CH.HARIPRASAD[1,*], R.KAYALVIZHI[2], N.KARTHIK[3]

J. Electrical Systems x-x (xxxx): xxx-xxx

Regular paper

Optimization for Position and Rating of Distributed Generating units using Harris Hawk Optimization Algorithm to Reduce Power Losses

Abstract: nature inspired Harris Hawk optimization algorithm for position and rating of distributed generating units in distribution system is proposed in this paper. By installing DGs nearby consumer load centers, line losses can be reduced and voltage profile improves. But penetration of DGs at unsuitable location with unmatched rating will have large impact on distribution systems. This will affect reliability of distribution network, will lessen voltage quality and rises harmonics. Hence there is a requirement of optimization of position and rating DGs before installing in distribution systems. Voltage profile and DG capacity limitation are considered while optimizing DGs. IEEE 33 bus radial distribution system is considered for allocation. Harris Hawk Optimization Algorithm is implemented to optimize position and rating because of its global convergence and reduced calculation liability. Minimization of main objective function is carried out by considering total losses, voltage profile and capacity of DGs. The recommended process is verified on IEEE 33 bus radial distribution system in MATLAB environment and results show the effectiveness of proposed algorithm.

Keywords: Voltage profile, Harris Hawk Optimization, heuristic, Distributed Generation, Radial distribution system.

1. Introduction

Due to increasing requirement of load demand need for stretchy and independent electrical energy sources is rising. Quality and consistent electrical energy is main necessity of customers to handle their sensitive loads. To reach consumer demands for quality energy grid alone unable to handle and distributed generating units are playing important role in power systems. Main benefits of DGs in distribution networks are reduction in power losses, improvement in voltage profile and reliability in power system [1].

Distribution line losses and hence cost of transmission of electrical power can be reduced by installing DGs nearby consumer load centres. solar and wind generation systems are renewable and aids climate and these are contamination free [2]. Due to large access of scarcity lessening solar and wind energy as DGs, complication in optimum dispatch of power in active distribution network is growing. This will affect the constancy and protection of distribution networks. Inappropriate access of DGs with unmatched rating will have large impact on distribution systems. This will affect reliability of distribution network, will lessen voltage quality and rises harmonics, reverse power flow, voltage fluctuation, dyssynchronization of the protection system, poor consistency of over load tap changer, poor power quality and so on. line losses also increase with low voltage quality and increasing harmonics [3].

So hence from preparation phase itself, it is very important to optimize or select location and rating of the DGs. If size of DGs not optimized efficiently, increased size of DGs in network, will inject high currents into the line. This will impact voltage quality and voltage level and hence, increases distribution losses more and magnitude and angle of voltage of the busses of the network will be affected. For a particular level of penetration of DGs, the

[*] Corresponding author: CH.HARIPRASAD, Ph.D Scholar, Annamalai University, Annamalai Nagar,Tamilnadu,608002, E-mail: hariprasad777@gmail.com

[2]Professorof EIE Department,Annamalai University, Annamalai Nagar, Tamilnadu,608002

[3]Associate Professor of EEE Department, Bapatla Engineering College,Bapatla,Andhra Pradesh,522102

performance of the distribution system will be improved. But outside of this level, loading on substation and feeder will worsen the distribution system and increase unconventionality in voltage and hence rises power losses. Hence there is a requirement to find optimal rating and position of DG units to install into Distribution systems [4].

To improve voltage magnitude and angle and to reduce line losses optimization of DGs is necessary and numerous methods are proposed by authors in recent times. These methods are divided into logical based, statistical based and metaheuristic based [5]. Gravitational search algorithm is proposed in [6], for optimizing location and capacity of solar photovoltaic based DGs to lessen total cost. Hybrid GA and intelligent water drop optimization algorithm were proposed in [7] to determine location and capacity of DG for improving voltage profile and to reduce power losses. Mixed integer nonlinear programming proposed in [8] and dynamic programming proposed in [9], gradient search in [10], optimal power flow in [11] for optimization are examples of statistical methods. Particle swarm optimization (PSO) [12], genetic algorithm (GA) [13], tabu search algorithms [14] multi objective harmony search algorithm [15] are metaheuristic-based algorithms.

