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Optimal Placement and Sizing of Distributed Generation in a Nigerian Distribution Network Using Cuckoo Search Algorithm

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Authors' contributions

This work was carried out in collaboration among all authors. Author GAA designed the study, painstakingly read through the manuscript and made necessary adjustments. Author SAS performed the software simulation analysis, wrote the first draft of the manuscript. Authors GAA and SAS managed the analyses of the study and the literature searches. Authors HAA and AOB Hassan provided an enabling environment for the completion of this paper read through the manuscript and made their necessary input. All authors read and approved the final manuscript.

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ABSTRACT

The optimal placement and sizing of Distributed Generation (DG) using has been shown by researchers to be effective in the reduction of power losses and improvement of voltage profile on a radial distribution network. However, it has not been applied to solve the inherent problems of real Nigerian distribution network. Therefore, this paper aimed at optimal placement and sizing of DG using Cuckoo Search Algorithm (CSA) in a real Nigerian distribution network taking Ayepe 34-bus as a case study.

The objective function was formulated considering the real power loss, the minimum Voltage Stability Index (VSI) and the reactive power loss using weight method. The formulated objective

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function was incorporated into the CSA. Power flow analyses were performed with line and load data of Ayepe 34-bus distribution network without the incorporation of DG for the base case, with incorporation of single DG and two DG units.
The total active power loss, minimum VSI and total reactive power loss for the base case were 0.762 MW, 0.4741, 0.146 MVar respectively. The optimal size and bus location after single DG installation were found to be (3.5 MW, 11) respectively while the optimal size and location for the two-DG units' installation were found to be (2.4 MW, 13; 1.4 MW, 21), respectively. With single DG unit, the total active power loss, minimum VSI and total reactive power loss were 0.141 MW, 0.9064 and 0.027 MVar respectively. For two-DG units, the total active power loss, minimum VSI and total reactive power loss 0.131 MW, 0.9287 and 0.025 MVar respectively.
The results established the effectiveness of the optimal placement and sizing of DG for the Nigerian distribution system in terms of reduction of power losses, improvement of voltage stability index and profile using CSA technique.

Keywords: Distributed generation; radial distribution network; cuckoo search algorithm; real power loss; voltage stability index; reactive power loss.

1. INTRODUCTION

The Distribution networks of the Nigerian electrical power systems are usually radial in nature for simplicity of operation. The Radial Distribution Network (RDN) is fed from a substation which receives power from a centralized generating station, which is often characterized by electricity crisis and large-scale power outage. Besides, the high resistance to reactance ratio of the radial distribution network results in huge power losses, low voltage stability and large voltage drops. Under critical loading conditions, sudden voltage collapse may occur due to a low value of voltage stability index at most of network's bus [1]. The problems of power losses and voltage instability of the RDN needs to be addressed in other to meet the requirements of the end-users, increase the life span of the distribution network and raise the overall efficiency and reliability of power system [2].

It has been discovered by researchers that the introduction of Distributed Generation (DG) into the power network may produce influence on the stability, voltage profile, economy, electric power loss and reliability [3]. This depends on several factors including the location of DG, the size of DG in relation to the network capacity, grid strength, total connected load local to the generator, and the topology of the network under consideration. Selecting the best places for installation of DG units and its preferable sizes in large distribution system is a complex combinatorial optimization problem which can be solved by any optimization technique. As more objectives and constraints are considered in the problem formulation, the application becomes more challenging because more data are required to generate results [4]. Several researchers have used various optimization techniques to solve the DG placement and sizing problems such as analytical methods [5] and artificial intelligent approaches such as Genetic Algorithm (GA) [6], Particle Swarm Optimization (PSO) [7], Artificial Bee Colony [8], Ant Colony Optimization [9], Cuckoo Search Algorithm [10]. Some of the algorithm have been modified to overcome their limitation and to improve their quality of solution. Additionally, most of the optimization methods have been tested on the standard networks.

Wang, et al. proposed two analytical optimization models to obtain the optimal placement of DGs and capacitor banks to maintain better voltage profile in the distribution systems which was validated on the IEEE 41 bus distribution network [11]. Sirish, et al. proposed a KVS- Direct Search Algorithm to determine the optimal sizes and location of static Capacitors and Distributed Generators (DGs) in a distribution system. The algorithm searches for all possible locations in the system for a particular size of capacitor or DG and places them at bus which gives maximum reduction in real power loss. The proposed method was tested on the IEEE 69-bus radial distribution systems [12]. Sharma, et al. developed a heuristic approach for selection of optimal location and determination of optimal capacity of DG sources. The technique adopted Genetic Algorithm and optimal power flow for the decision making process [13]. Alinejad-Beromi, et al. presented a Particle Swarm Optimization method for optimal siting and sizing of DG in distribution systems with the aim of optimal DG allocation and sizing for profile improvement, loss reduction and THD (Total Harmonic Distortion) reduction [14]. Roy, et al. presented oppositional Cuckoo optimization algorithm to solve DG allocation problem of radial distribution system. In the work, they introduced an oppositional based learning (OBL) with Cuckoo Optimization Algorithm (COA) for improving the convergence speed of the COA. The methodology was applied to the 33 and 69 bus radial distribution networks. The results revealed that the proposed methodology was very effective in finding the optimal siting and sizing of DG [15]. Kamarudin, et al. presented Firefly Algorithm for optimal location and sizing of DG on IEEE 33-bus radial distribution network. The result proved the capability of the algorithm in improving both the voltage profile and the power losses in the system [16].

