compared to the original configuration, showcasing significant output improvements in terms of power dissipation and gross savings.
4. The validation of HHA through statistical analysis and computational time comparisons, indicates that HHA requires fewer iterations and less computation time than other reported methods.

Future work will explore the application of network reconfiguration to larger systems using the latest approaches and incorporating renewable DG.

References:

[1] D. Das, "Reconfiguration of Radial Distribution Networks", *Indian Institute of Technology*, Kharagpur 721302, December 27-29, 2002, pp. 637-640, [Online]. https://www.iitk.ac.in/npsc/Papers/NPSC2002/101.pdf (Accessed Date: December 5, 2024).

[2] E. Dolatdar, S. Soleymani, and B. Mozafari, "A New Distribution Network Reconfiguration Approach Using A Tree Model", World Academy of Science, Engineering and Technology *Int. J. of Computer and Information Engineering,* Vol. 3, No. 10, 2009, pp. 2480-2487, [Online]. https://zenodo.org/records/1057593 (Accessed Date: December 5, 2024).

[3] L. Tang, F. Yang, and J. Ma, "A Survey on Distribution System Feeder Reconfiguration: Objectives and Solutions", *Proc. Innovative Smart Grid Technology Asia (ISGT),* Kuala Lumpur, Malaysia, May 2014, pp. 62-67, DOI: 10.1109/ISGT-Asia.2014.6873765.

[4] V. Kumar, R. Krishan, and Y. Sood, "Optimization of Radial Distribution Networks Using Path Search Algorithm", *Int. J. of Electronics and Electrical Engineering,* Vol. 1, No. 3, September, 2013, pp. 182-187, DOI: 10.12720/IJEEE.1.3.182-187.

[5] K. Kim, Y. Ko and K. H. Hung, "Artificial Neural Network Based Feeder Reconfiguration for Loss Reduction in Distribution Systems", *IEEE Transactions on Power Delivery,* Vol. 8, 1993, pp. 1356-1366, DOI: 10.1109/61.252662.

[6] B. Venkatesh and R. Ranjan, "Optimal Radial Distribution System Reconfiguration Using Fuzzy Adaptation of Evolutionary Programming", *Int. J. Electrical Power and Energy Systems,* Vol. 25, No. 10, 2003, pp. 775-780, https://doi.org/10.1016/S0142-0615(03)00046-2.

[7] M. Kaur, and S. Ghosh, "Network Reconfiguration of Unbalanced Distribution Networks Using Fuzzy-Firefly Algorithm", *Applied Soft Computing,* Vol. 49, 2016, pp. 868-886, https://doi.org/10.1016/j.asoc.2016.09.019.

[8] R. Čađenović, D. Jakus, P. Sarajčev and J. Vasilj, "Optimal Distribution Network Reconfiguration through Integration of Cycle Break and Genetic Algorithms", *Energies,* May 2018, Vol. 11, No. 5, pp.1278: DOI: 10.3390/en11051278

[9] A. Swarnkar, N. Gupta, and K. R. Niazi, "Minimal Loss Configuration for Large-Scale Radial Distribution Systems Using Adaptive Genetic Algorithms", *16th National Power Systems Conf.,* 15th-17th December 2010, Osmania University, Hyderabad, A.P, INDIA pp. 647-652, [Online]. https://www.iitk.ac.in/npsc/Papers/NPSC2010/6081.pdf (Accessed Date: December 5, 2024).

[10] D. Duan, X. Ling, X. Wu, and B. Zhong, "Reconfiguration of Distribution Network for Loss Reduction and Reliability Improvement Based on an Enhanced Genetic Algorithm", *Int. J. of Electrical Power and Energy Systems,* Vol. 64, January 2015, pp. 88-95, https://doi.org/10.1016/j.ijepes.2014.07.036.

[11] A. Abubakar, K. Ekundayo, and A. Olaniyan , "Optimal Reconfiguration of Radial Distribution Networks Using Improved Genetic Algorithm", *Nigerian J. of Technological Development,* Vol. 16, No. 1, March 2019, pp. 10-16, DOI: 10.4314/njtd.v16i1.2.

[12] A. Abdelaziz, F. Mohammed, S. Mekhamer, and M. A. L. Badr, "Distribution Systems Reconfiguration Using A Modified Particle Swarm Optimization", *Electric Power Systems Research,* Vol. 79, No. 11, November 2009, pp. 1521-1530, https://doi.org/10.1016/j.epsr.2009.05.004.

