JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Optimization of Radial Distribution Systems in the Presence of Distribution Generation by Network Reconfiguration using Spotted Hyena Optimizer Algorithm

C.Deepak[1], Dr.V.Usha Reddy[2]
[1]M. Tech, Dept. of EEE, SVUCE, Sri Venkateswara University, Tirupati, India
[2]Assistant Professor, Dept. of EEE, SVUCE, Sri Venkateswara University, Tirupati, India

Abstract:-

For many power distribution system issues, such as voltage control and power loss, a new methodology is introduced for optimization of the radial distribution system. Voltage profile improvement and power loss minimization are the main objectives. The optimization problem is solved using the Spotted Hyena Optimizer algorithm to determine the optimal size of Distribution Generation (DG) units. The Spotted Hyena Optimizer (SHO) algorithm is a meta-heuristic algorithm based on the hunting and social behaviours of spotted hyenas. Load flow analysis is calculated by the DLF matrix, using Bus Injection to Branch Current [BIBC] and Branch Currents to Bus Voltage [BCBV] matrices. Network reconfiguration is performed on the distribution network to reduce power losses and improve voltage profile with DG allocation, which leads to better results. This proposed methodology is verified on the IEEE-33 bus systems in MATLAB software.

Keywords:- Distribution Generation(DG), Radial Distribution Network, Network Reconfiguration, Voltage Profile Improvement, Bus Injection to Branch Current [BIBC] and Branch Currents to Bus Voltage [BCBV],Power loss Reduction, Spotted Hyena Optimizer(SHO) Algorithm.

1. Introduction

The distribution system is an important structure of the power system for maintaining the reliability of the power supply to end users. It interconnects the high voltage transmission system to low voltage consume service mains. It is a requirement to maintain the quality of the power supply for proper working of appliances, machines, etc.; for that, system losses should be minimized, the voltage profile must be within specified limits, and the harmonic content must be within standards. Based on the data, the total losses in the distribution system are about 5–13% of the total generated power. So, it is imperative to reduce the losses while improving the efficiency of the system. Due to the evolution of technology, it is possible through the placement of capacitors, distributed generator placement, network reconfiguration, and so on.

To reduce the burden on the generating station the reactive power is injected by placing the capacitor optimal locations. This helpful in reducing the power losses and maintains voltage stability of the system. In [1] the capacitor placement with type and size is calculated on radial distribution system for power loss reduction considering voltage constraints. Particle swarm optimization (PSO) [2] technique has been used for capacitor placement and sizing in unbalanced distribution system to improve voltage profile and reduce losses. In [3] Autonomous Group Particle swarm optimization algorithm is implemented for power loss reduction. Power Loss

Sensitivity (PLS) index for placing of capacitor by ZIP load model is compared with power loss(PI) and Index vector(IV) method in[4].Distribution Generation is another method to achieve the objects by placing near to the load centers by using renewable sources of solar, wind, biomass etc.,

Artificial intelligent techniques are introduced for the optimal placement of DG. Such techniques are Genetic Algorithm(GA), Artificial Bee Colony(ABC), Harmony Search Algorithm(HAS),Grey Wolf Optimization(GWO), Whale Optimization Algorithm(WOA) etc., In [5] Different types of DGs are placed at optimal location by using PSO for optimal power factor calculation. An Invasive Weed Optimization(IWO) [6] algorithm is implemented for the placement of multiple DG by considering different loads. Grey Wolf Optimization(GWO) [7] is used for optimal location of distribution generation in unbalanced distribution system. In [8] Cuckoo Search Algorithm is used for optimal capacitor placement for loss reduction in distribution system. The DG placement in unbalanced distribution system using voltage index with optimal sizing is presented in [9].

