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Ant Lion Optimization Algorithm for renewable Distributed Generations

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ABSTRACT

Renewable sources can provide a clean and smart solution to the increased demands. Thus, Photovoltaic (PV) system and Wind Turbine (WT) are considered here as sources of Distributed Generation (DG). Allocation and sizing of DG have greatly affected on the system losses. This paper aims to propose Ant Lion Optimization Algorithm (ALOA) for optimal allocation and sizing of renewable DG sources in various distribution networks. First the most candidate buses for installing DG are suggested using Loss Sensitivity Factors (LSFs). Then the proposed ALOA is employed to deduce the locations of DG and their sizing from the elected buses. The proposed algorithm is tested on 33 and 69 bus radial distribution systems. The obtained results via the proposed algorithm are compared with others to highlight its benefits in reducing total power losses and consequently maximizing the net saving. Moreover, the results are introduced to verify the superiority of the proposed algorithm to improve the voltage profiles for various loading conditions. Also, the Wilcoxon test is applied to confirm the effectiveness of the proposed algorithm.

1. Introduction

A fossil fuel power station is a power station which burns fossil fuel such as coal, natural gas or petroleum to produce electricity. It converts the heat energy of combustion into mechanical energy, which operates an electrical generator. The flue gas from combustion is discharged to the air. It has a destructive effect on earth's climate [1–5]. It contains carbon dioxide and a greenhouse gas that contributes to global warming [6–10]. Renewable generations like Wind Turbine (WT) and Photovoltaic (PV) system produce smaller amount of carbon dioxide compared with those of natural gas and coal. For example, natural gas emits between 0.6 and 2 pounds of carbon dioxide equivalent per kilowatt hour, coal emits between 1.4 and 3.6 pounds, WT emits only between 0.02 and 0.04 pounds and PV between 0.07 and 0.2 [11]. Renewable generations are candidate to be used as Distribution Generation (DG) in distribution network [12,13]. The main advantages of DG are reducing line losses, increasing efficiency, enhancing power quality, improving system reliability and minimizing fuel, operating and maintenance costs [14,15]. However, improper selection of site and size of DG lead to greater losses and costs than without DG [16].

The problem of DG placements and sizing was solved using various techniques. An adaptive protection scheme has been discussed in Ref. [17] via neural networks for distribution networks with high penetration of DG units, but the main problem of this technique is the long training time. The optimal sizing of renewable energy sources in DG is developed in Refs. [18,19], where the objective function and constraints are modeled with fuzzy sets, but a hard work is intrinsic to get the effective signals. A systematic simple approach to allocate multiple DG units in distribution network is introduced in Ref. [20]. The concept of equivalent load is presented to identify the load centroid precisely. In Ref. [21] load shedding is examined as a way to achieve a trade-off between the reliability enhancement and the size of DG to be installed.

Recently, numerous optimization algorithms have been illustrated in literature to deal with the problem of locations and sizing of DG in distribution networks. The contributions of [22–38] are epitomized in Table 1. They use a simple single objective function which is the minimization of the power losses or maximization the reduction in losses except [25,27,33] that use a multi-objective function to reduce losses, improve voltage stability and enhance

