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REDUCTION OF REAL POWER LOSS BY LAVA HERON OPTIMIZATION ALGORITHM

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Abstract

This paper presents a new Lava Heron Optimization (LHO) Algorithm for solving reactive power problem. This algorithm is inspired by the grab skill of the Lava Heron bird. Lava heron bird live in on the freshwater or saline water, swampy marshes or wetlands with tuft of trees mostly in low lying areas, where there are abundant convenience of fishes as their prey. By using the prey catching skill of the Lava Heron bird algorithm has been framed and utilized to minimize the real power loss. Proposed Lava Heron Optimization (LHO) Algorithm has been tested in standard IEEE 57,118 bus systems and simulation results demonstrate the commendable performance of the projected Lava Heron Optimization (LHO) Algorithm in reducing the real power loss.

Keywords: Lava Heron Optimization; Swarm Intelligence; Optimal Reactive Power; Transmission Loss.

1. Introduction

Optimal reactive power dispatch problem is one of the main problems in power systems. Main goal is to operate the system in secure mode and also to improve the economy of the system. Here the reactive power dispatch problem involves best utilization of the existing generator bus voltage magnitudes, transformer tap setting and the output of reactive power sources so as to minimize the loss and to enhance the voltage stability of the system. Various mathematical techniques have been utilized to Solve this optimal reactive power dispatch problem like the gradient method [1, 2], Newton method [3] and linear programming [4-7].The gradient and Newton methods failed to handle inequality constraints. In last few years several biological and natural processes have been utilized in the methodologies of science and technology in an increasing manner. Among the most popular nature inspired approaches are Particle Swarm Optimization [8], the artificial immune systems [9], the Ant Colony Optimization [10], etc. Also, a number of swarm intelligence algorithms, based on the behaviour of the bees have been

presented [11]. These algorithms are divided, mainly, in two categories according to their behaviour in the nature, the foraging behaviour and the mating behaviour. The most important methodologies that simulate the foraging behaviour of the bees are the Artificial Bee Colony (ABC) Algorithm proposed by [12], the Virtual Bee Algorithm proposed by [13], the Bee Colony Optimization Algorithm proposed by [14], the Beehive algorithm proposed by [15], the Bee Swarm Optimization Algorithm proposed by [16] and the Bees Algorithm proposed by [17]. This paper presents a new Lava Heron Optimization (LHO) Algorithm for solving reactive power problem. Lava heron bird live in on the freshwater or saline water, swampy marshes or wetlands with tuft of trees mostly in low lying areas, where there are abundant convenience of fishes as their prey. These highly territorial birds are found in intertidal zones and mangrove swamps on all of the islands of Galápagos Province. The lava heron stalks small crabs and fish slowly before quickly spearing and eating them. They have also been known to eat the flies that gather near cacti. Lava herons are typically seen hunched over and they have a sharp alarm call [18]. The performance of Lava Heron Optimization (LHO) Algorithm has been evaluated in standard IEEE 57,118 bus systems and the result analysis shows   that our projected approach outperforms all approaches examined in this paper.

2. Problem Formulation

The main objective of the reactive power dispatch problem is to minimize the real power loss .

2.1. Minimization of Real Power Loss

The main objective is to minmize the real power loss (P_{loss}) in transmission lines of a power system. This is stated as follows.

$$P_{loss=} \sum_{\substack{k=1 \\ k=(i,j)}}^{n} g_{k(V_i^2+V_j^2-2V_i V_j \cos \theta_{ij})} \tag{1}$$

Where n is the number of transmission lines, g_k is the conductance of branch k, V_i and V_j are voltage magnitude at bus i and bus j, and θ_{ij} is the voltage angle difference between bus i and bus j.

2.2. Minimization of Voltage Deviation

It is very important to minimize the Deviations in voltage magnitudes (VD) at load buses. This is stated as follows.

$$\text{Minimize VD} = \sum_{k=1}^{nl} |V_k - 1.0| \tag{2}$$

Where nl is the number of load busses and V_k is the voltage magnitude at bus k.