Several algorithms have been proposed to optimize the size and placement of DG in a standard IEEE radial distribution networks as reviewed in the few aforementioned studies. However, none considered nor reported how optimal placement and sizing of DG has affected practical distribution networks in developing countries such as Nigerian distribution networks. In this paper, a Cuckoo Search Algorithm (CSA) was proposed for the optimal placement and sizing of DG to mitigate the real and reactive power losses and improve the voltage stability of a Nigerian distribution network. The performance of the CSA was investigated by various test cases on a simplified Ayepe 34-bus distribution network of the Ibadan Electricity Distribution Company (IBEDC) in Nigeria.

2. METHODOLOGY

2.1 Problem Formulation

The main objective of this work is to minimize the active and reactive power losses while improving the voltage stability of the distribution system through the optimal placement and sizing of DG implementation. To solve the DG placement and sizing problem, the weight method is used for the three objectives. The main strength of this method is its efficiency and suitability to produce a strong non-dominated solution which can be used as an initial solution for other techniques [4]. The objective function is formulated as:

$$F_{min} = c_p f_p + c_v f_v + c_q f_q \quad (1)$$

Where f_p is the total real power loss reduction index, f_v is the voltage stability improvement index while f_q is the total reactive power loss reduction index. $c_p,\ c_v\ and\ c_q$ are the weighing coefficients which represent the relative importance of the objective functions. It is usually assumed that

$$c_p + c_v + c_q = 1 \text{ and } 0 < c \leq 1 \quad (2)$$

The choice of weighing factors depends on the importance of the objective function. In this study, real power which is the most crucial objective function receives a significant weight of 0.5; Voltage Stability Index (VSI) takes a weight of 0.3 due to its power quality impacts while the reactive power loss reduction index takes a least significant weight of 0.2. To minimize the objective function, the CSA was chosen due to its simplicity, fast convergence, ease of implementation and efficiency in solving highly non-linear optimizations with real world engineering applications. It is also effective in obtaining global value when solving complex optimization problems in that it explores search space more efficiently than other algorithms.

2.1.1 Objective functions

In this paper, the first objective function formulated as total power loss reduction index is given by:

$$f_p = \frac{\sum_{ni=1}^{N} I_{ni}^2 R_{ni}}{\sum_{ni=1}^{N} I_{ni(no\ DG)}^2 R_{ni}} = \frac{P_L}{P_{L(no\ DG)}} \quad (3)$$

Where $P_{L(no\ DG)}$ and P_L are the total real power losses of distribution system before and after installation of DG respectively; I_{ni} is the current magnitude and R_{ni} is the resistance of the branch between two buses. I_{ni} can be obtained from the power flow analysis.

The Voltage Stability Index (VSI) is given by [4]:

$$\text{VSI (ni)} = |V_{mi}|^4 - 4[P_{ni}(ni)R_{ni} + Q_{ni}(\text{ni})X_{ni}]\,|V_{ni}|^2 - 4[P_{ni}(ni)R_{ni} + Q_{ni}(\text{ni})X_{ni}]^2 \quad (4)$$

where V_{mi} is the sending node voltage; while V_{ni}, P_{ni}, Q_{ni}, $R_{ni}\ and\ X_{ni}$ are voltage, real power, reactive power, resistance, and reactance for the receiving node. The index is modified to become an objective function for improving VSI, as follow:

$$f_v = \frac{1}{(VSI(ni))_{min}} \quad n_i = 2, 3\ldots\ldots, n_n \tag{5}$$

where $(VSI(ni))_{min}$ >0 for i =2, 3…... n, so that a feasible solution will exist. It is very essential to identify the weak buses for nodes with minimum VSI that are exposed to voltage instability.

The total reactive power loss reduction index is given by:

$$f_q = \frac{\sum_{ni=1}^{N} I_{ni}^2 X_{ni}}{\sum_{ni=1}^{N} I_{ni(no\ DG)}^2 R_{ni}} = \frac{P_L}{P_{L(no\ DG)}} \tag{6}$$

where I_{ni} is the current magnitude with DG through branch 'ni', X_{ni} is the reactance of the branch and $I_{ni(no,DG)}$ is the current magnitude without DG through branch 'ni'.

