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Reduction of Real Power Loss by Ant Lion Optimizer Algorithm

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Abstract

This paper presents Ant Lion (AL) optimizer algorithm to solve reactive power problem. The Ant Lion (AL) optimizer algorithm algorithm is stimulated from the hunting method of ant lions. Mainly ant lions have an exclusive hunting behaviour and demonstrate elevated ability of moving away from the local optima stagnation, since it has a good balance between exploration and exploitation. In order to evaluate the proposed Ant Lion (AL) optimizer algorithm, it has been tested in standard IEEE 118 & practical 191 bus test systems and compared to other standard algorithms. Real power loss considerably reduced and voltage profiles are within the specified limits.

Keywords

Ant Lion optimizer algorithm, Particle Swarm Optimization, optimal reactive power, Transmission loss.

I. Introduction

Various mathematical techniques have been adopted to solve this optimal reactive power dispatch problem. These include the gradient method [1, 2], Newton method [3] and linear programming [4-7].The gradient and Newton methods suffer from the difficulty in handling inequality constraints. To apply linear programming, the input- output function is to be expressed as a set of linear functions which may lead to loss of accuracy. Recently Global Optimization techniques such as genetic algorithms have been proposed to solve the reactive power flow problem [8.9]. In recent years, the problem of voltage stability and voltage collapse has become a major concern in power system planning and operation. To enhance the voltage stability, voltage magnitudes alone will not be a reliable indicator of how far an operating point is from the collapse point [10]. This paper presents Ant Lion (AL) optimizer algorithm to solve reactive power problem. The Ant Lion (AL) optimizer algorithm algorithm is stimulated from the hunting method of ant lions. Mainly ant lions have an exclusive hunting behaviour and demonstrate elevated ability of moving away from the local optima stagnation, since it has a good balance between exploration and exploitation. In order to evaluate the proposed Ant Lion (AL) optimizer algorithm, it has been tested in standard IEEE 118 & practical 191 bus test systems and compared to other standard algorithms.

II. Problem Formulation

The OPF problem is considered as a general minimization problem with constraints, and can be written in the following form:

Minimize f(x, u) (1)

Subject to g(x,u)=0 (2)

and

$$h(x,u) \le 0 \quad (3)$$

Where f(x,u) is the objective function. g(x.u) and h(x,u) are respectively the set of equality and inequality constraints. x is the vector of state variables, and u is the vector of control variables.

The state variables are the load buses (PQ buses) voltages, angles, the generator reactive powers and the slack active generator power:

$$x = \left(P_{g1}, \theta_2, \ldots, \theta_N, V_{L1}, .., V_{LNL}, Q_{g1}, \ldots, Q_{gng}\right)^T \quad (4)$$

The control variables are the generator bus voltages, the shunt capacitors/reactors and the transformers tap-settings:

$$u = \left(V_g, T, Q_c\right)^T \quad (5)$$

or

$$u = \left(V_{g1}, \ldots, V_{gng}, T_1, \ldots, T_{Nt}, Q_{c1}, \ldots, Q_{cNc}\right)^T \quad (6)$$

Where Ng, Nt and Nc are the number of generators, number of tap transformers and the number of shunt compensators respectively.

III. Objective Function

A. Active power loss

The objective of the reactive power dispatch is to minimize the active power loss in the transmission network, which can be described as follows:

$$F = PL = \sum_{k \in Nbr} g_k \left(V_i^2 + V_j^2 - 2V_i V_j \cos\theta_{ij}\right) \quad (7)$$

or

$$F = PL = \sum_{i \in Ng} P_{gi} - P_d = P_{gslack} + \sum_{i \neq slack}^{Ng} P_{gi} - P_d \quad (8)$$

Where g_k: is the conductance of branch between nodes i and j, Nbr: is the total number of transmission lines in power systems. P_d: is the total active power demand, P_{gi}: is the generator active power of unit i, and P_{gsalck}: is the generator active power of slack bus.

B. Voltage profile improvement

For minimizing the voltage deviation in PQ buses, the objective function becomes:

$$F = PL + \omega_v \times VD \quad (9)$$

Where ω_v: is a weighting factor of voltage deviation.

VD is the voltage deviation given by:

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \quad (10)$$

C. Equality Constraint

The equality constraint g(x,u) of the ORPD problem is represented by the power balance equation, where the total power generation must cover the total power demand and the power losses:

$$P_G = P_D + P_L P_G = P_D + P_L \quad (11)$$

This equation is solved by running Newton Raphson load flow method, by calculating the active power of slack bus to determine active power loss.