Grey wolf optimization of DG location is proposed in [16] to reduce power losses and to improve voltage profile. Optimization of location and size of DG using Loss Sensitivity Factor is proposed in [17] for improving voltage magnitude. Rectification of optimal power flow problem after installing DG in distribution system using moth flame optimization is explained in [18]. Sine cosine algorithm for optimization is proposed in [19], in which sin and cosine formulations are used for updating positions of agents to get best solution. Objective function with real and reactive power losses is optimized to find best location and size of DG using biogeography-based optimization algorithm was proposed in [20].

By reducing power losses, optimization of location and size of DG on radial distribution system using Ant Colony Optimization algorithm is explained in [21]. Multi objective grey wolf optimization for optimal position of DG in 33 radial distribution system is proposed in []. Main downside of these optimization algorithms is input parameters should be set with proper value otherwise it leads to local convergence instead of global hence give indecorous results.

In this paper proposing an optimization algorithm based on Harris Hawk Optimization by considering all these nonlinear constraints to allocate DG location and size. Main advantages of Harris Hawk Optimization Algorithm are global convergence, easily optimizable and this algorithm can handle nonlinear constraints effectively compared with other algorithms.

This paper is systematized as: section II describes about the problem designing formulation, fitness function and nonlinear constraints. Section III explains about Harris Hawk Optimization Algorithm. Section IV discuss about algorithm implementation with flow chart. Section V discusses about procedure to implement HHO algorithm in DG allocation and simulation results.

2. Problem Formulation

Line real and reactive power losses reduction, improving voltage profile of distribution system in which distributed generating units are installed with optimized size and location by satisfying operation constraints is the main problem involved in the paper.

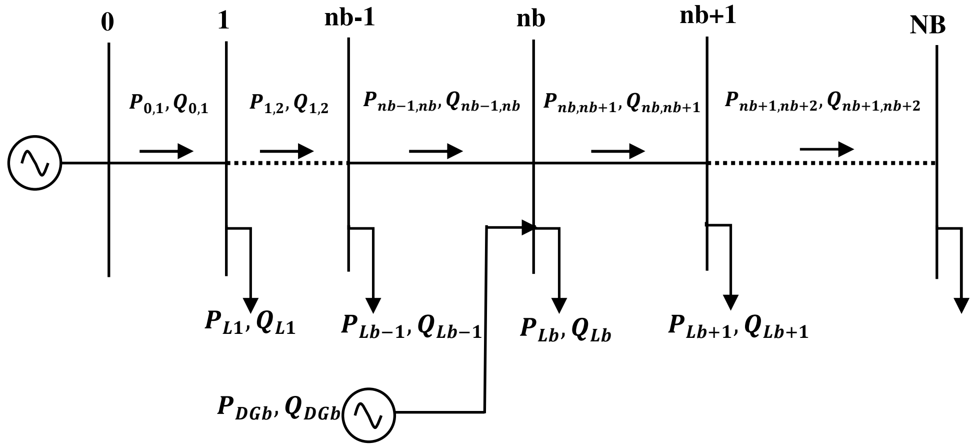


Fig 1. Radial Distribution System

As presented in fig 1. Real power losses of a line section between m and m+1 busses of radial distribution system with NB is total busses and NL is total line sections is given as

$$P_{nb,nb+1}^{losses} = G_{nb,nb+1}(P_{nb,nb+1}^2 + Q_{nb,nb+1}^2) \quad (1)$$

Where $G_{nb,nb+1} = \frac{R_{nb,nb+1}}{|V_{nb}|^2}$

Then total power losses are equal to sum of losses of all line sections which is given as

$$PL^{Total} = \sum_{i=0}^{NL} G_{nb,nb+1}(P_{nb,nb+1}^2 + Q_{nb,nb+1}^2) \quad (2)$$

V_{nb} is voltage at nbth bus, $P_{nb,nb+1}$ and $Q_{nb,nb+1}$ are active and reactive power flow from nbth bus to nb+1th bus, $R_{nb,nb+1}$ is the resistance of line section between nbth bus to nb+1th bus

Total reactive power losses are given as

$$QL^{Total} = \sum_{i=0}^{NL} B_{nb,nb+1}(P_{nb,nb+1}^2 + Q_{nb,nb+1}^2) \quad (3)$$

Where $B_{nb,nb+1} = \frac{X_{nb,nb+1}}{|V_{nb}|^2}$

$X_{nb,nb+1}$ is line inductive reactance amid nbth bus to nb+1th bus

Main objective of the paper is to find finest rating and finest position for distributed generating units to install in radial distribution system to curtail losses in active power flow in lines. After adding DG units to distribution system losses in active power flow can be modified as

$$PL_{DG}^{Total} = \sum_{i=0}^{NL} A_{nb,nb+1}[\left(P_{nb,nb+1} - \gamma_{DG_p} P_{DG,nb+1}\right)^2 + \left(Q_{nb,nb+1} - \gamma_{DG_q} Q_{DG,nb+1}\right)^2] \quad (4)$$