2.3. System Constraints

In the minimization of active power ,there is two types of constraints, which one is equality and others are inequality .
Load flow equality constraints:

$$P_{Gi} - P_{Di} - V_{i \sum_{j=1}^{nb} V_j} \begin{bmatrix} G_{ij} & \cos \theta_{ij} \\ +B_{ij} & \sin \theta_{ij} \end{bmatrix} = 0, i = 1,2 \dots , nb \tag{3}$$

$$Q_{Gi} - Q_{Di} - V_{i \sum_{j=1}^{nb} V_j} \begin{bmatrix} G_{ij} & \cos \theta_{ij} \\ +B_{ij} & \sin \theta_{ij} \end{bmatrix} = 0, i = 1,2 \dots., nb \tag{4}$$

where, nb is the number of buses, P_G and Q_G are the real and reactive power of the generator, P_D and Q_D are the real and reactive load of the generator, and G_{ij} and B_{ij} are the mutual conductance and susceptance between bus i and bus j.

Inequality constraints are as follows,

Generator bus voltage (V_{Gi})
$$V_{Gi}^{min} \leq V_{Gi} \leq V_{Gi}^{max}, i \in ng \tag{5}$$
Load bus voltage (V_{Li})
$$V_{Li}^{min} \leq V_{Li} \leq V_{Li}^{max}, i \in nl \tag{6}$$
Switchable reactive power compensations (Q_{Ci})
$$Q_{Ci}^{min} \leq Q_{Ci} \leq Q_{Ci}^{max}, i \in nc \tag{7}$$

Reactive power generation (Q_{Gi})
$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max}, i \in ng \tag{8}$$
Transformers tap setting (T_i) inequality constraint:
$$T_i^{min} \leq T_i \leq T_i^{max}, i \in nt \tag{9}$$
Transmission line flow (S_{Li}) inequality constraint:
$$S_{Li}^{min} \leq S_{Li}^{max}, i \in nl \tag{10}$$
Where, nc, ng and nt are numbers of the switchable reactive power sources, generators and transformers.

3. Lava Heron Optimization (LHO)Algorithm

Lava heron bird live in on the freshwater or saline water, swampy marshes or wetlands with tuft of trees mostly in low lying areas, where there are abundant convenience of fishes as their prey. These highly territorial birds are found in intertidal zones and mangrove swamps on all of the islands of Galápagos Province. The lava heron stalks small crabs and fish slowly before quickly spearing and eating them. They have also been known to eat the flies that gather near cacti. Lava herons are typically seen hunched over and they have a sharp alarm call. These birds have little fear of humans. Unlike most herons, these birds nest in solitary pairs in either the lower branches of mangrove trees or under lava rocks. They can breed year-round, though typically from September to March, and can mate up to three times a year. The prey catching attribute of lava heron bird is being exploited as a meta-heuristic for solving the optimization problem.

Inducement procedure
The inducement process is similar to holding attraction in the beak by the lava heron bird, as it does and will dive at the appropriate place where there is possibility of a grab. Similarly in the calculation the inducement is a solution subset that is arbitrarily produced and is held by the lava heron bird prior to find a high-quality position through local exploration all over the complete solution set.

The three following progression depends on the happenings and it depends on the problem, its constraints, and the execution and partially on the possibility. Local exploration are given as follows,

Fail To Spot - In this case the inducement gets established at one of its chosen place where it discover permanence and if the lava heron bird not succeeded to grab any prey and consequently the number of solutions in the solution set tends to raise. The absent node must be refurbished, in sequence to maintain the soundness of the solutions.

Grab - In this case the inducement helps the lava heron bird to grab a prey and thus the solution set elements remains steady and one appropriate element is added and one inappropriate element is eradicated.

Phony grab - Here the lava heron bird gets grip of a prey devoid of using inducement as occasionally fishes come close to the surface of the water. In this step an unsuitable element of the solution set is eradicated from the set. The exhaustion of a node in the form of a grab form the solution set must be reinstated for organization of soundness for definite constraints of the problems.

Modifying Locations

The Local exploration process can occur through assessment of all diminutive solution sets or part of extended enough solution sets. Depending on the solution sets for probable positions before it finds a appropriate one. This step is equivalent to the nature of the lava heron bird can sit very near the surface of the water such that at any point of time can take hold of a fish.

