

Integration of DG Units in Radial Distribution System Using Artificial Hummingbird Algorithm

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Abstract—Nowadays, the integration of distributed generators (DGs) in the electrical power network has become a promising solution to enhance effectively the performance of distribution system. DGs are contributed to reduce the total active power losses in the system through the increasing of the generated active power. Consequently, the system efficiency can be significantly raised by decreasing the active power drawn from the slack bus. The most crucial issue in this matter is to determine the optimal location and sizing of the DGs. To overcome this issue, a meta-heuristic algorithm called Artificial Hummingbird Algorithm (AHA) is employed in this paper, which is created by the inspiration of foraging strategies of hummingbirds. The main objective of using AHA algorithm is to benefit the strength of the three foraging strategies and using a visit table to simulate the robust memory of hummingbird. In this paper, the objectives were determined to ensure a high system performance in the form of keeping the power losses minimized. The proposed approach is tested using IEEE 33 and 69 radial distribution systems to prove its effectiveness. Finally, this paper introduces a comparative study between the results obtained by the proposed approach and those obtained by other algorithms.

Keywords—Distributed generation (DG)-Active power losses-Artificial Hummingbird Algorithm (AHA)

I. INTRODUCTION

Nowadays, the Distributed generator units (DGs) have widespread utilization in radial distribution system (RDS). One of the most popular sources of DGs is renewable sources such as photovoltaic and wind energy [1]. DGs have many advantages that encourage the operator to install it in the RDS mainly reducing active and reactive power losses, improvement of voltage profile, increase the reliability of the network and extend the system equipment lifetime [2-3]. But installing DGs in an unsuitable location could cause some negative problems like deterioration voltage stability and raising fault current, moreover increasing power losses and operational cost [4]. In addition to this benefit, DGs reduce the burdens from transmission lines and make the system more stable [5]. To avoid these problems, DGs site and size must be optimized to achieve maximum technical and economic benefits for RDS [5].

Based on that, there are many objectives like reducing power losses or voltage stability enhancement using different methods to obtain the best result in this problem. For example, in [6] authors used genetic algorithm (GA) to get a solution of optimal allocation and capacity of DGs

exploiting IEEE 33 and 69 bus systems to test these solutions. In [4], an enhanced coyote optimization algorithm is used to get optimal location and sizing of DGs in IEEE 33, 69 and 85 bus system. But not only GA is used in [13], the authors used GA for searching the positions of DG in the system and the DG size was determined by particle swarm optimization. However, many researchers seek to minimize active power losses only but in [8] authors take into consideration the minimization of the active and reactive power losses using power loss sensitivity and non-linear programming techniques with the aid of GAMS software. In [9], the GWO technique was applied to reduce active power losses and present a better voltage profile. Also, in [10] Whale optimization algorithm is applied to get a solution for optimal location and sizing of multi-DGs in the system. The authors in [10] used Whale optimization algorithm (WOA) to proposed location and sizing of DG units based on different types of renewable energy resources. Harris hawk's optimization (HHO) algorithm also was used in [11] to provide optimal size and location of the DG taking the advantage of its simplicity and having low exploratory and exploitative mechanisms. In [12] and [13] the active power was injected from DGs and reactive power from shunt capacitors, so the authors proposed a technique to find the placement and size of DGs and the capacitors. Also, in [14] the authors proposed voltage sensitivity factor which depends on voltage stability and deviation to reduce the search area for the chaotic bat algorithm to find DGs optimal site and size. DGs can be used to limit the fault current into the network not only reducing power losses so the DGs correlate with fault current limiter like in [15]. The DGs can also be integrated with capacitor bank and voltage regulator to relieve the power demand from the grid and minimize the expenses that was done in [16]. The authors in [17] searched for the optimal placement of DGs in the presence of Electric vehicle charging stations which consume more power from the network.

In this paper, artificial hummingbird algorithm (AHA) is adopted to search the best location and sizing of multi-DG units which can be P-type or PQ-type under different load values. The AHA has an accessible method to reach the optimal solution as it uses three types of flight skills. The previous studies did not consider the penetration limits. Moreover, these studies used algorithms with requiring large number of iteration and search agents to get allocation and

sizing of DGs. Consequently, in this paper to remedy this shortage, the penetration limits are taken into consideration and AHA algorithm with its three foraging strategies is employed to obtain a quick and precise solution. Therefore, the proposed algorithm can get the optimal allocation and size using low number of iteration and population. The proposed algorithm is tested on two standard system and compared with other algorithms in the literature.

The layout of the following sections is presented as follow: section II present the problem formulation. The proposed algorithm is presented in section III. Also, simulation results are presented in section IV. Finally, the paper conclusion is drawn in section V.

II. PROBLEM FORMULATION

The optimal site and size of DG units are playing a critical role in minimizing power losses of the system. DGs can contribute to system improvement by injecting active power only or active and reactive power. Therefore, DGs can reduce a few issues from the system such as power losses, voltage deviation, harmonic distortion etc.