Network reconfiguration in distribution systems can be done by changing the status of sectionalizing switches, and is usually done for minimizing losses, voltage improvement, or for load balancing in the system. An optimal reconfiguration of distribution network for loss reduction and load balancing is presented in [10] with forward backward sweep method for load flow calculation. The impact of reconfiguration for reducing losses in radial system using multi objective fuzzy approach is presented [11]. A GA approach is used for loss minimum reconfiguration by maintaining radial nature of distribution network [12]. The minimum power losses with improved voltage profile can be achieved by using optimal network reconfiguration, Binary Particle Swarm Optimization algorithm (BPSO) optimization technique is used to find the minimum power losses in the system[13]. A modified Plant Growth Simulation Algorithm(PGSA) for simultaneous reconfiguration and DG installation at multiple location for loss reduction is presented [14]. An adaptive CSA [15] for network reconfiguration and DG allocation based on the voltage stability index(VSI) with multi-DG placement is presented.

2. Problem formulation

This section performs the DG allocation and feeder reconfiguration along with DG allocation for balanced distribution system. For that the objective functions, voltage limits, DG limits and the load flow solution method is to be stated.

2.1 Objective function:

The objective function for the balanced system is defined as

$$\min (P_{loss}) = \sum_{i=1}^{n} I_i^{\,2} R_i \qquad (1)$$

where, i is the bus number, I_i is the branch current, R_i is the branch resistance and n is the number of branches.

2.2 Constraints:

The constraints are

Voltage Constraints:

Voltage magnitude (V_k) at each node must be between pre-defined range.

$$0.95 \le V_k(pu) \le 1.05 \qquad (2)$$

DG limits

$$60 \le P_{DG}(kVA) \le 3500 \qquad (3)$$

Power balance constraints

$$P_G + \sum_{1}^{N} P_{DG} = P_D + P_{loss} \qquad (4)$$

P_G is active power generation; P_D is active power demand/load and P_{loss} is active power losses of the system, P_{DG} is active power generation.

2.3 Load flow solution:

J.H Teng [16] proposed a new load flow method of analysis for radial distribution system. Matrices called Bus Injection to Branch Current [BIBC] and Branch Currents to Bus Voltage [BCBV] have been developed which describes relationship of bus injection to branch current and branch currents to bus voltage is written as

$$[B] = [BIBC]\,[I] \quad (5)$$

$$[\Delta V] = [BCBV]\,[B] \quad (6)$$

Combining (6) and (7) we get

$$[\Delta V] = [BCBV]\,[BIBC]\,[I] \quad (7)$$

$$[\Delta V] = [DLF]\,[I] \quad (8)$$

The load flow solution of the distribution system is obtained by solving below equations (10), (11) and (12) iteratively.

$$[I_i] = \left(\frac{P_i+jQ_i}{V_i}\right)^* \quad (9)$$

$$[\Delta V_{i+1}] = [DLF]\,[I_i] \quad (10)$$

$$[\Delta V_{i+1}] = [V_\circ] - [\Delta V_{i+1}] \quad (11)$$

2.4 Index Vector Method:

It is used to find the optimal location of DG [4]. value of each bus is calculated as

$$IV(n) = \frac{1}{{V_n}^2} + \frac{I_q(i)}{I_p(i)} + \frac{Q_{eff}(n)}{Q_{total}} \quad (12)$$

Where, V_n is the voltage at n^{th} bus. $I_q(i)$, $I_p(i)$ are the imaginary and real current values of the i^{th} branch. $Q_{eff}(n)$ is the reactive load of the n^{th} bus. Q_{total} is the total reactive load of the system.

Steps:

1. Perform load flow analysis for the given system.
2. Calculate IV values for each bus.
3. Normalize voltage values as $V_n/0.95$.
4. Arrange the IV values in descending order.
5. Buses with high IV values and normalized voltage <1.01 is suitable for optimal location.

3. Proposed Method

The Spotted Hyena Optimizer(SHO) algorithm is a novel nature-inspired meta-heuristic algorithm based on the hunting behaviour of spotted hyenas [17]. They are able to fight nonstop for food and survival, typically live in tribes, and communicate by making alarm noises when they find new delicacies. The SHO provides better solutions, can handle a variety of constraints, and has a high convergence speed and accuracy.

