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# Optimal allocation of wind based distributed generators in distribution system using Cuckoo Search Algorithm

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**Abstract**

In recent years the demand of electrical energy increases and limited availability of conventional generation sources, it is very important to use renewable energy resources in the power system network. Optimal location of renewable based distributed generators in distribution system is a challenging issue in recent years. In this paper an effective technique based on the cuckoo search algorithm is proposed to determine optimal allocation of wind based distributed generators in the distribution system. The objective is to reduce power loss of the distribution system. The proposed method is tested on IEEE 69 bus test system and the obtained results are compared with other methods for validation.


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*Keywords:* Distributed Genarators(DGs); Cuckoo Search Algorithm(CSA); Radial distribution system(RDS)

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## 1. Introduction

With the mounting demand of electrical energy, depleting fossil fuels and environmental concerns, it is essential to consider renewable based distributed generators (DGs) such as wind, solar and biomass based generation in the distribution system. Among these solar and wind based technologies are used because of its availability in nature. Generally power losses in the distribution system are high compared to the transmission systems because of high R/X ratio and radial nature [1]. So reduce these losses and improving operating efficiency the system, it is necessary to place these sources optimally in the distribution network. Proper allocation of these sources reduces the power losses, improving the voltage profile of the system. In the same manner improper allocation of these sources diminishes the distribution network performance, i.e. power losses and operating cost increases. So the optimal allocation of these sources in the distribution system for reducing power losses and improving the voltage profile is a challenging issue for researchers working in this field.

Various methods like mixed integer linear programming (MILP) [2], dynamic programming [3], analytical [4], improved analytical (IA) [5] methods are used to solve DG allocation problem for reducing power losses in the distribution system. But the above mentioned techniques are depending upon certain assumptions like continuity, differentiability and convexity. Also, these methods solve only linear optimization problems effectively. But the DG location and sizing problem is not a linear optimization problem, it is a discrete nonlinear optimization problem. So these techniques are not that much effective in solving optimal allocation problem in the distribution system. So it is necessary to consider search algorithms importance in solving above mentioned problem. Recently many search algorithms, i.e. Genetic Algorithm (GA) [6], Particle Swarm Optimization (PSO) [7], Combined Genetic and Particle Swarm Optimization [8], Multi Objective Particle Swarm Optimization (MOPSO) [9], Tabu Search(TS) [10] Simulated Annealing (SA) [11], artificial bee colony(ABC)[12] are used to solve DG allocation problem effectively with reduced power losses as an main objective. But the convergence time and operating efficiency of the system is high for these methods. In this paper an efficient technique based on the cuckoo search algorithm is presented for optimal allocation of wind based distributed generators for reducing real power loss of the distribution system. The developed method is implemented on IEEE 69 bus test system and the results are compared with other methods for validation.

The remaining sections of the paper are as follows: In section 2 problem formulation is explained, In section 3 wind turbine modeling is explained, In section 4 Cuckoo Search Algorithm (CSA) is used for optimal allocation of wind based DGs is explained, Results and Discussion explained in section5 followed by the conclusion is explained in Section 6.

## 2. Problem Formulation

### 2.1. Power flow equations

A sample radial distribution system is shown in Fig.1. The current injected, branch current, voltage, real power losses are calculated from the direct approach of distribution load flow [13] and it is given in Eq.(1), Eq.(2), Eq.(3) , Eq.(4) and Eq.(5).

$$I_a = \left( \frac{P_a + jQ_a}{V_a} \right)^* \tag{1}$$

$$J_{a,a+1} = \mathrm{I}_{a+1} + I_{a+2} \tag{2}$$

$$J = [BIBC][I] \tag{3}$$

$$V_{a+1} = V_a - J_{a,a+1}(R_{a,a+1} + jX_{a,a+1}) \tag{4}$$

$$P_{loss}(a,a+1)=\left(\frac{P_{a,a+1}^{2}+Q_{a,a+1}^{2}}{|V_a|^{2}}\right) \tag{5}$$