Inequality constraint to be considered while optimizing location and size of DG units are given as

1. Voltage profile at each bus should be in between maximum and minimum values.

$$V_{nb,min} \leq V_{nb} \leq V_{nb,max} \quad (5)$$

2. Size of each DG should be in available capacities of units

$$S_{DG,nb,min} \leq S_{DG,nb} \leq S_{DG,nb,max} \quad (6)$$

3. Power factor at each DG unit should be within limit

$$pf_{DG,nb,min} \leq pf_{DG,nb} \leq pf_{DG,nb,max} \quad (7)$$

Location and rating of DG units in distribution system can be optimized by reducing fitness function i.e reducing losses. while optimizing fitness function equality and inequality constraints should be considered. Magnitude of voltage at each bus should be maintained in between lower and upper limits while optimizing size and location.
Harris Hawk Optimization Algorithm is adopted for optimizing position and rating of DG stations to lessen losses in active and reactive power flow in lines of radial distribution system.

3. Harris Hawk Optimization Algorithm

To find and analyse IQ behind innovative ways by the avian's nourishing practices, an approach has been proposed by Louis Lefebvre [22]. Hawks are considered to utmost brainy avian in wildlife. Harris's Hawk with a scientific name parabuteo unicintus subsists in brazil, western Europe and in southwestern united states. Due to its inimitable supportive hunting actions, Harris's Hawk is eminent and can be known as intelligent accommodating predators. Usually other raptors attack, notice and snatch prey unaccompanied, but Harris's Hawk will forage by cooperating with other fellows living in same group. While attacking the latent prey, squad of these desert hunters will show amazing pioneering rushing skills in finding, surrounding, forcing out.

In this optimization algorithm cluster of hawks which are trying to chase their target are taken as initial population. The target can be defined as solution to the problem. Hawks take different directions to chase the target using surprise swoop. Initially the target can be attacked by leader of the group. Success rate of the leader in chasing depends on fugitive behaviour and energetic nature of the target. Now the switching tactics can be followed by other members of the group to catch the target. By baffling and enervation of the target, the hawks in the group can pursue it with cooperative strategies. In Harris's Hawk optimization algorithm, candidate solutions are the birds and solution is the projected target. Exploratory and exploitative are the two main phase while Hawks or candidate solutions are finding the target or optimal solution.

3.1. Exploration Phase

Harris hawks perceive and monitor the target by waiting and alighting in random locations. Leader of the group of hawks roosts at a spot by considering other members and target position. Mathematically this can be defined using following equation

$$P(n+1) = \begin{cases} P_{rand}(n) - r_1 |P_{rand}(t) - 2r_2 P(n)| & q < 0.5 \\ P_r(i) - P_m(i) - r_3(lb + r_4(ub - lb)) & q \geq 0.5 \end{cases} \quad (8)$$

$P_{rand}(t)$ is the initial population selected randomly using lower and upper bounds, $P_m(i)$ is the mean value of population. ub is maximum range of candidates and lb is minimum range of candidates. $P_r(i)$ is the position of the target, $P_{rand}(n)$ is the vector of random population in nth iteration. $P(n+1)$ is new vector of population for $(n+1)th$ iteration, r_{1-4}, q are random numbers in the range of 0 and 1.
Average candidates' position of each hawk is defined as

$$P_{n+1}(t) = \frac{1}{N}\sum_{i=1}^{N} P_i(t) \qquad (9)$$

$P_i(t)$ is the current position of hawks, $P_{n+1}(t)$ is the updating position vector and N is the total number of hawks.
During exploration phase, target can be chased and hit by hawks, due to which the energy of the target can be altered significantly. Then the change in energy of the target is defined as

$$J = 2J_0\left(1 - \frac{t}{T}\right) \qquad (10)$$

J is the escaping energy, J_0 is the initial energy at every iteration, T is the maximum iteration, t is the present iteration. Initial energy at each iteration can be chosen randomly within the range of -1 and 1. If escaping energy $J \geq 1$, then target is jumping and hawks should search for target in other location. If escaping energy $J < 1$, target's energy is becoming drain and hawks has to strengthen its attack by astonishment jump. This will become the solution to the exploitation phase.