3.1 Mathematical Modelling of SHO

The sections involved in modeling of SHO is described below

1. Encircling prey
2. Hunting
3. Attacking prey
4. Search for prey

3.1.1 Encircling prey.

Other searching factors can be considered their best position related to the prey or target as the best response and update it. To mathematical model of this behaviour is expressed as follows

$$D_h = B.P_P(x) - P(x) \quad (13)$$

$$P(x+1) = P_P(x) - E.D_h \quad (14)$$

where D_h represents the distance between the spotted hyena and the prey,P_P represents the position vector related to the prey, P represents the position vector of the spotted hyena, x represents the current iteration, and B and E represent the coefficient factor vectors

$$B = 2.r_{d1} \quad (15)$$

$$E = 2h.r_{d2} - h \quad (16)$$

$$h = 5 - (Iteration \times \frac{5}{Max\ Iteration}) \quad (17)$$

here Iteration=0, 1, 2, ... , MaxIteration

where $r_{d1}$and r_{d2} are random vectors in range of [0, 1]and h can be linearly reduced from 5 to 0.

3.1.2 Hunting.

To proposed SHO algorithm hunting strategy is described as follows

$$D_h = |B.P_h - P_k| \quad (18)$$

$$P_k = P_h - E.D_h \quad (19)$$

$$C_h = P_k + P_{K+1} + \cdots + P_{k+N} \quad (20)$$

Here, P_h represents the best position of the spotted hyena related to the prey, and $P_k$represents another position of the spotted hyena. N represents the total number of spotted hyena and is calculated as follows.

$$N = countnos(P_h, P_{h+1}, P_{h+2}, \ldots, P_{h+M}) \quad (21)$$

Here, M represents a random vector in the range of [0.5, 1], countnos represents the number of answers (the reference answers are counted), and C_h represents a group of N optimal answers.

3.1.3 Attacking prey (exploitation).

To mathematical formula for attacking prey can be defined as follows

$$P(x+1) = \frac{C_h}{N} \quad (22)$$

Here P (x +1) saves the best pass and updates the positions of other factors relative to the position of the best search factor.

3.1.4 Search for prey (exploration).

To identify the correct answer, E must be>1 or<1 , according to Eq.(20). T0 other part of the SHO algorithm, which makes exploration possible, is B. Vector B contains random values that provide the prey's random weights according to Eq. (22). Suppose that the B>1 vector has priority over the B<1 vector to show more random behaviour of the SHO algorithm and the effect of the distance.

3.2 SHO applied to optimization:

1. Read line data and load data for the given system.
2. Calculate the best location for placement of DG using Index Vector method.
3. Initialize the parameters of population size, max iterations, DG limits.
4. Generate a random population within DG limits.
5. Calculate the power losses for the randomly initialized population.
6. Best Solution of the current iteration is noted.
7. Generate a new set of population by using SHO algorithm of equations (19), (20), and (21).
8. Check these values are within the limits and if violated replace them with bound values.
9. Calculate losses and if the new value is better than previous value then replaces it with new value else go to step 7.
10. After iteration reached to maximum value then print the results.