D. Inequality Constraints

The inequality constraints h(x,u) reflect the limits on components in the power system as well as the limits created to ensure system security. Upper and lower bounds on the active power of slack bus, and reactive power of generators:

$$P_{gslack}^{min} \le P_{gslack} \le P_{gslack}^{max} \quad (12)$$

$$Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max}, i \in N_g \quad (13)$$

Upper and lower bounds on the bus voltage magnitudes:

$$V_i^{min} \le V_i \le V_i^{max}, i \in N \quad (14)$$

Upper and lower bounds on the transformers tap ratios:

$$T_i^{min} \le T_i \le T_i^{max}, i \in N_T \quad (15)$$

Upper and lower bounds on the compensators reactive powers:

$$Q_c^{min} \le Q_c \le Q_c^{max}, i \in N_c \quad (16)$$

Where N is the total number of buses, N_T is the total number of Transformers; N_c is the total number of shunt reactive compensators.

IV. Ant Lion (AL) optimizer algorithm

The Ant Lion (AL) optimizer algorithm [11,12] is a new optimization algorithm which recently developed and it has better balance between exploration and exploitation ability No need to modify internal parameters and external parameters such as number of agent and max iteration has to be modified based on the needs.

The AL algorithm mimics the hunting behavior of ant lions, i.e., the interaction between predator (ant lions) and prey (ant). Like all other insects in nature, ants can easily detect the location of food by using a stochastic movement. This behavior is expressed mathematically by the following equations [12]:

$$X(t) = \left[0, cumsu\left(2r(t_1)-1\right), cumsu\left(2r(t_2)-1\right), ..., cumsu\left(2r(t_n)-1\right)\right]$$

(17)

where $X(t)$ is the random walks of ants, n is the max_iterations, t is the step of random walk, and $r(t)$ is a function defined as follows:

$$r(t) = \begin{cases} 1 & if\ rand > 0.5 \\ 0 & if\ rand < 0.5 \end{cases}$$

(18)

Where, rand is a randomly generated number uniformly distributed in the range of [0, 1].

In every step of optimization, ants update their positions b to a arbitrary walk search equation .To ensure that all the positions of ants are inside the boundary of the search space, they are normalized by using the following expression[12]:

$$X_i^t = \frac{\left(X_i^t - a_i\right) \times \left(d_i^t - c_i^t\right)}{\left(b_i - a_i\right)} + c_i^t \quad (19)$$

Where the a_i, b_i are respectively the minimum and maximum of random walk corresponding of i^{th} variable. c_i^t, d_i^t : are respectively indicated the minimum and maximum of i^{th} variables at t^{th} iteration.

The following equations describes the effect of ant lions traps on arbitrary walks of ants:

$$c_i^t = Antlion_j^t + c^t \quad (20)$$

$$d_i^t = Antlion_j^t + d^t \quad (21)$$

During optimization, the Ant Lion (AL) optimizer algorithm use the roulette wheel selection operator, to choose antlions based on their fitness. This strategy gives more chance for antlions to traps prey.

According to the aforementioned mechanisms, ant lions are able to construct traps proportional to their fitness and the ants move near of the center of pit. Once ant lions catch an ant in trap, they will shoot the sand outward the middle of the trap. This mechanism mathematically modeled [12] as follow, where I is the ratio.

$$c^t = \frac{c^t}{I} \quad (22)$$

$$d^t = \frac{d^t}{I} \quad (23)$$

The catching the ants by predator and rebuilding the pit in order to catch new prey can be described with the following equations.

$$Antlion_j^t = Ant_i^t, \ if \ f\left(Ant_i^t\right) > f\left(Antlion_j^t\right) \quad (24)$$

where $Antlion_j^t$ is j^{th} the position of the selected ant lion at iterationt and Ant_i^t is the position of the selected ant at iteration t.

Elitism[12] is one of the most important characteristic of evolutionary algorithms. In Ant Lion (AL) optimizer algorithm, at any iteration the best ant lion obtained (solution) is saved as an elite. Since the elite is the fittest antlion which is able to guide the movements of the remaining ants along the iterations.The elitism mechanism mathematicallydescribedas follows.

$$Ant_i^t = \frac{R_A^t + R_E^t}{2} \quad (25)$$

where R_A^t is the random walk around the ant lion is selected by using the roulette wheel at t^{th} iteration, R_E^t is the random walk around the elite at t^{th} iteration, and Ant_i^t denote the position of i^{th} ant in t^{th} iteration.

Ant Lion (AL) optimizer algorithm for solving reactive problem

a. Read system data, bus data, line data, and unit data;
b. parameter for Ant Lion (AL) optimizer algorithm are initialized
c. calculate their values of fitness of the lion ants;
d. In order to obtain the power losses,mapping of control

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variables from ants into power flow data, and it has been evaluated

e. Excellent ant lions has been found and make it as the elite;

f. select the ant lions and update the parameters by using roulette wheel method.

g. Generate arbitrary walk and normalize it.

h. Positions of ant's has been updated

i. fitness value of all solutions and boundary values are checked.

j. Replace an ant lion with its corresponding ant if it has high-quality fitness.

k. Replace elite with ant lion if an ant lion is better than the elite.