3.2. Exploitation Phase

In this phase to attack the target hawks has to follow swapping strategies. Target always try to escape from the hawks and the chance of escaping from the hawk is defined as r. If target is evasion successfully then r will be less than 0.5 and if r is greater than or equal to 0.5 then fugitive trial by target is ineffective. Soft and hard siege can be defined by using escaping ability of target and attacking procedure of hawks. Hard siege is the stage at which target is escaped when $r \geq 0.5$ and $|J| < 0.5$. soft siege is the stage at which $r \geq 0.5$ and $|J| \geq 0.5$.

3.3. Soft siege

In this stage, hawks surround the target softly and the target gains energy and tries to escape by jumping. This can be defined mathematically as

$$P(t+1) = \Delta P(t) - J\left|r_j P_{target}(t) - P(t)\right| \qquad (11)$$

$$\Delta P(t) = P_{target}(t) - P(t) \qquad (12)$$

$$r_j = 2(1 - r_5) \qquad (13)$$

$\Delta P(t)$ is the difference between the candidates position vector of previous and present iteration, r_5 is the random number which is in range of 0 and 1.

3.4.Hard Siege

In this stage, target is completely tired and the hawks enfold it barely and complete the surprise jump. Candidate positions are updated as

$$P(t+1) = P_{target}(t) - J|\Delta P(t)| \quad (14)$$

3.5. Soft siege with persistent speedy drives

Even after soft and hard siege, target will have the energy and it still try to escape. This state is possible when $|J| \geq 0.5$ and $r < 0.5$. Due to this there is a requirement of another soft siege before surprise jump by the hawks. This soft siege should be sharper than previous case. To execute this soft siege hawks will evaluate next move of target using levy flight theory given as

$$Q = P_{target}(t) - J\left|r_j P_{target}(t) - P(t)\right| \quad (15)$$

Each step of hawk can be compared with previous step and hawks will decide if the present step is good or not. If the present step is not efficient, then hawks will step quickly and snappishly for reaching the target. Then steps of hawks will be based on patterns of Levy Flight using the rule given as

$$R = Q + S * LF(D) \quad (16)$$

D is the dimension of the problem, S is the random vector size of $1XD$, LF is levy flight function defined as

$$LF(p) = 0.01 * \frac{u * \sigma}{|v|^{\frac{1}{\beta}}} \quad (17)$$

$$\sigma = \left(\frac{\Gamma(1+\beta) * \sin\left(\frac{\pi\beta}{2}\right)}{\Gamma\left(\frac{1+\beta}{2}\right) * \beta * 2^{\left(\frac{\beta-1}{2}\right)}}\right)^{\frac{1}{\beta}} \quad (18)$$

u, v are accidental values lying in the range of 0 and 1, β is an assumed constant equal to 1.5.
Then hawk's position can be updated in soft siege using

$$P(t+1) = \begin{cases} Q \ if \ F(Q) < F(P(t) \\ Z \ if \ F(R) < F(P(t)) \end{cases} \quad (19)$$

3.6.Hard siege with persistent speedy drives

In this state, target losses its energy and become exhausted where $|J| < 0.5$ and $r < 0.5$. now hard siege can be used by the hawks and it decreases the distance of their location from the target. Hence updated rule is given as

$$P(t+1) = \begin{cases} Q \ if \ F(Q) < F(P(t) \\ Z \ if \ F(R) < F(P(t)) \end{cases} \quad (20)$$

$$Q = P_{target}(t) - J\left|r_j P_{rabbit}(t) - P_m(t)\right| \quad (21)$$

$$R = Q + S * LF(D) \quad (22)$$

Q and R are the next locations for the new iteration until the target is killed, i.e. obtaining optimal solution.