4. Simulation Results

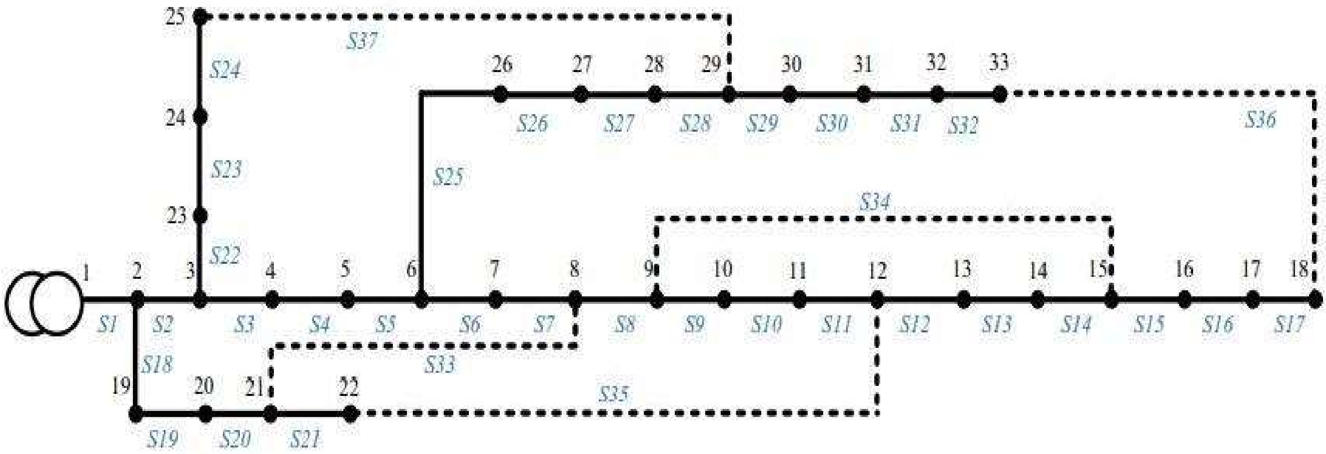

Figure 1.Line diagram of 33 bus test system

SHO is applied on the IEEE balanced 33 bus systems for optimal sizing of DG. Network reconfiguration is performed and then optimal size DG is installed on the network using SHO.

4.1 33 bus test system:

The network data for 33-bus system is taken from [10] which consists of 32 branches and 5 tie lines. The total active and reactive power load on the system is 3.715 MW and 2.3MVAr. the losses of the system for base configuration are 202.665 kW and 135.1327 kVAr with minimum voltage of 0.9131 p.u at bus 18.

Table 1.Simulation results with DG (33 bus system)

	Basecase [1]	WithDG				
		PSO [2]	HAS [6]	GWO [7]	WOA [19]	SHO
PLOSS(kW)	202.665	64.5219	64.5219	64.5219	64.5219	64.5219
QLOSS (kVAr)	135.132	47.2887	47.2896	47.2887	47.2878	47.2865
DGsize (kVA)	-	1981.243, 0.8 lag	1981.454, 0.8 lag	1981.245, 0.8 lag	1981.02, 0.8 lag	1980.72 0.8 lag
LOCATION	-	30	30	30	30	30
V_{min}	0.9131 at 18	0.9484 at 18	0.9484 at 18	0.9484 at 18	0.9484 at 18	0.9484 at 18

