Engineering Science and Technology, an International Journal xxx (2016) xxx–xxx

HOSTED BY

ELSEVIER

Contents lists available at ScienceDirect

Engineering Science and Technology, an International Journal

journal homepage: www.elsevier.com/locate/jestch

Full Length Article

Stud Krill herd Algorithm for multiple DG placement and sizing in a radial distribution system

S.A. ChithraDevi *, L. Lakshminarasimman, R. Balamurugan

Department of Electrical Engineering, Annamalai University, Annamalai Nagar, Tamil Nadu, India

ARTICLE INFO

Article history:
Received 23 July 2016
Revised 22 October 2016
Accepted 10 November 2016
Available online xxxx

Keywords:
DG placement
Power loss minimization
Stud Krill herd Algorithm (SKHA)
Krill herd algorithm (KHA)
Radial Distribution System (RDS)

ABSTRACT

In this paper a new meta-heuristic technique, Stud Krill herd Algorithm (SKHA) is employed for the solution of optimal placement and sizing of Distributed Generation (DG) in radial distribution system. The main objective is to minimize the line losses considering various constraints like voltage limit, DG real power generation limit, power balance constraint and DG location constraint. Krill movement is based on the two factors – minimum distance of the Krill individual from food and highest density of the herd and for better performance adaptive genetic operators, stud selection and crossover (SSC) are included. The proposed algorithm is implemented on 33, 69 bus IEEE test system and 94 bus Portuguese radial distribution system. The results are compared with recently developed heuristic and analytical methods from the literature. The outcomes reveal the effectiveness of the algorithm.

1. Introduction

Distributed generation (DG) is a small scale generation otherwise called as embedded generation, dispersed or decentralized generation, which generates power in the range of 3–10,000 kW from wind, solar, bio-mass, fuel cells, micro turbines etc. DG units are connected closer to the customers and are used for industrial, commercial and domestic applications. The main advantages of using DG units are improving voltage stability, real power loss reduction, reliability, grid strengthening and reduction of SO_2, CO_2 gas emissions. Although DG has lots of advantages, the key problem in DG placement is the selection of optimal location and size of DG units. If DG units are improperly allocated and sized, the reverse power flow from larger DG units can lead to higher system losses, voltage fluctuations and increase in costs. Hence, to minimize losses, it is important to find the best location and size of DG units [1–4]. In recent years many researchers have proposed new analytical approaches based on power stability index (PSI) and power loss sensitivity (PLS) index to find the optimal location and sizing of DGs for obtaining an optimal solution of the power loss minimization problem in the radial distribution system [5–7].

The critical bus can be found out from PSI and the DG should be placed at the end of the line which is having highest PSI. The size of DG is determined based on real power loss minimization. Voltage profile, the real and reactive power intake by the grid, real and reactive power flow patterns, cost of energy losses, savings in the cost of energy loss and cost of power obtained from DGs have also been considered while solving the DG problem. Near optimal results are the main drawbacks in all the above methods. The method described in [6], though the convergence is achieved at few iteration, but the method is not applicable for unbalanced and meshed distribution system. Several artificial intelligence based techniques have been proposed for solving the DG optimization problem. In [8], the authors used firefly algorithm for solving DG placement and sizing in order to obtain minimum loss, voltage profile improvement and minimum generation cost. But the key

Abbreviations: DG, Distributed Generation; RDS, Radial Distribution System; ODGP, Optimal Distributed Generation Placement; KHA, Krill herd Algorithm; SKHA, Stud Krill herd Algorithm; SSC, Stud Selection and Crossover; PSI, Power Stability Index; PLS, Power Loss Sensitivity index; CVD, Cumulative Voltage Deviation; LSF, Loss Sensitivity Factor; MOPI, Multi Objective Performance Index; KCL, KVL, Kirchhoff's Current Law, Kirchhoff's Voltage Law; PSO, Particle Swarm Optimization; ACO, Ant Colony Optimization; GA, Genetic Algorithm; SA, Simulated Annealing; BFOA, Bacterial Foraging Optimization Algorithm; REPSO, Rank Evolutionary Particle Swarm Optimization; TLBO, Teaching Learning Based Optimization; CABC, Chaotic Artificial Bee Colony algorithm; QOTLBO, Quasi – Oppositional Teaching Learning Based Optimization; SOS, Symbiotic organism search algorithm; MOShBAT, Multi-objective Shuffled Bat algorithm; FPA, Flower Pollination Algorithm; OKHA, Oppositional Krill herd Algorithm.

* Corresponding author.
E-mail address: chithradevi.sa@gmail.com (S.A. ChithraDevi).

Peer review under responsibility of Karabuk University.

http://dx.doi.org/10.1016/j.jestch.2016.11.009
2215-0986/© 2016 Karabuk University. Publishing services by Elsevier B.V.