Magnetize Victim Swarm

In this step the point of discharge of the inducement will stay same but the complete set will swing to produce position for the most excellent agent to obtain the inducement and this will assist in an evolution like step where a move can change the solution particularly when the positions of the solution hold huge sense and the right progression is of greatest significance.

Articulate in a solution string represented as $S = \{a_1, a_2, .., a_n\}$ and the lined segments are characterized as $\{b_1, b_2, .., b_n\}$ where each $b_i \subseteq S$ and $= \{1, 2, .., m\}$,

Derivative Fitness $= m$ (11)

And with development of linkages m will continually reduce. In this case we can use each of the subsets as nodes for link foundation.

For each unremitting variable of the fitness function of the problem that is where D is the dimension of the problem $x_1 \in \{y_t^1, y_t^2, .., y_t^D\}$ and y_t^D is the Dth element in the tth iteration. It encompasses the subsequent equations prevailing the variation of the variable's variation and is self-adaptive, preceding iteration based and error sensitive based on the fitness function of the t and t-1 iteration.

$$y_t = y_{t-1} + |(y_{best} - y_r)|(y_{best} - y_f)|e_{(t,f)} \in_{(t,f)} + bias \qquad (12)$$

Where $\left[\{e_{(t,r)}, e_{(t,f)}\} \in e_t\right]$ and $\left[\{\in_{(t,r)}, \in_{(t,f)}\} \in \in_t\right]$ given by $e_{(t+1)} and \in_{(t+1)}$, where

$$e_{(t+1)} = \begin{cases} \frac{J_{t-1}-J_t}{|J_t-1|} \\ \frac{J_t-j_{t-1}}{|J_t-1|} \end{cases} \quad for \; y_t \geq y_{t-1} \& \; y_t < y_{t-1} \tag{13}$$

$$\in_{(t+1)} = \begin{cases} \in_t/k & for \; y_t > y_{max} \\ \in_t * k & for \; y_t < y_{max} \\ \in_t & otherwise \end{cases} \tag{14}$$

For our reactive power problem with $J_t < J_t\text{-}1$ or $J_t > J_t\text{-}1$ where x_t^1 is the ith variable for iteration t, J_t is the fitness value at iteration t, y_f and y_r are the front and rear neighbours respectively where $y_f^D \in \{y_t^D \; of \; new \; fellow \; agents\}$ and $y_r \in \{y_t^D \; of \; previous \; fellow \; agents\}$, δ_t is the variations contributor with respect to the tth iteration generated from previous iteration t - 1, $\in$ is the constantly changing adaptive contributor which denotes what percentage of the δ must be incorporated into the variable.

Lava Heron Optimization (LHO) Algorithm for Solving Optimal Reactive Power Problem

Stage 1: Initiate the Solution set all its n (n = dimension of problem) events$\{y_1, y_2, \ldots, y_n\}$.
Stage 2: Engender N Solution set each consist of element $\{y_1, y_2, \ldots, y_n\}$ denote an event.
Stage 3: Assess the fitness of each string.
Stage 4: Modernize the Global best if superior is found.
Stage 5: For each string Perform "Inducement procedure" where location is picked arbitrarily.
Stage 6: Execute "Modifying locations" operation depending upon the necessity and preliminary exploration results.
Stage 7: Execute "Magnetize Victim Swarm" and Complete "Inducement" operation.
Stage 8: Estimate the fitness of each string. Store the value of turnover if constraint fulfilled or else construct it zero.
Stage 9: on completion of every iteration, swap Y% most awful solutions with arbitrary initialization. (Y depends on N and according to the exploration necessity)
Stage 10: If numbers of iteration is completed then stop or else continue from stage 5.

4. Simulation Results

At first Lava Heron Optimization (LHO) Algorithm has been tested in standard IEEE-57 bus power system. The reactive power compensation buses are 18, 25 and 53. Bus 2, 3, 6, 8, 9 and 12 are PV buses and bus 1 is selected as slack-bus. The system variable limits are given in Table 1. The preliminary conditions for the IEEE-57 bus power system are given as follows:
P_{load} = 12.119 p.u. Q_{load} = 3.059 p.u.
The total initial generations and power losses are obtained as follows:
$\sum P_G$ = 12.442 p.u. $\sum Q_G$ = 3.3158 p.u.
P_{loss} = 0.25862 p.u. Q_{loss} = -1.2064 p.u.