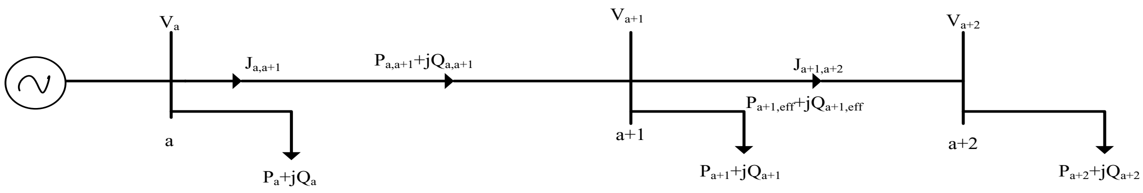


**Fig. 1**.Sample distribution system

The total power losses of the system can be calculated from the following equation

$$P_{Totalloss}=\sum_{a=1}^{nbr}P_{loss}(a,a+1) \tag{6}$$

2.2 Objective function formulation

The objective of the proposed method is to reduce power losses of the system with the optimal allocation of wind based DGs in the distribution system.

$$Minimize(OF)=\min(P_{Totalloss}) \tag{7}$$

The above objective function satisfying the following operating constraints of the distribution network

*2.3. Constraint*

Power balance constraint:

$$\sum_{a=2}^{n}P_{DG,a}\le\sum_{a=2}^{n}P_a+\sum_{a=1}^{nbr}P_{lossa,a+1} \tag{8}$$

*Voltage constraint*

$$V_{a,\min}\le|V_a|\le V_{a,\max} \tag{9}$$

**3. Wind generation system modeling**

The power generated from wind turbine depends upon the model and resource data that is the wind speed at a particular location and type of wind turbine used [14]. The electrical output power of a wind turbine is determined by using Eq.(10).

Where $v_{cin}$, $v_{cout}$, $v_N$ are different speeds corresponding to the wind turbine and $P_{rated}$ is rated output power of wind turbine and it can be determined from Eq. (11).

$$P_w = \begin{cases} 0 & v_w < v_{cin} \quad or \quad v_w > v_{out} \\ P_{rated} \dfrac{v_w - v_{cin}}{v_N - v_{cin}} & v_{cin} \le v_w \le v_N \\ P_{rated} & v_N \le v_w \le v_{cout} \end{cases} \tag{10}$$

$$P_{rated} = 0.5 \rho A v_w^3 C_p \tag{11}$$

## 4. Cuckoo Search Algorithm

A Cuckoo Search algorithm is developed by Yang and Deb [15]. This is based on the concept of brood parasitism behaviour of cuckoo species. For easy understanding and implementation three idealized rules are to be used [16].
1) In a single time every cuckoo lays one egg and dumps into the randomly chosen nest.
2) The nests with the highest quality of eggs can carry to succeeding generations.
3) The number accessible host nests square measure mounted, the egg set by a cuckoo is discovered by the host bird with a likelihood Pa ϵ [0, 1]. During this case, the host bird will abandon the nest or throw the egg away or fully build a replacement nest.
When generating new solutions for a Cuckoo i, a Levy flight is performed

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

Where α > 0 is the step size which should be related to the problem of interest. The value of α for most of the studies used is 1. In general stochastic process could be a Mark off process whose next status/location depends on current location and transition chance that is that the initial and second terms of Eq. (12). The product $\oplus$ means that the entry wise multiplications, that is comparable to use in PSO. The stochastic process via Levy flight is a lot of economical in exploring search space as its step length is way longer within the long-standing time [16].
The levy flight is actually provides a stochastic process, the random step length is drawn from levy distribution that has an infinite variance with an infinite mean.

$$Levy \sim u = t^{-\lambda} \tag{13}$$

Here the steps of cuckoo primarily type a stochastic process with an influence law step-length distribution with a big tail. Various new solutions are generated by Levy walk around the best solutions obtained so far this will speed up the process and avoid to trapping in local optimum. [15].