Nomenclature

S^a	specific apparent power injection at node a (kVA)
a	number of nodes, 1 to n
P_D^a	real power injected at node a (kW)
Q_D^a	reactive power injected at node a (kVAR)
$iter_{max}$	maximum number of iterations
$I^{iter,a}$	node current at node a at iterth iteration (amps)
$V^{(iter-1),a}$	voltage at node a at (iter-1)th iteration (volts)
$i^{iter,B}$	branch current at branch B at iterth iteration (amps)
$I^{iter,B2}$	current injection at node B2 at iterth iteration (amps)
$V^{iter,B1}$	updated voltage at node B1 at (iter)th iteration (volts)
Z^B	series impedance of branch B (ohms)
S_{inj}^1	injected apparent power at bus 1 (kVA)
V_{inj}^1	injected/input voltage at bus 1(volts)
I_{inj}^1	branch current at bus 1(amps)
P_{inj}	injected real power at bus 1 (kW)
Q_{inj}	injected reactive power at bus 1 (kVAR)

disadvantage is slow convergence. Bacterial foraging optimization algorithm (BFOA) and modified BFOA are used in [9] and [10] respectively for solving the optimal DG placement (ODGP) problem. The main drawback is complexity of the algorithm and hence the less convergence speed.

Invasive Weed Optimization algorithm is applied for reconfiguration and DG placement problem in [11] and [12]. But % power loss reduction is near optimal when compared to other optimization methods. In [13], Rank Evolutionary Particle Swarm Optimization (REPSO) is used for solving reconfiguration and DG placement problem. The main disadvantage is poor convergence speed. The authors of [14] improved the teaching learning based optimization (TLBO) with quasi-opposition based rules for obtaining the optimal solution for ODGP problem. The results are enhanced still the convergence time is slightly high. The authors considered power loss minimization and DG installation cost as two objectives using the weighted sum method and solved using sequence quadratic programming deterministic technique in [15]. The proposed technique in [16] is adjusted to attempt the deficit of loss sensitivity factors and to decide the final placement of the DGs. Initial DG locations are obtained by framing fuzzy rules based on sensitivity factors and bus voltages. Cumulative Voltage Deviation (CVD) is used to indicate the voltage profile improvement. The backtracking search optimization algorithm is also a population based iterative, evolutionary algorithm consists of initialization, selection, mutation, crossover and selection. The determination of optimal location and sizing of DG units using multi objective performance index (MOPI) for enhancing the voltage stability of the radial distribution system is presented in [17]. The different technical issues are combined using various weighting coefficients and solved under different operating constraints using a Chaotic Artificial Bee Colony (CABC) algorithm.

In [18], the authors utilized a new nature inspired approach intelligent water drop algorithm for sizing of DGs and loss sensitivity factor (LSF) is used to find the optimal location. The drawback of this method is the results are near optimal. The authors of [19] presented a two stage approach fuzzy set theory to find optimal location of DG and clonal selection algorithm to find the DG size. Time consumption for obtaining the solution is slightly high. In [20], the authors projected cuckoo search algorithm to find the optimal location of wind based distributed generators in order to reduce the power loss of the distribution system. The authors of [21], used Newton-Raphson extended method with Naplan software to find the power losses at each bus. The power losses at each DG connected bus are considered for the selection of optimal location of DG.

In [22], Particle Swarm Optimization (PSO) is proposed for multi DG placement for power loss reduction and voltage profile improvement. The authors of [23] used Symbiotic organism search (SOS) algorithm to DG placement problem. SOS algorithm is a nature inspired heuristic technique, based on the symbiotic relationship between different biological individual species. In [24], the authors proposed Grey Wolf Optimizer (GWO) to solve the multi objective function in terms of minimization of reactive power losses and voltage profile improvement. The authors [25] presented a hybrid approach with an analytical method used to find the size of DGs and PSO based technique is applied to determine the location. They have considered different types of DGs for analysis. The authors of [26] developed Multi-objective Shuffled Bat (MOShBAT) algorithm to determine the DG placement and sizing, in order to minimize the multi objective function considering the power losses, cost and voltage deviation. The method is based on the Shuffled frog leaping algorithm and Bat algorithm.

In [27], modified Firefly Algorithm is applied to determine the optimal size and location of DGs in unbalanced distribution system. The DG in this algorithm is framed with a flexibility to change the PV node to PQ node, when the reactive power limit is violated. The authors of [28] proposed flower pollination algorithm (FPA) to find the DG size and index vector method to determine the DG location. Index vector is framed with reactive component of current in the branches and reactive power load concentration at each node obtained from the base case load flow results. In [29], backtracking search algorithm is presented to find the optimal location and size of DG. The initial location of DGs is found out by framing fuzzy expert rules using loss sensitivity factor and bus voltages. The authors framed multi objective function which comprises minimization of power loss and maximization of voltage stability index. DG sources classified as four types. The authors applied the algorithm to first three types to validate the results.

i. Type-I: DG capable of injecting real power only
ii. Type-II: DG capable of injecting reactive power only
iii. Type-III: DG capable of injecting both real and reactive power
iv. Type-IV: DG capable of injecting real but consuming reactive power

The main drawbacks in all the above methods are poor convergence speed and obtaining near optimal solutions. In 2012, Gandomi and Alavi [30], proposed a biologically inspired swarm intelligence algorithm, known as Krill Herd Algorithm (KH). This method is based on the simulation of herding behavior of the large number of individual krills. The KH algorithm is capable to explore the search space globally, but it fails to select sometimes the global optimum solution in the search space. In [32], the authors have minimized annual energy losses by using different renewable energy resources like bio-mass, solar and wind DG units. The Oppositional Krill herd Algorithm (OKHA) is used to determine the optimal location and size of DG units. Later in 2014, Wang et al. [35], added updated genetic operators namely stud selection and crossover to KH method to avoid being trapped in local optima. In SKH, stud selection and crossover (SSC) operator is used, which