A. objective function formulation

There are many methods of computing power flow for RDS such as bus injection to branch current (BIBC) and branch current to bus voltage (BCBV) algorithm. This method converges very fast to the solution so it needs a little time to execute so the power losses can be calculated as follows [18-19].

$$P_{losses} = \sum_{i=1}^N \left(\frac{\Delta V_i}{(R_i + jX_i)} \right)^2 R_i \quad (1)$$

$$Q_{losses} = \sum_{i=1}^N \left(\frac{\Delta V_i}{(R_i + jX_i)} \right)^2 X_i \quad (2)$$

$$\Delta V = [BIBC] [BCBV] [I] \quad (3)$$

Where ΔV_i , R_i and X_i are representing the voltage difference, resistance, and reactance between any two buses respectively. Also, the total number of the branches is denoted as N . where I matrix represents the current of each branch. P_{loss} and Q_{losses} indicate the total active and reactive power losses of the system respectively.

The problem formulation can be represented as follow:

$$F_{objective} = \min(P_{losses}) \quad (4)$$

B. Equality constraints

The system balance is achieved, so the power generated must be equal to the summation of power consumed.

$$P_G + \sum_{K=1}^M P_{DG}(K) = \sum_{y=1}^Y P_L(a) + P_{losses} \quad (5)$$

$$Q_G + \sum_{K=1}^M Q_{DG}(K) = \sum_{y=1}^Y Q_L(a) + Q_{losses} \quad (6)$$

where P_G and Q_G are representing active and reactive powers supplied by slack bus of the system respectively. Also, the active and reactive powers of each DG unit are denoted as P_{DG} and Q_{DG} respectively. P_L and Q_L are equal to active and reactive power demand of each load respectively. Where, a represents the bus number of each load and Y refers to total number of buses. Also, M indicates the total number of DGs.

C. Inequality constraints

1) Bus voltage limits

The bus voltage must be in the range of limits as follow:

$$0.9 \leq V_b \leq 1.05 \quad (7)$$

where V_b is the voltage magnitude of each bus.

2) DG power limits

The total penetration level of DGs into the system should not exceed the limit as follow [1]:

$$\sum_{K=1}^M P_{DG}(K) \leq 0.75 \left(\sum_{y=1}^Y P_L(a) + P_{losses} \right) \quad (8)$$

$$\sum_{K=1}^M Q_{DG}(K) \leq 0.75 \left(\sum_{y=1}^Y Q_L(a) + Q_{losses} \right) \quad (9)$$

As presented the total power of DGs must be equal to 0.75 of total power demand and power losses.

3) Branch current limits

$$I_{br} \leq I_{Max} \quad (10)$$

where I_{br} and I_{Max} represent branch current and maximum branch current respectively.

III. PROPOSED ALGORITHM

Artificial hummingbird algorithm (AHA) is proposed for solving the problem of selecting the best location and sizing of DGs. AHA technique has been employed for many applications, such as tuning the gains of proportional-integral-derivative (PID) controllers under various loading conditions, as in [20]. Also, the proposed technique was used to estimate the important parameters of solar photovoltaic different models, as in [21] and [22]. In [23], the AHA algorithm is managed to identify the unknown parameters of Li-Ion batteries. AHA is inspired from skills and intelligent foraging methods of hummingbirds while they have three foraging strategies including guided foraging, territorial foraging, and migrating foraging. Axial, diagonal, and omnidirectional flights are the flight skills that hummingbirds can use in searching for their food. The most feature effect in foraging is that the hummingbirds have supernormal memory that can be mimicked by visit table in the algorithm [24]. The main steps of AHA for determining the optimal allocation and sizing of DGs is presented below:

Step 1: initialize important parameters, such as maximum number of iterations, Axial, diagonal and omnidirectional flights.

Step 2: initialize population randomly within the limits that predetermined as shown in (11):

$$x_{pos} = Lb + r * (Ub - Lb) \quad (11)$$

where Lb , Ub are lower boundaries and upper boundaries respectively. Also, r is a random vector between $[0, 1]$ and x_{pos} refers to the position of food source.

Step 3: calculate fitness value for each hummingbird.

Step 4: initialize the food source visit table as in Eq. (12) as:

$$VT_{i,k} = \begin{cases} 0 & \text{if } i \neq k \\ \text{null} & \text{if } i = k \end{cases} \quad i = 1, \dots, n \quad k = 1, \dots, n \quad (12)$$

where $VT_{i,k}$ indicates the visit table, k and i denote the number of hummingbird and number of food source respectively.

Step 5: calculate hummingbirds' flight skills and the three foraging strategies as follow:

Guided foraging (GF):

$$v_k(t+1) = x_{k,int}(t) + a.D.(x_k(t) - x_{k,int}(t)) \quad (13)$$

Territorial foraging (TF):

$$v_k(t+1) = x_k(t) + b.D.x_k(t) \quad (14)$$

Migrating foraging (MF):

$$x_w(t+1) = Lb + r.(Ub - Lb) \quad (15)$$

where, $V_k(t+1)$: the visit table at time $t+1$