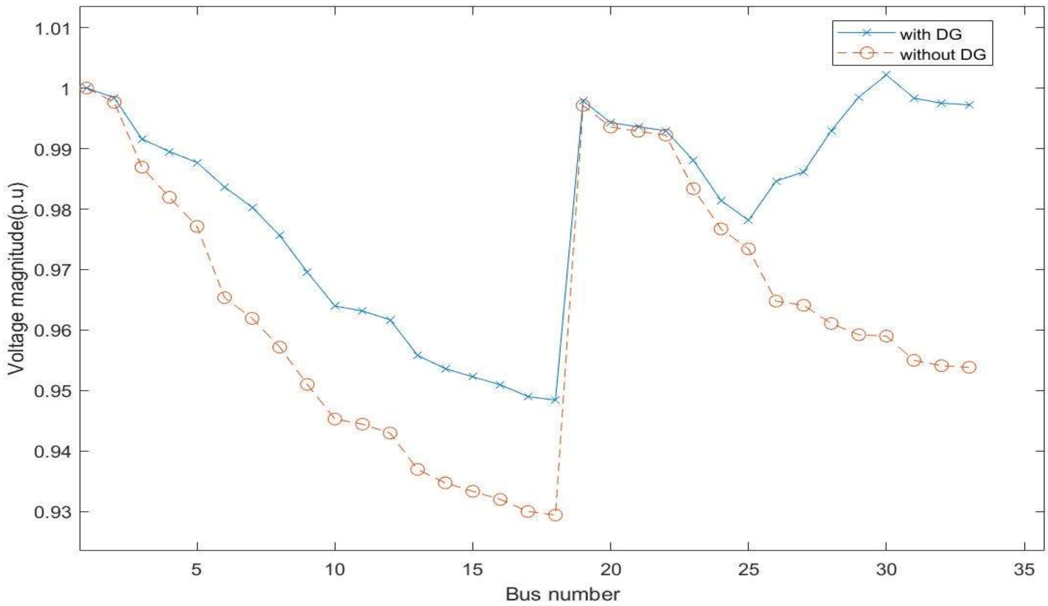

Figure 2. Voltage profile of 33 bus system with and without DG

Table 1 shows the losses, minimum voltage for base configuration and different algorithms used for optimal sizing of DG. The optimal location of the DG is identified as 30 based upon the Index Vector Method. The optimal DG size calculated as 1980.72 kVA at 0.8lag using SHO algorithm. After the placement of DG, the minimum voltage is improved from 0.9131 p.u to 0.9484 p.u and losses reduced from 202.665 KW to 64.5219 kW. Spotted hyena optimizer algorithm provided the accurate results better than other algorithms. Voltage profile of the 33-bus system is shown in Fig. 2.

4.2 Reconfigured 33 Bus Test System:

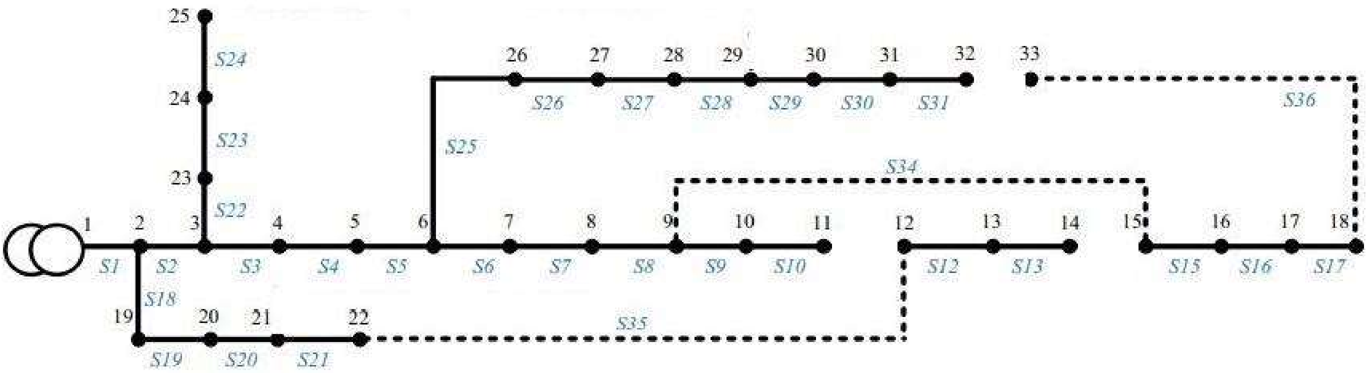

Figure 3. Line diagram of reconfigured 33 bus test system

Fig. 3shows the line diagram of reconfiguration system obtained by opening of the tie line switches 11,14,32,33,37. [18].

Table 2. Simulation results for reconfigured network with and without DG (33 bus system)

Parameters	Before reconfiguration	After reconfiguration	
		Without DG	With DG
PLOSS (kW)	202.665	167.4406	53.9549
QLOSS (kVAr)	135.132	112.8950	40.9571
DGsize (kVA)	---	---	1807.39, 0.8 lag
LOCATION	---	---	30
V_{min} ,BUS NO	0.9131 at 18	0.9249 at 32	0.9631 at33
TIE SWITCHES	33,34,35,36,37	11,14,32,33,37	11,14,32,33,37
POWER LOSS REDUCTION(%)	---	17.39	79.79

Table 2 shows the information of power losses and minimum voltage for after reconfiguration without DG. The losses have been reduced to 167.4406 kW and the minimum voltage is improved to 0.9249 p.u. After the placement of DG at location 30 the losses have been reduced to 53.9549kW and minimum voltage is improved to 0.9631 p.u.