The objective functions are subject to equality and inequality constraints.

2.1.2 The equality constraints

The equality constraints are the non-linear power flow equations of the distribution system and are written as equations (7) and (8) respectively:

$$P_{Gi} - P_{Di} - \sum_{i=1,j=2}^{N} V_i V_j Y_{ij} \cos(\theta_i - \delta_i + \delta_j) = 0 \tag{7}$$

$$Q_{Gi} - Q_{Di} - \sum_{i=1,j=2}^{N} V_i V_j Y_{ij} \sin(\theta_i - \delta_i + \delta_j) = 0 \tag{8}$$

Where P_{Gi} and P_{Di} are the real power generated/demand at the ith bus; $Q_{Gi}$and Q_{Di} are the reactive power generated/demand at the ith bus; V_i and V_j are the voltage magnitudes at the i^{th} and j^{th} bus; θ_i is the angle of the ij^{th} element in the admittance matrix; δ_i and δ_j are the voltage angle at the i^{th} and j^{th} bus.

2.1.3 The inequality constraints

The occurrence of the voltage rise that regularly arises due to reverse power after DG implementation will be considered throughout this work. Consequently, the voltage profile is retained within standard limits at each bus, which is expressed as:

$$0.90 \text{ p.u.} \leq V_i \leq 1.00 \text{ p.u.} \tag{9}$$

As DG capacity is naturally limited by the energy resources at any given location and the capacity of the distribution network, the active and reactive power for DG was formulated as a discrete value with 100-kW, 50kVar increments and restricted by lower and upper limit, as:

$$0\text{MW} \leq P_{dg} \leq 5MW \tag{10}$$

$$0 \text{ MVar} \leq Q_{dg} \leq 1\ M\text{Var} \tag{11}$$

2.1.4 Power flow technique

Due to the topology and radial structure of the distribution network, high resistance to reactance, large number of nodes, ill-conditioned and unbalanced nature of loads, conventional load flow methods (such as Gauss-Seidel, Newton Raphson, Fast decoupled methods) may provide inaccurate results and may not converge. Hence, the forward/backward sweep power flow method was used to obtain the losses in the system due to its high computational performance, implementation simplicity, robust convergence, low memory requirement [17]. It also takes advantage of the radial structure of the distribution system in order to achieve fast convergence.

2.2 Cuckoo Search Algorithm

Cuckoo Search Algorithm is a meta-heuristic optimization technique whose birth was claimed from inspiration surrounding the brood parasitism of cuckoo species, which lay their eggs in the nests of other host birds. CSA was developed by Yang and Deb in 2009 [18], and it has been applied to various engineering optimization problems. The fundamental ideas in modeling this algorithm was borrowed from the fact that if a host bird discovers foreign egg in its nest, it will either abandon the nest and build a new nest elsewhere or throw the foreign egg away.

Three rules are taken into account in cuckoo search algorithm as follows:

(i) At one time, each cuckoo only lays one egg, and leaves it in a randomly chosen nest;
(ii) The algorithm will carry over the best nest with high quality eggs (solutions) to the next generations;
(iii) A host bird can discover a foreign egg with a probability, p_a = [0, 1] while the number of available host nests is fixed. In this case, the host bird can either abandon its nest and build a completely new nest elsewhere or simply throw the eggs away [19].

A Lévy flight is performed in other to produce new solutions, $x^{i(t+1)}$ for a cuckoo as given in the equation.

$$x^{i(t+1)} = x^{i(t)} + \alpha \oplus \text{Levy}(\lambda) \tag{12}$$

where α is the step size which should be associated to the problem of interests scales; α can be set to value 1 in most situations. Equation (12) is basically the stochastic equation for random walk, which is a Markov chain whose next status or location only depends on the current status or location, and the transition probability, which are the first and second term respectively. The product ⊕ represents the entry wise multiplication, which is similar to those used in Particle Swarm Optimization (PSO). In terms of exploring the search space, random walk via Lévy flight is more efficient as its step length is much longer in the long run [19].

The random step length of Lévy flight, which fundamentally provides a random walk, is derived from a Lévy distribution with an infinite variance and infinite mean [4].

$$\text{Levy} \sim u = t^{-\lambda} \quad (13)$$

Here, the sequential jumps of a cuckoo fundamentally form a random walk process with a power law step length distribution with a heavy tail [19]. Numerous new solutions should be generated by Lévy walk near the best solution obtained, since this procedure will speed up the local exploration. However, to confirm the algorithm will not be trapped in a local optimum, a substantial part of the new solutions must be generated through far field randomization, so that the locations would be sufficiently far from the current best solution [18].