### *4.1. Implementation of the Cuckoo search algorithm for optimal allocation of wind based distributed generators*

Step1: Generate the initial population with n host nests
Step2: Cuckoo is randomly generated by Levy flight using Eq. (12). The generated cuckoo evaluates the load flow and the objective function is determining the solution quality.
Step3: Calculate the objective function or fitness function (OF) by using Eq. (6)
Step4: Randomly select a nest
Step5: The solution corresponding to selected new nest is best than replace with this solution.
Step6: Again calculate the fitness or objective function
Step7: Based on the probability worst nests are abandoned and new nest are build.
Step8: After reached the maximum iterations (100) and satisfied stopping criterion the results of cuckoo search with reduced objective function is obtained.

## 5. Results and analysis

To test validity and performance of proposed method it is implemented on an IEEE test system consisting of 69 buses. The bus and line data are taken from [17]. The real and reactive power loads and voltage of radial distribution system are 3.8MW, 2.69Mvar and 12.66KV respectively. The parameters selected for Cuckoo search algorithm are number of nests=25, step size α=1, the discovery rate of alien eggs=0.25, maximum no of iterations=100 and tolerance limit=$10^{-5}$ are used. The proposed method is implemented in MATLAB environment and to run the load flow and determine the objective function. The real power loss before placement of wind based distributed generators is 224.9KW and minimum voltage profile is 0.9092 at bus number 65. Before placement of DGs, first determine the size of wind turbine generator that is calculated by using Eq. (10). For determining output power of wind turbine the annual average speed is considered is 6.02m/s that is taken from [18]. Also the parameters of wind turbines are taken from [19]. From the wind speed data and wind turbine parameters the output power of one wind turbine generating unit is calculated that is 168KW. First, identify the number of optimal locations and then find out number wind turbines placed at these locations are determined by using a Cuckoo search algorithm. It is considered that maximum six distributed generators are connected at any bus and this wind turbine generating unit operating at unity power factor mode.

After identification of the best locations and corresponding wind based generators placed at these locations, results of wind based DGs penetration from minimum to maximum levels are observed in Table 1. The results of Table 1 clearly indicate that power loss reduced effectively with increased penetration of wind based distributed generators. At maximum penetration level power loss is reduced to 67.33%.

**Table 1**. Optimal location and number WTG units penetration for 69-bus test system with power loss minimization in each case

| Test system | No of buses | Bus location(number WTG) | $P_{Totalloss}$(KW) | Power loss minimization (%) |
|---|---|---|---|---|
| 69-Bus system | 1 | Bus-62(6) | 111.32 | 50.63 |
| | 2 | Bus-61(5), Bus-65(4) | 91.03 | 59.52 |
| | 3 | Bus-13(3),Bus-62(5), Bus-61(6), | 73.49 | 67.33 |

**Table 2**. Comparison of proposed method with GA and PSO methods for 69 bus system

| Method | No of connection buses | Bus location | DG size(KW) | $P_{Totalloss}$(KW) | Power loss minimization (%) |
|---|---|---|---|---|---|
| GA[8] | 3 | 64 | 992.5 | 89.0 | 60.44 |
| | | 62 | 1075.2 | | |
| | | 21 | 929.7 | | |
| PSO[8] | 3 | 63 | 795.6 | 83.2 | 63.02 |
| | | 61 | 1199.8 | | |
| | | 17 | 992.5 | | |
| **CSA** | **3** | **62** | **840** | **73.49** | **67.33** |
| | | **61** | **1008** | | |
| | | **13** | **504** | | |

Next proposed method is compared with other methods, i.e. GA, PSO and the results are indicated in Table 2. From Table 2 it is clear that the proposed method reduces the power losses effectively compared to GA and PSO methods. This represents Cuckoo search Algorithm performs well in finding the optimal allocation of wind based distributed generators in the distribution system for minimizing power losses effectively.

Also a comparison of the voltage profile with and without placement of wind based distributed generators at different penetration level is shown in Fig.2. From Fig.2. It is observed that voltage profile at all buses is improved effectively at highest penetration level.

From the above discussion proposed method is very accurate in finding the optimal solutions in terms voltage profile improvement and loss minimization.