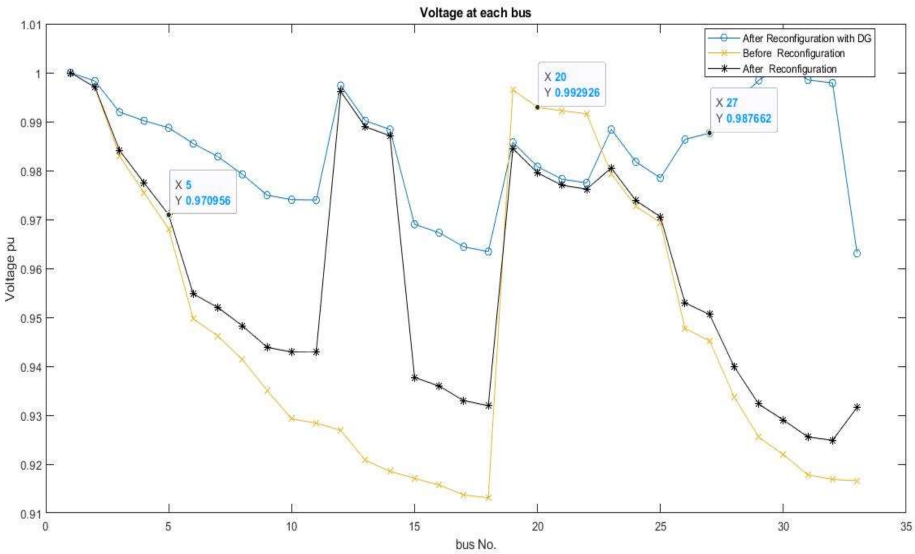

Figure 4. Voltage profile of reconfigured network without and with DG for 33 bus system.

5. Conclusion

The Spotted Hyena Optimizer algorithm is a novel nature-inspired meta-heuristic algorithm based on the unique behaviour of hyenas. It is implemented for the optimal sizing of DG in this article. The optimal location of DG is identified using the index vector method. Network reconfiguration is performed, and then the DG is installed at an optimal location with optimal sizing of the DG using SHO. It is tested on the IEEE 33-bus balanced system and achieves the objectives of voltage profile improvement and power loss reduced up to 79.79%, and it is compared with other methods. It is observed that the power loss has been reduced and the voltage is enhanced compared to base cases. The results indicate that SHO is competitive with other methods to solve optimization problems.

References

[1] Mesut E. Baran, and Felix F. Wu, "Optimal capacitor placement on radial distribution systems", *IEEE Transactions on Power Delivery*, Vol. 4, No. 1, pp. 725-734.January **1989.**

[2] Abdelsalam A. Eajal, and M. E. El-Hawary, "Optimal Capacitor Placement and Sizing in Unbalanced Distribution Systems with Harmonics Consideration Using Particle Swarm Optimization", *IEEE Transactions on Power Delivery*, Vol. 25, No. 3,pp. 1734-1741 July **2010**.

[3] Ch.Silpa and V.Usha Reddy, "Power loss reduction in distribution system using Autonomous Group Particle Swarm optimization algorithm", *International Advanced research journal in Science, Engineering and Technology(IARJSET),* Vol. 2, Issue 11, pp. 134-138, November **2015**.

[4] Veera Venkata Satya Narayana MURTY, and Ashwani KUMAR, "Comparison of optimal capacitor placement methods in radial distribution system with load growth and ZIP load model", *Front.Energy*,Vol.7, No.2,pp.197-213, **2013**.

[5] Satish Kansal,Vishal Kumar,and Barjeev Tyagi, "Optimal placement of different type of DG sources in distribution networks", *Electrical Power and EnergySystems,*Vol.53,pp.752-760,**2013**.