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Nomenclature

P_k,Q_k	The total effective active and reactive power supplied behind the bus 'k'
V_k	The magnitude of voltage at bus k
R_{ik},X_{ik}	The resistance and reactance of transmission line between bus'i' and 'k'
V_i	The magnitude of voltage at bus i
K_p	The cost per kW Hours
n	The maximum number of ants
$r(t)$	A stochastic function
t	The step of random walk
M_{ant}	The matrix for saving the position of each ant
$ant_{i,j}$	The value of the jth variable of ith ant
d	The number of variables
M_{oa}	The matrix for saving the fitness of each ant
$M_{antlion}$	The matrix for saving the position of each ant lion
$antlion_{i,j}$	The value of the jth variable of ith ant lion
M_{oal}	The matrix for saving the fitness of each ant lion
A_i	The minimum of random walk of ith variable
C_i^t	The minimum of ith variable at tth iteration
C^t	The minimum of all variables at tth iteration
C_j^t	The minimum of all variables for ith ant
D_j^t	The maximum of ith variable at tth iteration
D^t	The vector including the maximum of all variables at tth iteration
D_j^t	The maximum of all variables for ith ant
$Ant\ lion_j^t$	The position of the selected jth ant lion at tth iteration
I	This ratio equals to $10^w\frac{t}{T}$
T	The maximum number of iterations
w	To adjust the accuracy level of exploitation
r_a^t	The random walk around the ant lion selected by the roulette wheel at tth iteration
r_e^t	The random walk around the elite at tth iteration
Ant_i^t	The position of ith ant at tth iteration
P_{Loss}	The total power losses after compensation
F_t	The total objective function
f_1	The part of F_t that presents the minimization of power losses
f_2	The part of F_t that presents the improvement of voltage profiles
f_3	The part of F_t that presents the enhancement of VSI
w_1,w_2,w_3	The weighting factors
P_{Swing}	The active power of swing bus
Q_{Swing}	The reactive power of swing bus
L	The number of transmission line in a distribution network
$Pd(q)$	The demand of active power at bus q
$Qd(q)$	The demand of reactive power at bus q
N	The number of total buses
V_{min}	The minimum voltage at bus i
V_{max}	The maximum voltage at bus i
P_{DG}	The installed active power of the DG
Q_{DG}	The installed reactive power of the DG
N_{DG}	The number of installed unit of the DG
$P_{DG}^{min}P_{DG}^{max}$	The minimum and maximum real outputs of the DG unit
Q_{DG}^{min}, Q_{DG}^{max}	The minimum and maximum reactive outputs of the DG unit
S_{Li}	The actual complex power in line i
$S_{Li(rated)}$	The rated complex power in that line i

List of abbreviations

ALOA	Ant Lion Optimization Algorithm
DG	Distributed Generation
LSFs	Loss Sensitivity Factors
PV	Photovoltaic system
WT	Wind Turbine
SA	Simulated Annealing
TS	Tabu Search
GA	Genetic Algorithm
PSO	Particle Swarm Optimization
PGSA	Plant Growth Simulation Algorithm
MPGSA	Modified Plant Growth Simulation Algorithm
DSA	Direct Search Algorithm
MTLBO	Modified Teaching Learning-Based Optimization
CSA	Cuckoo Search Algorithm
ABC	Artificial Bee Colony
ACO	Ant Colony Optimization
FA	Firefly Algorithm
MINLP	Mixed Integer Non Linear Programming
HSA	Harmony Search Algorithm
ICA	Imperialist Competitive Algorithm
DE	Differential Evolution
BF	Bacteria Foraging
BSOA	Backtracking Search Optimization Algorithm
VSI	Voltage Stability Index
BB-BC	Big Bang–Big Crunch
SGA	Standard Genetic Algorithm
NR	Not Reported

the voltage profiles. Also, only [22,32,36] use renewable DG source which presents a cleaner power production than fossil fuel power system. Moreover, the effect of variable loading as a realistic case is considered only in Refs. [26,30,33] while the others ignore this effect by taking constant load. Furthermore, the statistics analysis is only added in Refs. [25,30]. They run their algorithms many times and then get the worst, best, mean case, standard deviation and variance. They don't-test their results compared with others by a familiar statistical test. Finally, the suggested algorithms by these papers may not guarantee finding the optimum locations and sizing of DG and get trapped in local minimum solution due to the complexity of the problem.

A new optimization algorithm known as Ant Lion Optimization Algorithm (ALOA) has been presented by Mirjalili [39]. It is one of the most recently nature-inspired algorithms that emulate the hunting mechanism of ant lions in nature. It confirms its superiority in solving various optimization problems as given in Refs. [40,41]. Also, it is sufficient algorithm for power system problems such as economic power dispatch [42–45], load forecasting [46] and load frequency control [47–49]. The aim of the study is to detect the optimal locations and sizing of renewable DG in radial distribution systems via LSF and ALOA. The obtained results are compared with many techniques to prove its superiority in solving the problem of optimal locations and sizing of DG and thus decreasing the active power losses and alleviating the voltage profiles for various loading conditions. Also, the statistical assessment of the proposed algorithm is demonstrated.

The paper is arranged as follows. The Loss Sensitivity Factors (LSFs) are discussed in Section 2. The proposed ALOA is developed in Section 3. Next, the proposed objective function is illustrated in