2.3 Realization of DG Placement and Sizing Using the Cuckoo Search Algorithm

The implementation of Cuckoo Search Algorithm (CSA) for optimal placement and sizing of DG problem entailed the determination of several steps of procedure as shown in the flowchart of Fig. 1. On the other hand, forward/backward sweep algorithm was used to evaluate the objective function, due to its computational effectiveness, low memory consumptions, and robust convergence characteristics. The algorithm for the code development is as follows which is in line with the flow chart in Fig. 1:

Step 1- Input: Enter the line and load data of the test systems. The weighing factors C_p, C_v and C_q are set to 0.5, 0.3 and 0.2 respectively.

Step 2- Initialize the Cuckoo Search Algorithm Parameters: The CSA parameter setting, number of nests n=20, step size, α=1, maximum generation of 100 iterations and the probability to discover foreign eggs, P_a=0.6 were applied in this work. This values were adapted for use because they have been discovered by researchers [4] that this range of value gives optimal values optimization.

Step 3- Load Flow for Base Case: The load flow is performed using forward/backward sweep according to obtain the branch currents and bus voltages of the distribution network. The VSI, total active and reactive power loss are calculated for the base case using equations (3), (4) and (6) respectively.

Step 4- Generate Initial Population of the Host Nest*:* The CSA was provided with an initial range of host nest, n=20 at the start. Each nest was initialized randomly within their effective operating bounds. The initialization was done based on the inequality constraints (equations 8-10). Each nest consists of the DG size and location which is a solution.

Step 5- Run power flow for each Host Nest: Obtain the corresponding load flow solution for each of the host nest obtained in step 4.

Step 6- Calculate Objective Function for each Host Nest and Determine Fitness: Find the fitness value of the host nest by calculating the objective function as given in equation 1.

Step 7- Generation of Cuckoo: A cuckoo, which is a new solution, is randomly generated by Levy flight.

Step 8- Power Flow and Evaluation of Cuckoo: The load flow is performed for the new cuckoo. The branch currents and the nodal voltages are obtained. The objective function is then calculated according to equation (1) to determine the quality of solution of the cuckoo.

Step 9- Replacement: A nest is selected among n randomly, if the quality of new solution in the selected nest is better than the old solution, it is replaced by the new solution (Cuckoo).

Step 10- Generation of new nest: The worst nests are abandoned based on the probability (P_a) and new ones are built using levy flight.

Step 11-Termination: The stopping criterion is set to a tolerance value of 1×10^{-6} and maximum generation of 100 iterations in case of a divergent result. If the maximum number of iterations is reached or specified accuracy level is achieved, the iterative process is terminated and the result of the CSA displayed. Otherwise, go to step 7 for continuation.