[6] D. Rama Prabha, and T. Jayabarathi, "Optimal placement and sizing of multiple distributed generating units in distribution networks by invasive weed optimization algorithm", *Ain Shams Engineering Journal*, Vol. 7, No. 2**, 2016**.

[7] Arjun Tyagi,AshuVerma and LokeshKumar Panwar, "Optimal placement and sizing of distributed generation in an unbalance distribution system using grey wolf optimization method", *International Journal of Power and Energy Conversion,*Vol. 10, No.2,pp.208-224, **2019**.

[8] V. Usha Reddy, Dr T. Gowri Manohar, "Optimal Capacitor Placement for loss reduction in Distribution Systems using Cuckoo Search Algorithm", *ITSI Transaction on Electrical and Electronics Engineering*, Vol.1, Issue 2, pp.68-70, **2013.**

[9] J.B.V.Subrahmanyam, and C.Radhakrishna, "Distributed Generator Placement and Sizing in Unbalanced Radial Distribution System", *International Journal of Electrical and Computer Engineering,* Vol.3,No.4,pp.753-760, **2009**.

[10] Mew E.Baran, and Felix F. Wu, "Network reconfiguration in distribution systems for loss reduction and load balancing", *IEEE Transactions on Power Delivery*, Vol. 4,No.2,pp. 1401-1407,April **1989**.

[11] J. S. Savier, and Debapriya Das, "Impact of Network Reconfiguration on Loss Allocation of Radial Distribution Systems*", IEEE Transactions on Power Delivery*, Vol.22,No.4, pp.2473-2480, October **2007.**

[12] Koichi Nara, Atsushi Shiose, Minoru Kitagawa, and Toshihisa Ishihara, "Implementation of genetic algorithm for distribution systems loss minimum re-configuration", *IEEE Transactions on Power Systems*, Vol. 7, No. 3, pp. 1044-1051,August **1992**.

[13] P.Haritha, Dr. V. Usha Reddy, P.Dinakara Prasad Reddy, "Optimal Network Reconfiguration using BPSO in Distribution Systems", *International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)*Impact Factor: 5.22 (SJIF-2017), e-ISSN:2455-2585Volume 4, Issue 11, November-**2018**.

[14] R.Srinivasa Rao,K. Ravindra,K. Satish,and S.V.L.Narasimham, "Power Loss Minimization in Distribution System Using Network Reconfiguration in the Presence of Distributed Generation", *IEEE Transactions on Power Systems*, Vol. 28,No.1,pp. 317-325 February **2013.**

[15] Seyed Abbas Taher, and Mohammad Hossein Karimi, "Optimal reconfiguration and DG allocation in balanced and unbalanced distribution systems", *Ain Shams Engineering Journal*, Vol.5,No.3, pp.735-749, September **2014.**

[16] Jen-Hao Teng, "A Direct Approach for Distribution System Load Flow Solutions*", IEEE Transactions on Power Systems,* Vol. 18, No. 3, July **2003.**

[17] Naderipour, A., Abdul-Malek, Z., Hajivand, M. *etal.* Spotted hyena optimizer algorithm for capacitor allocation in radial distribution system with distributed generation and micro grid operation considering different load types. *Sci Rep* **11,** 2728(**2021**).doi:10.1038/s41598-021-82440-9.

[18] B.Esmailnezhad, and H.Shayeghi, "Simultaneous Distribution Network Reconfiguration and DG Allocation

for Loss Reduction by Invasive Weed Optimization Algorithm", *Conference on Smart Electric Grids Technology (SEGT2012),* December18-19, pp.166-172, **2012**, Tehran ,Iran.

[19] J. N. Chandrasekhar and R. Gowtham Kumar Reddy, "Optimization of Radial Distribution system in the presence of Distribution Generation by Network Reconfiguration using Whale Optimization Algorithm", *Journal of information and computational sciences,* Vol.12,No.2, pp.132-146**, 2022**.