4. Algorithm Implementation

4.1. Flow Chart

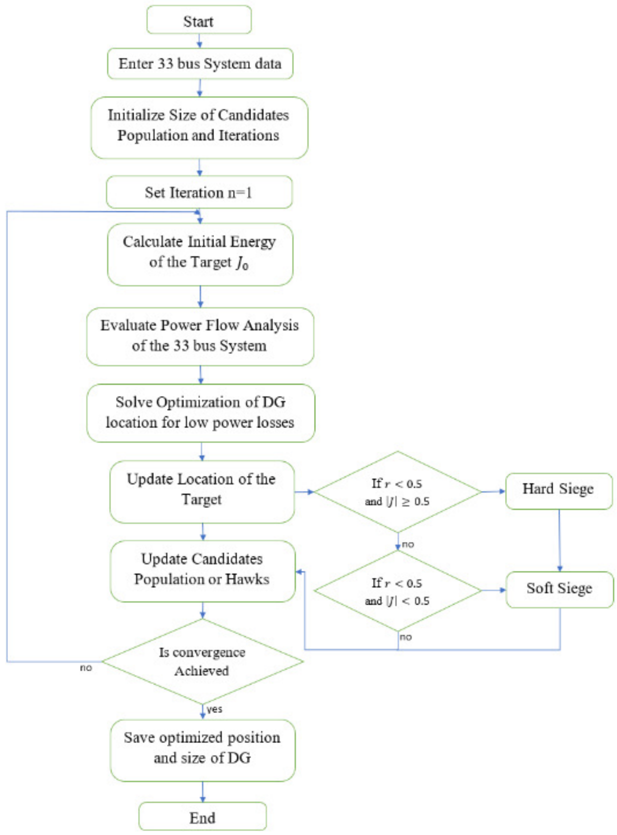


Fig 2. Flow chart of proposed Algorithm

4.2. Pseudo Code

1. Initialize number of iterations and number of candidate positions or hawks
2. Start Iteration=1
3. While (convergence condition) do
4. Find the fitness of candidates positions or hawks (Power losses)
5. P_{target} is the best position of candidates
6. For 1:no of candidates position or hawks
7. Update energy and jumping strength of hawk
8. Initial energy $J_0 = 2r - 1$ and jumping strength $r_j = 2(1 - r_5)$
9. If $J \geq 1$ then, Exploration Phase
10. If $J < 1$ then, Exploitation phase
11. If $r \geq 0.5$ and $|J| \geq 0.5$ then, Soft Siege
12. If $r \geq 0.5$ and $|J| < 0.5$ then, Hard Siege

13. Find global optimal soluton with updated candidates position
14. Check for convergence
15. If convergence reached, better candidates position are the optimized position and size of DGs

4.3. System Under Study

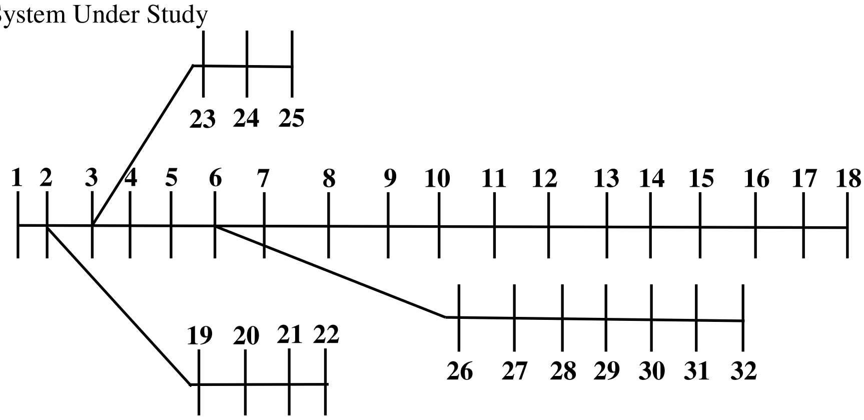


Fig 3. Bus and line Connection diagram of radial distribution system of 33 bus

4.4. Optimizing DG location using HHO algorithm

To improve voltage profile and to reduce active and reactive power losses in the line position and size of the DG units are optimized using Harris Hawk optimization algorithm. Control variables which are to be optimized are size of the DGs and position or place of the bus at which DGs should be connected. These variables can be taken as candidates population and then voltage profile and active and reactive power losses are the fitness solution of the algorithm. Fitness solution can be calculated using load flow analysis of 33 bus radial distribution system by placing DGs with specified size and at specified place by candidates population.

Steps involved to find optimal position and size of DGs using HHO

1. Initialize number of maximum iterations and tolerance, no. of DG units to be optimized, maximum rating of DG and size of candidates population or no. of Hawks.
2. Set the constrains for candidates population or Hawks.
3. By considering constraints, generate initial candidates. Perform load flow analysis on 33 bus radial distribution system and execute the fitness for each generated candidates population
4. Perform soft siege and hard siege in each iteration to generate new candidates population
5. Find fitness function for every iteration and for every candidate in population using load flow analysis.
6. Check constraints in each loop
7. If convergence reached then stop, else goto step 4.