Firstly, set the control parameters of Ant Lion (AL) optimizer algorithm like the number of agents and maximum number of iteration. Construct the set of initial solution X_i^0 that comprises the variables of vector of control. The vector of initial solution can be expressed as follows:

$$M_{Antlion} = \begin{bmatrix} AL_{i1} & AL_{12} & \cdots & AL_{1D} \\ AL_{21} & AL_{22} & \cdots & AL_{2D} \\ \cdots & \cdots & & \cdots \\ AL_{N,SA1} & AL_{N,SA2} & & AL_{NSA\times D} \end{bmatrix}_{NSA\times D} \quad (26)$$

with $(i = 1,2,......, NSA \text{ and } j=1,2,......, D)$, where the NSA is the number of search agents and D is the number of control variables to be optimized or position of ant lions.

l. At this stage, each initial solution mapped into the power flow data and then evaluated by using Newton-Raphson load flow method to obtain the value of desired objective function

m. Then, the same principle of evaluation process repeated until the maximum number of iterations is reached.

V. Simulation Results

At first Ant Lion (AL) optimizer algorithm has been tested in standard IEEE 118-bus test system [13].The system has 54 generator buses, 64 load buses, 186 branches and 9 of them are with the tap setting transformers. The limits of voltage on generator buses are 0.95 -1.1 per-unit., and on load buses are 0.95 -1.05 per-unit. The limit of transformer rate is 0.9 -1.1, with the changes step of 0.025. The limitations of reactive power source are listed in Table 1, with the change in step of 0.01.

Table 1. Limitation of reactive power sources

BUS	5	34	37	44	45	46	48
QCMAX	0	14	0	10	10	10	15
QCMIN	-40	0	-25	0	0	0	0
BUS	74	79	82	83	105	107	110
QCMAX	12	20	20	10	20	6	6
QCMIN	0	0	0	0	0	0	0

The statistical comparison results of 50 trial runs have been list in Table 2 and the results clearly show the better performance of proposed Ant Lion (AL) optimizer algorithm.

Table 2 : Comparison results

Active power loss (p.u)	**BBO [14]**	**ILSBBO/ strategy1 [14]**	**ILSBBO/ strategy1 [14]**	**Proposed AL**
Min	128.77	126.98	124.78	115.38
Max	132.64	137.34	132.39	119.92
Average	130.21	130.37	129.22	116.16

Then the Ant Lion (AL) optimizer algorithm has been tested in practical 191 test system and the following results have been obtained. In Practical 191 test bus system – Number of Generators = 20, Number of lines = 200, Number of buses = 191 Number of transmission lines = 55. Table 3 shows the optimal control values of practical 191 test system obtained by AL method. And table 4 shows the results about the value of the real power loss by obtained by Ant Lion (AL) optimizer algorithm.

Table 3 : Optimal Control values of Practical 191 utility (Indian) system by AL method

VG1	1.10		VG 11	0.90
VG 2	0.70		VG 12	1.00
VG 3	1.01		VG 13	1.00
VG 4	1.01		VG 14	0.90
VG 5	1.10		VG 15	1.00
VG 6	1.10		VG 16	1.00
VG 7	1.10		VG 17	0.90
VG 8	1.01		VG 18	1.00
VG 9	1.10		VG 19	1.10
VG 10	1.01		VG 20	1.10

T1	1.00		T21	0.90		T41	0.90
T2	1.00		T22	0.90		T42	0.90
T3	1.00		T23	0.90		T43	0.91
T4	1.10		T24	0.90		T44	0.91
T5	1.00		T25	0.90		T45	0.91
T6	1.00		T26	1.00		T46	0.90
T7	1.00		T27	0.90		T47	0.91
T8	1.01		T28	0.90		T48	1.00
T9	1.00		T29	1.01		T49	0.90
T10	1.00		T30	0.90		T50	0.90
T11	0.90		T31	0.90		T51	0.90
T12	1.00		T32	0.90		T52	0.90
T13	1.01		T33	1.01		T53	1.00
T14	1.01		T34	0.90		T54	0.90
T15	1.01		T35	0.90		T55	0.90
T19	1.02		T39	0.90			
T20	1.01		T40	0.90			

Table 4. Optimum real power loss values obtained for practical 191 utility (Indian) system by AL method.

Real power Loss (MW)	**AL**
Min	143.102
Max	147.116
Average	144.174

VI. Conclusion

Proposed Ant Lion (AL) optimizer algorithm has been successfully solved reactive power problem. Ant Lion (AL) optimizer algorithm is applied to obtain the optimal control variables so as to minimize the real power loss the system. The proposed Ant Lion (AL) optimizer algorithm has been tested in standard IEEE 118 & practical 191 bus test systems. And the results were compared with other standard algorithms. Simulation study make known about the most outstanding performance of the projected algorithm in dropping the real power loss and voltage profiles are well within the limits.

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