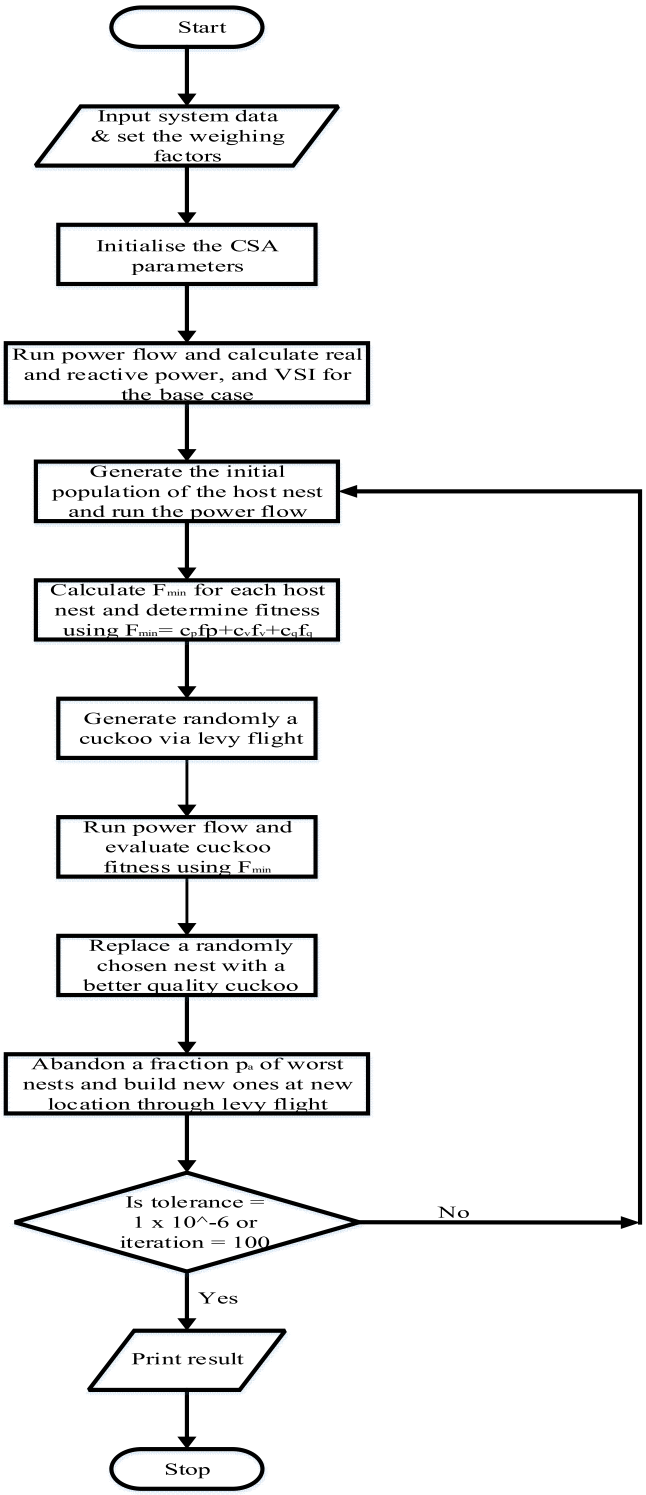

Fig. 1. The flow chart of CSA method for optimal placement and sizing of DG

3. RESULTS AND DISCUSSION

To evaluate the performance of a Cuckoo Search Algorithm in the application of DG placement and sizing, the 11kV Ayepe 34-bus distribution system of Ibadan Electricity Distribution Company (IBEDC) shown in Fig. 2 was employed in this paper. The network consists of 34 buses with the first bus serving as the substation which delivers load to other buses in the network. The total real power loads and reactive loads on the 34 bus network are 4.12 MW and 2.05 Mvar respectively.

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To simulate the optimal placement and sizing of DG in the distribution system, the parameters used are according to the data provided in Table 1. In the simulation, all the buses of the system have been considered as candidate for installation of DGs except the first bus which is represented as in-feed of electric power from transmission system.

Table 1. The parameter settings

Parameters	Value
Real power limit of DG (MW)	0-5
Voltage limit (pu)	0.90-1.00
Reference power in MVA	100
Reference voltage in KV	11
Maximum number of DG units	2

In this paper, four different test cases were explored which are as follows:

Case 1: No DG was installed, then the power flow was performed so as to calculate the real power loss, reactive power loss and the VSI.

Case 2: 1 DG was installed in the system, then the optimal location and size was obtained through the CSA. The power flow was then performed to obtain the real power loss, reactive power loss and the VSI.

Case 3: 2 DG units were installed in the system, then the optimal locations and sizes were obtained through the CSA. The power flow was then performed to obtain the real power loss, reactive power loss and the VSI.

Case 4: The optimal size obtained in case 2 was installed at a bus with a very low VSI to demonstrate the effectiveness of the CSA. The power flow was then performed to obtain the real power loss, reactive power loss and the VSI.

The simulation results of the optimal placement and size of DG in case of no DG installation was compared with the installation of one DG (single-DG), two DG units (multi-DG) and case four are tabulated in Table 2 while the characteristics of the voltage stability index and voltage profile are illustrated in Figs. 3 and 4 respectively.

In Table 2, it can be seen that the objective function values before installation of DG, which include the total power losses, minimum VSI values and total reactive power losses, are 0.762 MW, 0.4741 and 0.146 MVar respectively. The optimal size obtained by the CSA for the single DG installation was found to be 3.5MW at bus 11 while for the multi-DG (2 DG) the optimal sizes were found to be 2.4 MW and 1.4 MW at buses 13 and 21 respectively. It can also be seen that the power loss reduction in case of one DG, two DGs installation compared to no DG (the base case) are 81.5% and 82.8% respectively. The optimal size obtained by the CSA was installed at bus 15 which had a very low VSI for the fourth case. The result showed 78.1% loss reduction which is lesser than that obtained for case 2 (81.5%). This shows that the CSA is effective in obtaining an optimal placement for the DG when compared with when DG was installed at a bus with a very low VSI.

Figures 3 and 4 clearly illustrates the voltage stability index and the voltage profile for the Ayepe 34-bus. It can be clearly seen that the VSI values for all nodes were poor before the DG installation. After the DG was installed for both single and multi-DG, the VSI values improved. Furthermore, the results showed different voltage levels throughout pre and post installation of DG. Fig. 3 illustrates the worst voltage profile refers to the system without DG and it improved through optimal placement and sizing of DG such as case 2 and case 3 with best voltage profile compared with other cases.

The results of this work have shown that the installation of DG with the appropriate capacity reduces the total power losses in a typical Nigerian distribution network, improved the voltage stability index and maintain the voltage profile within acceptable limits.