5. Simulation results

A 33 bus radial distribution system is chosen to check effectiveness of proposed Harris's Hawk optimization algorithm in finding optimal size and place of DGs to improve voltage profile and to reduce line active and reactive power losses. Power flow analysis can be performed before and after DGs on radial distribution system to evaluate voltage profile and line losses. Data of IEEE 33 bus radial distribution system is given in appendix I. Bus and line connection diagram of system is shown in fig . Using the flow chart and pseudo code given in section IV Harris's Hawk optimization algorithm and load flow analysis are developed in MATLAB.

10 MVA and 12.66 KV are base power and base voltage of chosen distribution system. Number of busses are 33 and 34 lines are connected through these busses. Total active power load is 3855 KVA and reactive power load is 2875 KVA. Number of candidates population chosen is 30 and number of iterations are 500. Limits or constraints for DG capacity is selected as 120% and 20% of total connected load and limitation for voltage magnitude is chosen as 1.1 and 0.9 pu.

Real and reactive power losses of 33 bus radial distribution system before installing DGs are 208.065 KW and 140.85 KVA. After optimization using HHO algorithm results of active and reactive power losses are depicted in table.

Table 2. Real and Reactive power losses before and after connecting DG

	Without DG	1 DG	2 DG
Position of the DG		32	22,33
Capacity of the DG		2756.6 KVA	2399.1 KVA and 1157.5 KVA
Real Power Losses	208.065 KW	179.856 KW	126.985 KW
Reactive Power Losses	140.85 KVA	108.087 KVA	65.159 KVA

Position of the DG optimized by proposed algorithm is 32 bus and the capacity of DG is 2756.6 KVA. Optimized size of the DG is 57.3% of total loading of system. Active and reactive power losses are reduced to 179.856 KW and 108.087 KVA after installing 1 DG. 14% of active power losses and 23% of reactive power losses are reduced due optimized size of single DG at optimized place. For 2 DGs losses are further reduced to 126.985 KW and 65.159 KVA which are 39% and 54% of losses without DG. This reduction in losses is due to insertion of 2 DGs with optimized capacity of 2399.1 KVA and 1157.5 KVA at 22 and 33 busses. Improvement in voltage profile is shown in fig.

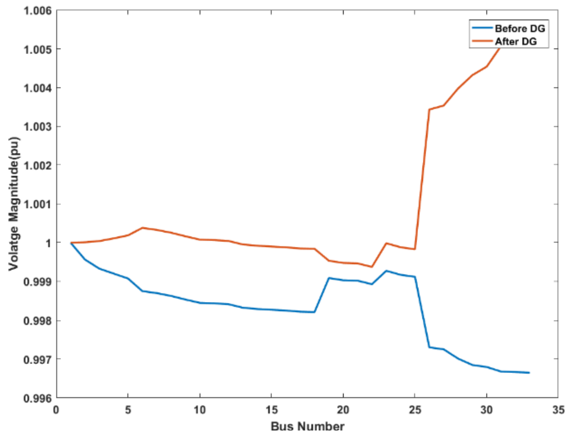
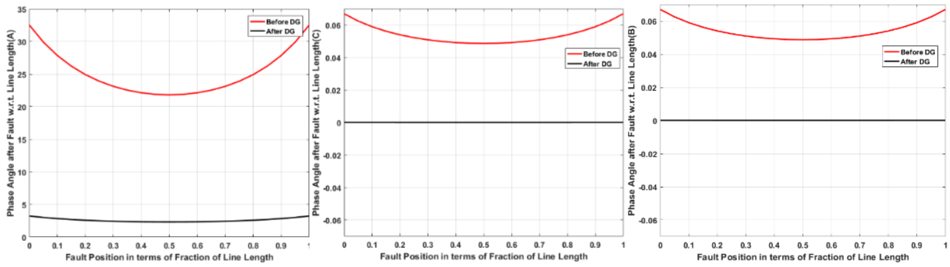
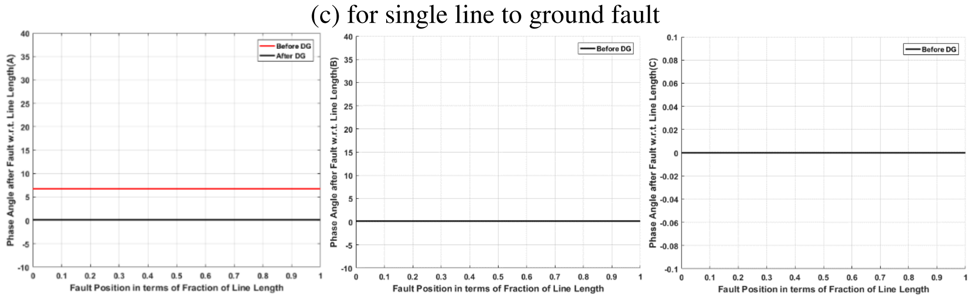