Table 2 shows the various system control variables i.e. generator bus voltages, shunt capacitances and transformer tap settings obtained after optimization which are within the acceptable limits. In Table 3, shows the comparison of optimum results obtained from proposed methods with other optimization techniques. These results indicate the robustness of proposed approaches for providing better optimal solution in case of IEEE-57 bus system.

Table 1: Variable Limits

Reactive Power Generation Limits							
Bus no	1	2	3	6	8	9	12
Qgmin	-1.4	-.015	-.02	-0.04	-1.3	-0.03	-0.4
Qgmax	1	0.3	0.4	0.21	1	0.04	1.50
Voltage And Tap Setting Limits							
	vgmin	**Vgmax**	**vpqmin**	**Vpqmax**	**tkmin**	**tkmax**	
	0.9	1.0	0.91	1.05	0.9	1.0	
Shunt Capacitor Limits							
Bus no	18	25	53				
Qcmin	0	0	0				
Qcmax	10	5.2	6.1				

Table 2: Control variables obtained after optimization

Control Variables	LHO
V1	1.1
V2	1.038
V3	1.039
V6	1.028
V8	1.026
V9	1.002
V12	1.011
Qc18	0.0660
Qc25	0.200
Qc53	0.0478
T4-18	1.002
T21-20	1.047
T24-25	0.860
T24-26	0.870
T7-29	1.050
T34-32	0.873
T11-41	1.012
T15-45	1.030
T14-46	0.910
T10-51	1.020
T13-49	1.060
T11-43	0.910
T40-56	0.900
T39-57	0.950
T9-55	0.950

Table 3: Comparison results

S.No.	Optimization Algorithm	Finest Solution	Poorest Solution	Normal Solution
1	NLP [19]	0.25902	0.30854	0.27858
2	CGA [19]	0.25244	0.27507	0.26293

3	AGA [19]	0.24564	0.26671	0.25127
4	PSO-w [19]	0.24270	0.26152	0.24725
5	PSO-cf [19]	0.24280	0.26032	0.24698
6	CLPSO [19]	0.24515	0.24780	0.24673
7	SPSO-07 [19]	0.24430	0.25457	0.24752
8	L-DE [19]	0.27812	0.41909	0.33177
9	L-SACP-DE [19]	0.27915	0.36978	0.31032
10	L-SaDE [19]	0.24267	0.24391	0.24311
11	SOA [19]	0.24265	0.24280	0.24270
12	LM [20]	0.2484	0.2922	0.2641
13	MBEP1 [20]	0.2474	0.2848	0.2643
14	MBEP2 [20]	0.2482	0.283	0.2592
15	BES100 [20]	0.2438	0.263	0.2541
16	BES200 [20]	0.3417	0.2486	0.2443
17	Proposed LHO	0.22091	0.23010	0.22202

Then Lava Heron Optimization (LHO) Algorithm has been tested in standard IEEE 118-bus test system [21].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 4, with the change in step of 0.01.

Table 4: 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 5 and the results clearly show the better performance of proposed Lava Heron Optimization (LHO) Algorithm in reducing the real power loss.

Table 5: Comparison results

Active power loss (MW)	BBO [22]	ILSBBO/strategy1 [22]	ILSBBO/strategy1 [22]	Proposed LHO
Min	128.77	126.98	124.78	116.72
Max	132.64	137.34	132.39	119.94
Average	130.21	130.37	129.22	117.02

5. Conclusion

In this paper a novel approach Lava Heron Optimization (LHO) Algorithm used to solve optimal reactive power problem. Mainly inducement process, Modifying locations, Magnetize Victim

Swarm has been utlized to solve the problem. The proposed approach has been tested in standard IEEE 57,118 bus systems. The simulation results indicate the efficiency and heftiness of the projected algorithm in reducing the real power loss.

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