Table 2. Comparison of results between the four test cases for ayepe 34-Bus feeder

Case	Bus no	DG size (MW)	Ploss (MW)	Qloss (MVar)	%Ploss reduction	Min VSI
1			0.762	0.146		0.4741
2	11	3.5	0.141	0.027	81.5	0.9064
3	13, 21	2.4, 1.4	0.131	0.025	82.8	0.9287
4	15	3.5	0.167	0.032	78.1	0.8645

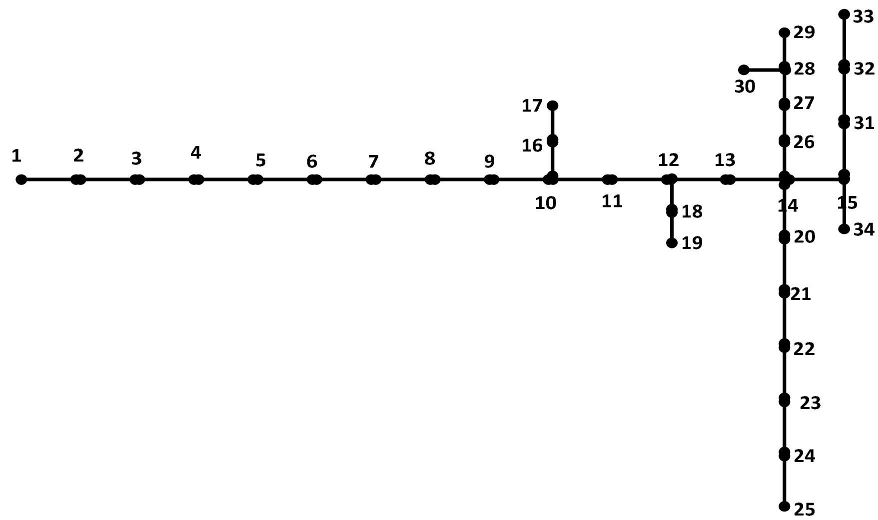

Fig. 2. Ayepe 34-bus distribution network

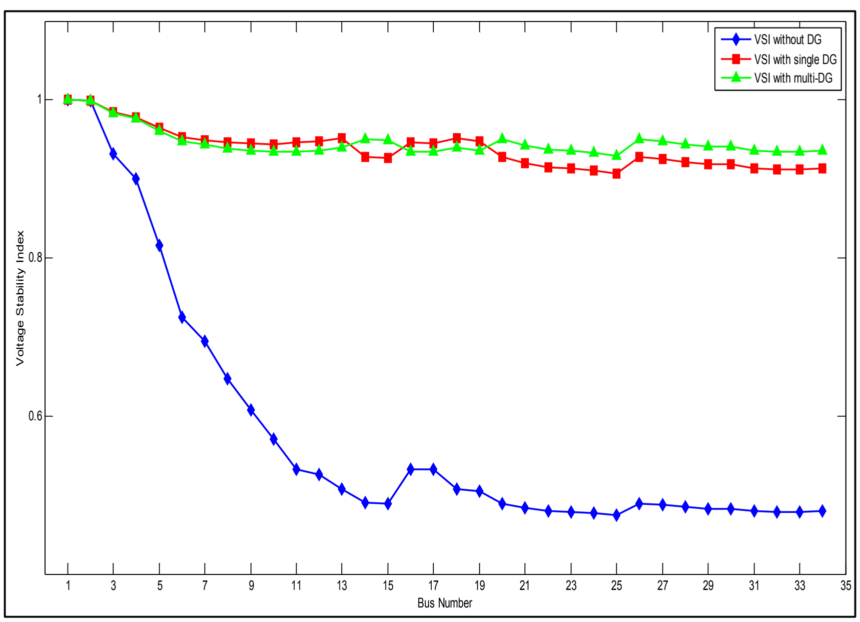

Fig. 3. Voltage stability index for Ayepe 34-bus

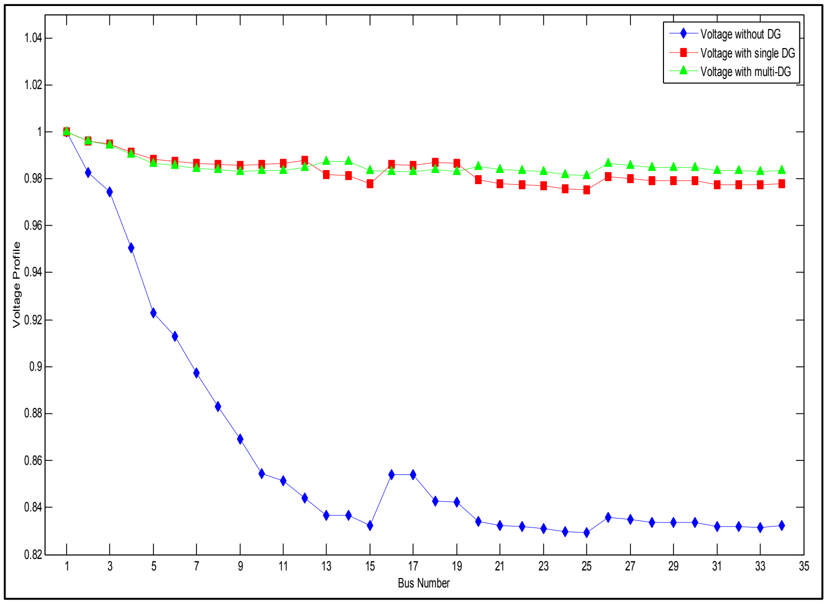

Fig. 4. Voltage profile for Ayepe 34-bus

4. CONCLUSION

In this paper, the application of Cuckoo Search Algorithm for DG placement and sizing problem in a radial distribution system has been investigated. The main objective was to reduce total power losses and improve the voltage stability within the voltage constraints. The CSA algorithm was implemented in the MATLAB environment and applied to Ayepe 34-bus distribution network of the IBEDC to show the applicability of the CSA algorithm. It has been demonstrated that the CSA is capable of saving an enormous amount of power, attain improvement in stability and voltage profile when used for optimal location and sizing of DG in Nigerian distribution network. Thus, the CSA is suitable for DG allocation in practical distribution network.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Moradi MH, Abedini M. Optimal multi-distributed generation, location and capacity by genetic algorithms. 4th International Power Engineering and Optimization Conference (PEOCO). 2010; 440 – 444.
2. Priyanka D, Banerjee S. Optimal sizing and placement of capacitor in a radial distribution system with loss sensitivity factor and firefly algorithm. International Journal of Engineering and Computer Science. 2014;3(4):5346-5352.
3. Liu W, Zhang H. Allocation of DG based on improved particle swarm optimization algorithm. 2nd International Conference on Measurement, Information and Control. 2013;1242-1245.
4. Tan, WS, Hassan MY, Majid MS, Rahman HA. Allocation and sizing of DG using cuckoo search. IEEE International Conference on Power and Energy (PECon), Kota Kinabalu Sabah, Malasia. 2012;133–138.
5. Nweke JN, Ekwue AO, Ejiogwu EC. Optimal location of distributed generation on the Nigerian power system. Nigerian Journal of Technology (NIJOTECH). 2016; 35(2):398-403.
6. Hassan A, Fahmy F, Nafeh A, Abuelmagel M. Genetic single objective optimization for sizing and allocation of renewable DG systems. Int. J. Sustain Energy. 2015;1(1): 1-8.