Fig 4. Voltage profile before and after installation of 2 DGs with optimized capacity



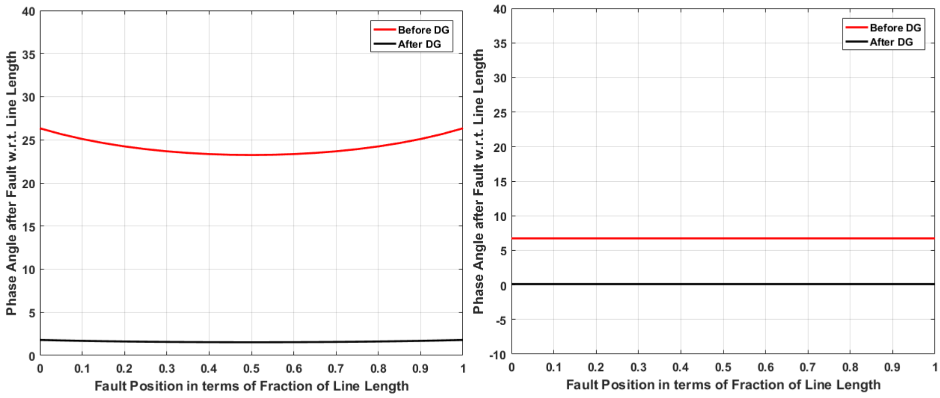
(a) (b) (c)

Fig 5. Effect of fault on voltage angle before and after DG in Phase A(a), Phase B(b), Phase (c) for single line to ground fault



(a) (b) (c)

Fig 6. Effect of fault on voltage angle before and after DG in Phase A(a), Phase B(b), Phase (c) for Line to Line fault



(a) (b)

Fig 7. Effect of fault on voltage angle before and after DG in Phase A for double line to ground(a) and three line to ground(b) fault

Voltage profile of 33 bus radial distribution system after and before installing is shown in fig 4. Due to optimized DG, voltage profile is improved and voltage angles are also not effected much due to faults. Faults are introduced on line no 10 between bus no 10 and 11. Voltage angles are evaluated at bus 10 by changing position of fault from 10^{th} bus. Before installation of DG variation in voltage angle in faulted phase is very high from base value which is in the range of 25-30 degrees as shown in fig 5. Due to DG installation voltage angles are reduced to around 3 degrees in faulted phase. Variation of voltage angles in terms of line length is shown in fig 5 for single line ground fault. Voltage angle variation for Line to line fault is shown in fig 6. For double line to ground and three line to ground fault voltage angles for before and after DG are shown in fig 7.

6. Conclusion

In this paper, Harris Hawk Optimization Algorithm is adopted for optimizing position and rating of DG stations to lessen losses in active and reactive power flow in lines of radial distribution system. Racing for prey using their supportive behaviour of Harris's hawks is main motivation behind this algorithm. 33 bus radial distribution system is chosen to check the effectiveness of proposed algorithm. Both position and capacity of DGs to be installed are optimized using this algorithm in the paper. A fitness function is mentioned which includes voltage profile and active and reactive power losses. After installing optimized DGs in distribution system significant improvement is there in terms of voltage profile which includes magnitude and angle. Line active and reactive power losses are also reduced due to optimized DGs.

References

1. M. Khalid, U. Akram and S. Shafiq, "Optimal Planning of Multiple Distributed Generating Units and Storage in Active Distribution Networks," in IEEE Access, vol. 6, pp. 55234-55244, 2018, doi: 10.1109/ACCESS.2018.2872788.
2. Li, K., Bian, H., Liu, C., Zhang, D. and Yang, Y., 2015. Comparison of geothermal with solar and wind power generation systems. *Renewable and Sustainable Energy Reviews*, *42*, pp.1464-1474.
3. Ghosh, S., Ghoshal, S.P. and Ghosh, S., 2010. Optimal sizing and placement of distributed generation in a network system. *International Journal of Electrical Power & Energy Systems*, *32*(8), pp.849-856.
4. Mishra, M., 2015, March. Optimal placement of DG for loss reduction considering DG models. In *2015 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT)* (pp. 1-6). IEEE.