**Fig.2.**Comparison of voltage profile at different penetration levels of wind turbines

## 6. Conclusion

In this paper an effective technique based on the Cuckoo search algorithm is presented for optimal allocation of wind based distributed generators in the radial distribution network. The proposed method is tested on IEEE test system consisting of 69 buses. From the simulated results it verified that the proposed method reduces the power loss effectively at highest penetration level of wind based DGs placed. The power loss of proposed with optimal placement of DGs is reduced effectively compared to the GA and PSO methods. From simulated results it can be concluded that the developed method is accurate in finding the optimal solutions. Also the proposed method can be implemented in any type of test system.

**References**

1. El-Fergany, Attia. "Optimal capacitor allocations using evolutionary algorithms." *Generation, Transmission & Distribution, IET* 7.6 (2013): 593-601.
2. Borghetti, Alberto. "A mixed-integer linear programming approach for the computation of the minimum-losses radial configuration of electrical distribution networks." *Power Systems, IEEE Transactions on* 27.3 (2012): 1264-1273.
3. Khalesi, N., N. Rezaei, and M-R. Haghifam."DG allocation with application of dynamic programming for loss reduction and reliability improvement."*International Journal of Electrical Power & Energy Systems* 33.2 (2011): 288-295.
4. Wang, Caisheng, and M. Hashem Nehrir. "Analytical approaches for optimal placement of distributed generation sources in power systems." *Power Systems, IEEE Transactions on* 19.4 (2004): 2068-2076.
5. Hung, Duong Quoc, and NadarajahMithulananthan. "Multiple distributed generator placement in primary distribution networks for loss reduction."*Industrial Electronics, IEEE Transactions on* 60.4 (2013): 1700-1708.
6. López-Lezama, JesúsMaría, Javier Contreras, and Antonio Padilha-Feltrin. "Location and contract pricing of distributed generation using a genetic algorithm." *International Journal of Electrical Power & Energy Systems* 36.1 (2012): 117-126.
7. El-Zonkoly, A. M. "Optimal placement of multi-distributed generation units including different load models using particle swarm optimization." *Swarm and Evolutionary Computation* 1.1 (2011): 50-59.
8. Moradi, M. H., and M. Abedini. "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 (2012): 66-74.
9. Kayal, Partha, and C. K. Chanda. "Placement of wind and solar based DGs in distribution system for power loss minimization and voltage stability improvement." *International Journal of Electrical Power & Energy Systems*53 (2013): 795-809.
10. Nara, Koichi, et al. "Application of tabu search to optimal placement of distributed generators." *Power Engineering Society Winter Meeting, 2001. IEEE*. Vol. 2. IEEE, 2001.
11. Injeti, Satish Kumar, and N. Prema Kumar. "A novel approach to identify optimal access point and capacity of multiple DGs in a small, medium and large scale radial distribution systems." *International Journal of Electrical Power & Energy Systems* 45.1 (2013): 142-151.
12. Abu-Mouti, Fahad S., and M. E. El-Hawary. "Optimal distributed generation allocation and sizing in distribution systems via artificial bee colony algorithm."*Power Delivery, IEEE Transactions on* 26.4 (2011): 2090-2101.
13. Teng, Jen-Hao. "A direct approach for distribution system load flow solutions."*Power Delivery, IEEE Transactions on* 18.3 (2003): 882-887.
14. Divya KC, Rao PSN. Models for wind turbine generating systems and their application in load flow studies. Electri Power Syst Res 2006;76:844–56.
15. X.-S. Yang and S. Deb, "Cuckoo Search via Lévy flights," in Nature &Biologically Inspired Computing, 2009. NaBIC 2009. World Congresson, 2009, pp. 210-214.
16. X.-S. Yang and S. Deb, "Engineering Optimisation by Cuckoo Search,"Int. J. Mathematical Modelling and Numerical Optimisation, vol. 1,

pp.330-343, 2010.
17. Sahoo, N. C., and K. Prasad. "A fuzzy genetic approach for network reconfiguration to enhance voltage stability in radial distribution systems."*Energy Conversion and Management* 47.18 (2006): 3288-3306.
18. http://www.synergyenviron.com/tools/wind_data.asp.
19. Lubosny Z. Wind turbine operation in electric power systems advanced modeling. Verlag: Springer; 2003.