7. Varesi K. Optimal allocation of DG units for power loss reduction and voltage profile improvement of distribution network using PSO algorithm. World Academy of Science, Engineering and Technology; 2011.

8. Karaboga D, Akay B. A comparative study of artificial bee colony algorithm. Applied Mathematics and Computation. 2009; 214(1):108-132.
9. Dorigo M, Stutzle T. Ant colony optimization. A Bradford book, the MIT Pree, Cambridge, Massachusett, London, England; 2004.
10. Majid M, Ozdemir A, Ceylen. Optimal DG allocation and sizing in radial distribution networks by cuckoo search algorithm. 19th International Conference on Intelligent System Application to Power System (ISAP). 2017;1-6.
11. Wang M, Zhong J. A Novel Method for Distributed Generation and Capacitor Optimal Placement considering Voltage Profiles. IEEE; 2011.
12. Sirish TS, Rao GVS, Murthy KVS. Optimal capacitor and DG placement for loss less distribution on 69- bus system using KVS – Direct Search Algorithm. International Journal of Engineering Trends in Electrical and Electronics. IJETEE. 2013;3(1). ISSN: 2320-9569.
13. Sharma KM, Vittal KP, Seshagiri P. A heuristic approach for distributed generation sources location and capacity evaluation in distribution systems. TENCON IEEE regional 10 conferences. IEEE Publication Conference. 2008;1-6.
14. Alinejad – Beromi Y, Sedighizadeh M, Sadighi MM. A particle swarm optimization for sitting and sizing of distributed generation in distribution network to improve voltage profile and reduce TDH and Losses in Universities Power Engineering Conference (UPEC),43rd International. 2008;1-5.
15. Roy S, Sultana S, Roy PK. Oppositional optimization algorithm to solve DG allocation problem of radial distribution system. International Conference on Recent Developments in Control, Automation and Power Engineering (RDCAPE). 2015;44-49.
16. Kamarudin MN, Hashim TJT, Musa A. Optimal placement and location of distributed generation for loss minimization using fierfly algorithm. Indonesian Journal of Electrical Engineering and Computer Science. 2019;14(1):421-427.
17. Moeini A, Yassami, AM, Owlady M, Sadeghi MH. Disco planner flexible DG allocation in MV distribution networks using multi-objective optimization procedures. 12th International Conference on Optimization Procedures. International Conference on Optimization of Electrical and Electronic Equipment, OPTIM. 2010; 240-245.
18. Yang XS, Deb S. Engineering optimization by cuckoo search. Int. J. Mathematical Modelling and Numerical Optimization. 2009;1:330-343.
19. Yang XS, Deb S. Cuckoo search via levy flights in nature and biologically inspired computing, (NaBIC), World Congress. 2010;32(4):210-214.