5. D. Demirol, F. Oztemiz and A. Karci, "Performance Comparison of Physics Based Meta-Heuristic Optimization Algorithms," *2018 International Conference on Artificial Intelligence and Data Processing (IDAP)*, Malatya, Turkey, 2018, pp. 1-5.
6. Srivastava, Adhishree, et al. "Optimal coordination of overcurrent relays using gravitational search algorithm with DG penetration." *IEEE Transactions on Industry Applications* 54.2 (2017): 1155-1165.
7. Prabha, D. Rama, et al. "Optimal location and sizing of distributed generation unit using intelligent water drop algorithm." *Sustainable Energy Technologies and Assessments* 11 (2015): 106-113.
8. Porkar, S., Poure, P., Abbaspour□Tehrani□fard, A. and Saadate, S., 2011. Optimal allocation of distributed generation using a two□stage multi□objective mixed□integer□nonlinear programming. *European Transactions on Electrical Power*, *21*(1), pp.1072-1087.
9. Khalesi, N., Rezaei, N. and Haghifam, M.R., 2011. DG allocation with application of dynamic programming for loss reduction and reliability improvement. *International Journal of Electrical Power & Energy Systems*, *33*(2), pp.288-295.
10. Salomon, R., 1998. Evolutionary algorithms and gradient search: similarities and differences. *IEEE Transactions on Evolutionary Computation*, *2*(2), pp.45-55.
11. Ochoa, L.F. and Harrison, G.P., 2010, July. Using AC optimal power flow for DG planning and optimisation. In *IEEE PES General Meeting* (pp. 1-7). IEEE.
12. Khaled, U., Eltamaly, A.M. and Beroual, A., 2017. Optimal power flow using particle swarm optimization of renewable hybrid distributed generation. *Energies*, *10*(7), p.1013.
13. Moradi, M.H. and Abedini, M., 2012. A combination of genetic algorithm and particle swarm optimization for optimal DG location and sizing in distribution systems. *International Journal of Electrical Power & Energy Systems*, *34*(1), pp.66-74.
14. Gandomkar, M., Vakilian, M. and Ehsan, M., 2005. A genetic–based tabu search algorithm for optimal DG allocation in distribution networks. *Electric Power Components and Systems*, *33*(12), pp.1351-1362.
15. Nekooei, K., Farsangi, M.M., Nezamabadi-Pour, H. and Lee, K.Y., 2013. An improved multi-objective harmony search for optimal placement of DGs in distribution systems. *IEEE Transactions on smart grid*, *4*(1), pp.557-567.
16. Sultana, U., Khairuddin, A.B., Mokhtar, A.S., Zareen, N. and Sultana, B., 2016. Grey wolf optimizer based placement and sizing of multiple distributed generation in the distribution system. *Energy*, *111*, pp.525-536.
17. Abdel-mawgoud, Hussein, et al. "Optimal installation of multiple DG using chaotic moth-flame algorithm and real power loss sensitivity factor in distribution system." *2018 International Conference on Smart Energy Systems and Technologies (SEST)*. IEEE, 2018.
18. Abdel-mawgoud, Hussein, et al. "Optimal installation of multiple DG using chaotic moth-flame algorithm and real power loss sensitivity factor in distribution system." *2018 International Conference on Smart Energy Systems and Technologies (SEST)*. IEEE, 2018.
19. Manrique, María Lourdes, et al. "Sine-Cosine Algorithm for OPF Analysis in Distribution Systems to Size Distributed Generators." *Workshop on Engineering Applications*. Springer, Cham, 2019.
20. Mosbah, Mustafa, et al. "Optimal power flow for transmission system with photovoltaic based DG using biogeography-based optimization." *2018 International Conference on Electrical Sciences and Technologies in Maghreb (CISTEM)*. IEEE, 2018.
21. Kasaei, M.J., 2014. Optimal placement of distributed generation and capacitor in distribution networks by ant colony algorithm. *International Journal on Technical and Physical Problems of Engineering (IJTPE)*, (20), pp.52-56.
22. Lefebvre, P. Whittle, E. Lascaris, A. Finkelstein, Feeding innovations and forebrain size in birds, Animal Behaviour 53 (1997) 549–560