[13] I. Atteya, H. Ashour, N. Fahmi, and D. Strickland, "Radial Distribution Network Reconfiguration for Power Losses Reduction Using A Modified Particle Swarm Optimisation", *24th Int. Conf. & Exhibition on Electricity Distribution (CIRED),* 12-15 June 2017, pp. 2505-2508, Vol. 2017, Glasgow – Scotland, DOI: 10.1049/oap-cired.2017.1286.

[14] T. Nguyen, T. Nguyen, A. Truong, Q. Nguyen, and T. Phung, "Multi-Objective

Electric Distribution Network *Reconfiguration Solution Using Runner-Root Algorithm*", Applied Soft Computing, March 2017, Vol.52, pp.93-108, https://doi.org/10.1016/j.asoc.2016.12.018.

[15] R. Rao, S. Narasimham, M. Raju, and A. Rao, "Optimal Network Reconfiguration of Large-Scale Distribution System Using Harmony Search Algorithm", *IEEE Transactions on Power Systems,* Vol. 26, 2011, pp. 1080-1088, DOI: 10.1109/TPWRS.2010.2076839.

[16] H. Teimourzadeha, and B. M. Ivatloo, "A Three Dimensional Group Search Optimization Approach for Simultaneous Planning of Distributed Generation Units and Distribution Network Reconfiguration", *Applied soft computing J.* , Vol. 88, 2020, pp. 106012, https://doi.org/10.1016/j.asoc.2019.106012.

[17] H. Shareef, A. Ibrahim, N. Salman, A. Mohamed, and W. Ling Ai, "Power Quality and Reliability Enhancement in Distribution Systems Via Optimum Network Reconfiguration by Using Quantum Firefly Algorithm", *Int. J. of Electrical Power and Energy Systems,* Vol. 58, June 2014, pp. 160-169, https://doi.org/10.1016/j.ijepes.2014.01.013.

[18] M. Sedighizadeh, M. Esmaili, and M. Mahmoodi, "Reconfiguration of Distribution Systems to Improve Reliability and Reduce Power Losses Using Imperialist Competitive Algorithm", *Iranian J. of Electrical & Electronic Engineering,* Vol. 13, No. 3, September 2017, pp. 287-302, DOI: 10.22068/IJEEE.13.3.6.

[19] T. Nguyen, and T. Nguyen, "An Improved Cuckoo Search Algorithm for The Problem of Electric Distribution Network Reconfiguration", *Applied soft computing J.,* Vol. 84, 2019, pp. 105720, https://doi.org/10.1016/ j. asoc. 2019.105720.

[20] H. Hamour, S. Kamel, L. Nasrat, and J. Yu, "Distribution Network Reconfiguration Using Augmented Grey Wolf Optimization Algorithm for Power Loss Minimization", *2019 Int. Conf. on Innovative Trends in Computer Engineering (ITCE'2019),* Aswan, Egypt, 2-4 February 2019, pp. 450-454, DOI: 10.1109/ITCE.2019.8646595.

[21] A. A. Heidari, S. Mirjalili, H. Faris, I. Aljarah, M. Mafarja, and H. Chen, "Harris Hawks Optimization: Algorithm and Applications", *Future Generation Computer Systems,* Vol. 97, 2019, pp.849-872, https://doi.org/10.1016/j.future.2019.02.028.

[22] B. K. Tripathy, P. K. R. Maddikunta, Q. V. Pham, T. R. Gadekallu, K. Dev, S. Pandya, and B. M. ElHalawany, "Harris Hawk Optimization: A Survey on Variants and Applications", *Hindawi, Computational Intelligence and Neuroscience,* Vol. 2022, Article ID 2218594, 20 pages, https://doi.org/10.1155/2022/2218594.

[23] A. S. Menesy, H. M. Sultan, A. Selim, M. G. Ashmawy, and S. J. I. A. Kamel, "Developing and Applying Chaotic Harris Hawks Optimization Technique for Extracting Parameters of Several Proton Exchange Membrane Fuel Cell Stacks", *IEEE Access,* Vol. 8, 2019, pp. 1146- 1159, DOI: 10.1109/ACCESS.2019.2961811.

[24] H. Chen, S. Jiao, M. Wang, A. A. Heidari, and X. J. J. o. C. P. Zhao, "Parameters Identification of Photovoltaic Cells and Modules Using Diversification-Enriched Harris Hawks Optimization with Chaotic Drifts", *J. of Cleaner Production,* Vol. 244, 2020, pp. 118778, https://doi.org/10.1016/j.jclepro.2019.118778.

[25] E. S. Ali "Harris Hawks Approach for Distinct Economic Dispatch Problems", *Yanbu Journal of Engineering and Science,* Vol. 20, No. 1, pp. 32-50, 2023, https://doi.org/10.53370/001c.75397.