APPENDIX A1

Bus Data of AYEPE 34-Bus Radial Distribution System,

Base MVA=100; Base Voltage kV=11, f= 50Hz

Bus_I	Pd	Qd	Bs	Type	Vm	Va	BasekV	Vmax	Vmin
1	0	0	0	3	1	0	11.00	1.05	0.95
2	200	100	0	3	1	0	11.00	1.05	0.95
3	200	100	0	3	1	0	11.00	1.05	0.95
4	120	50	0	3	1	0	11.00	1.05	0.95
5	120	50	0	3	1	0	11.00	1.05	0.95
6	120	50	0	3	1	0	11.00	1.05	0.95
7	120	50	0	3	1	0	11.00	1.05	0.95
8	23	15	0	3	1	0	11.00	1.05	0.95
9	200	100	0	3	1	0	11.00	1.05	0.95
10	45	30	0	3	1	0	11.00	1.05	0.95
11	120	50	0	3	1	0	11.00	1.05	0.95
12	23	15	0	3	1	0	11.00	1.05	0.95
13	45	30	0	3	1	0	11.00	1.05	0.95
14	135	90	0	3	1	0	11.00	1.05	0.95
15	200	100	0	3	1	0	11.00	1.05	0.95
16	23	15	0	3	1	0	11.00	1.05	0.95
17	200	100	0	3	1	0	11.00	1.05	0.95
18	200	100	0	3	1	0	11.00	1.05	0.95
19	200	100	0	3	1	0	11.00	1.05	0.95
20	120	50	0	3	1	0	11.00	1.05	0.95
21	200	100	0	3	1	0	11.00	1.05	0.95
22	120	50	0	3	1	0	11.00	1.05	0.95
23	120	50	0	3	1	0	11.00	1.05	0.95
24	200	100	0	3	1	0	11.00	1.05	0.95
25	120	50	0	3	1	0	11.00	1.05	0.95
26	200	100	0	3	1	0	11.00	1.05	0.95
27	120	60	0	3	1	0	11.00	1.05	0.95
28	120	60	0	3	1	0	11.00	1.05	0.95
29	40	30	0	3	1	0	11.00	1.05	0.95
30	120	60	0	3	1	0	11.00	1.05	0.95
31	120	60	0	3	1	0	11.00	1.05	0.95
32	80	60	0	3	1	0	11.00	1.05	0.95
33	120	60	0	3	1	0	11.00	1.05	0.95
34	23	15	0	3	1	0	11.00	1.05	0.95

APPENDIX A2

Line Data of AYEPE 34-Bus Radial Distribution System

f	t	r (ohms)	x(ohms)	Status	Ratio	RateA
1	2	0.41975	0.72266	1	0	9990
2	3	0.073	0.12568	1	0	9990
2	4	0.0365	0.06284	1	0	9990
4	5	0.2555	0.43988	1	0	9990
5	6	0.01825	0.03142	1	0	9990
6	7	0.00913	0.0152	1	0	9990
6	8	0.01825	0.03142	1	0	9990
8	9	0.00913	0.0157	1	0	9990
8	10	0.09125	0.0157	1	0	9990
10	11	0.073	0.12568	1	0	9990
11	12	0.073	0.12568	1	0	9990
12	13	0.05475	0.09426	1	0	9990
13	14	0.05475	0.09426	1	0	9990
13	15	0.0365	0.06284	1	0	9990
15	16	0.00913	0.01571	1	0	9990
15	17	0.1095	0.18852	1	0	9990
17	18	0.2190	0.37704	1	0	9990
18	19	0.0913	0.1571	1	0	9990
19	20	0.1825	0.3142	1	0	9990
20	21	0.1552	0.26707	1	0	9990
21	22	0.01825	0.03142	1	0	9990
18	23	0.01825	0.03142	1	0	9990
23	24	0.05475	0.09426	1	0	9990
18	26	0.01825	0.31420	1	0	9990
26	27	0.1825	0.03142	1	0	9990
27	28	0.01825	0.03142	1	0	9990
27	29	0.0365	0.06284	1	0	9990
29	30	0.01825	0.03142	1	0	9990
30	31	0.05475	0.09426	1	0	9990
31	32	0.073	0.12568	1	0	9990

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