[26] H. Samma and A. S. B. Sama, "Rules Embedded Harris Hawks Optimizer for Large-Scale Optimization Problems", *Neural Computing and Applications,* 2022, Vol. 34, pp. 13599-13624, https://doi.org/10.1007/s00521-022-07146-z.

[27] K. Hussain, N. Neggaz, W. Zhu, E. H. Houssein, "An Efficient Hybrid Sine-Cosine Harris Hawks Optimization for Low and High-Dimensional Feature Selection", *Expert Systems with Applications,* Vol. 176, 15 August 2021, 114778, https://doi.org/10.1016/j.eswa.2021.114778.

[28] M. Mansoor A. F. Mirza, and Q. Ling, "Harris Hawk Optimization-based MPPT Control for PV Systems Under Partial Shading Conditions", *Journal of Cleaner Production,* Vol. 274, 20 November 2020, 122857, https://doi.org/10.1016/j.jclepro.2020.122857.

[29] E. S. Ali, and S. M. Abd-Elazim, "Optimal Locations and Sizing of Capacitors in Radial Distribution Systems Using Mine Blast Algorithm", E*lectrical Engineering,* Springer,

Vol. 100, No.1, 2018, pp. 1-9, https://doi.org/10.1007/s00202-016-0475-1.

[30] E. S. Ali, and S. M. Abd Elazim, "Optimal Sizing and Locations of Capacitors Using Slime Mould Algorithm", *WSEAS Transactions on Power Systems,* Vol. 17, 2022, pp.382-390, https://doi.org/10.37394/232016.2022.17.38.

[31] D. Das, D. Kothari, and A. Kalam, "Simple and Efficient Method for Load Flow Solution of Radial Distribution Networks", *Int. J. of Electrical Power and Energy Systems,* Vol. 17, 1995, pp. 335-346, https://doi.org/10.1016/0142-0615(95)00050-0.

[32] J. Olamaei, T. Niknam, and S. Arefi, "Distribution Feeder Reconfiguration for Loss Minimization Based on Modified Honey Bee Mating Optimization Algorithm", *Energy Procedia,* Vol. 14, 2012, pp. 304-311, https://doi.org/10.1016/j.egypro.2011.12.934.

[33] D. Shirmohammadi, and W. Hong, "Reconfiguration of Electric Distribution Networks for Resistive Line Loss Reduction", *IEEE Trans. Power Delivery,* Vol. 4, No. 2, 1989, pp. 1492-1498, DOI: 10.1109/61.25637.

[34] J. Martín, and A. Gil, "A new Heuristic Approach for Distribution Systems Loss Reduction", *Electric Power Systems Research,* Vol. 78, No. 11, November 2008, pp. 1953-1958, https://doi.org/10.1016/j.epsr.2008.04.001.

[35] J. Zhu, "Optimal Reconfiguration of Electric Distribution Network Using Refined Genetic Algorithm", *Electrical Power System Research,* Vol. 62, November 2008, pp. 37-42, https://doi.org/10.1016/S0378-7796(02)00041-X.

[36] M. Ghorbani, S. Hosseinian, and B. Vahidi, "Application of Ant Colony System Algorithm to Distribution Networks Reconfiguration for Loss Reduction", *2008, 11th Int. Conf. on Optimization of Electrical and Electronic Equipment,* 22-24 May 2008, Brasov, Romania DOI: 10.1109/OPTIM.2008.4602377.

[37] A. Tandon, and D. Saxena, "A Comparative Analysis of SPSO and BPSO for Power Loss Minimization in Distribution System Using Network Reconfiguration", *in Computational Intelligence on Power, Energy and Controls with their impact on Humanity (CIPECH),* 2014 Innovative Applications of, 2014, pp. 226-232, Ghaziabad, India, DOI: 10.1109/cipech.2014.7019093.

[38] S. Taher, and M. Karimi, "Optimal Reconfiguration and DG Allocation in Balanced and Unbalanced Distribution Systems", *Ain Shams Engineering Journal,* Vol. 5, 2014, pp.735-749, https://doi.org/10.1016/j.asej.2014.03.009.

[39] T. Niknam, E. Azadfarsani, M. Nayeripour, and B. Firouzi, "A New Tribe Modified Shuffled Frog Leaping Algorithm for Multiobjective Distribution Feeder Reconfiguration Considering Distributed Generator Units", *European Transaction Electric Power,* Vol. 22, No. 3, 2012, pp. 308-343, https://doi.org/10.1002/etep.564.

[40] S. M. Abd-Elazim, and E. S. Ali, "Optimal Network Restructure via Improved Whale Optimization Approach", *International Journal of Communication Systems,* Vol. 34, No. 1, e4617, January 2021, https://doi.org/10.1002/dac.4617.

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