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Hodotermitidae Optimization Algorithm for Reduction of Real Power Loss

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Abstract

In this paper, a unique technique, called Hodotermitidae Optimization (HO) algorithm, is utilized for solving reactive power problem. Hodotermitidae Optimization (HO) algorithm is an population based optimization method which is inspired from rational behaviours of Hodotermitidae. The projected Hodotermitidae Optimization (HO) algorithm provides an option making model which is used by Hodotermitidae to adjust their progress trajectories. Hodotermitidae move arbitrarily in the search space, but their trajectories are inclined towards regions with more pheromones. The proposed Hodotermitidae Optimization (HO) algorithm has been tested in standard IEEE 57,118 bus systems and simulation results demonstrate the commendable performance of the projected Hodotermitidae Optimization (HO) algorithm in reducing the real power loss.

Keywords*:* Optimal Reactive Power, Transmission loss, Hodotermitidae Optimization.

1. Introduction

Optimal reactive power problem is to minimize the real power loss and bus voltage deviation by satisfying a set of physical and operational constraints enacted by apparatus limitations and security requirements. Numerous mathematical techniques like the gradient method [1-2], Newton method [3] and linear programming [4-7] have been adopted to solve the optimal reactive power dispatch problem. Both the gradient and Newton methods has the complication in handling inequality constraints. The problem of voltage stability and collapse play a key role in power system planning and operation [8]. Evolutionary algorithms such as genetic algorithm have been already proposed to solve the reactive power flow problem [9, 10].In [11], Genetic algorithm has been used to solve optimal reactive power flow problem. In [12], Hybrid differential evolution algorithm is suggested to improve the voltage stability index. In [13] Biogeography Based algorithm is proposed to solve the reactive power dispatch problem. In [14], a fuzzy based method is used to solve the optimal reactive power scheduling method .In [15], an improved evolutionary programming is used to solve the optimal reactive power dispatch problem. In [16], the optimal reactive power flow problem is solved by integrating a genetic algorithm with a nonlinear interior point method. In [17], a pattern algorithm is used to solve ac-dc optimal reactive power flow model with the generator capability limits. In [18], proposes a two-step approach to evaluate Reactive power reserves with respect to operating constraints and voltage stability. In [19], a programming based proposed approach used to solve the optimal reactive power dispatch problem. In [20], presents a probabilistic algorithm for optimal reactive power provision in hybrid electricity markets with uncertain loads. In this paper, a unique technique, called Hodotermitidae Optimization (HO) algorithm, is utilized for solving optimal reactive power problem. Hodotermitidae Optimization (HO) algorithm provides a colony of Hodotermitidae with a stochastic judgment making method. The judgment making procedure is used by the Hodotermitidae to select their progress prototype. A Hodotermitidae selects a progress prototype based on the confined information which is obtained by knowing the close by areas [21]. A Hodotermitidae moves randomly, but its progression may biased by observed pheromones in close by regions. Arbitrary movement is biased by pheromone. A Hodotermitidae be inclined to move toward a region which holds additional pheromones. The proposed Hodotermitidae

Optimization (HO) algorithm has been evaluated in standard IEEE 57,118 bus systems & the simulation results show that our proposed approach outperforms all reported algorithms in minimization of real power loss.

2. Problem Formulation

2.1. 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:

$$F = PL = \sum_{k \in Nbr} g_k \left(V_i^2 + V_j^2 - 2V_iV_j cos\theta_{ij}\right) \quad (1)$$

Where F- objective function, P_L – power loss, g_k-conductance of branch,V_i and V_j are voltages at buses i,j,Nbr- total number of transmission lines in power systems.

2.2. Voltage profile improvement

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

$$F = PL + \omega_v \times VD \quad (2)$$

Where ω_v: is a weighting factor of voltage deviation.
VD is the voltage deviation given by:

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \quad (3)$$

2.3. Equality Constraint

The equality constraint of the reactive power problem is represented by the power balance equation, where the total power generation must cover the total power demand and the power losses:

$$P_G = P_D + P_L \quad (4)$$

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

2.4. Inequality Constraints

The inequality constraints 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:

$$P_{gslack}^{min} \le P_{gslack} \le P_{gslack}^{max} \quad (5)$$

$$Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max}, i \in N_g \quad (6)$$

Upper and lower bounds on the bus voltage magnitudes:

$$V_i^{min} \le V_i \le V_i^{max}, i \in N \quad (7)$$

Upper and lower bounds on the transformers tap ratios:

$$T_i^{min} \le T_i \le T_i^{max}, i \in N_T \quad (8)$$

Upper and lower bounds on the compensators reactive powers:

$$Q_c^{min} \le Q_c \le Q_C^{max}, i \in N_C \quad (9)$$

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.

3. Hodotermitidae Optimization (HO) algorithm

A colony of Hodotermitidae is dispersed organization & is capable to execute versatile tasks using simple rules of individual Hodotermitidae' deeds. Such association contains simple individuals interrelate locally with one another and with their environment. Despite of a shortage of central control, local communications between simple individuals cause a global prototype to come out. The ability of social insects to self-organize depends on four attitudes: positive feedback, negative feedback, randomness, and multiple interactions. A fifth attitude, stigmergy, occur as a product of the preceding four .Such self association is known usually as swarm intelligence. A meek example of the hill building performance of Hodotermitidae provides a burly analogy to the mechanisms of Hodotermitidae. This illustration demonstrates the four principles of self organization .Alike to other population based algorithms, the swarm intelligence philosophy such as positive feedback, negative feedback, and arbitrariness, multiple interaction, and stigmergy play significant roles in social behaviors of Hodotermitidae.

Hodotermitidae Optimization (HO) algorithm utilizes stochastic sequence to find optimal solution. It employs a population of Hodotermitidae which move in a D-dimensional search space $S \subset R^D$ to find the optimal solution. Envisage that we have a population of N Hodotermitidae. Each Hodotermitidae "i" in the population is associated with a position vector $\vec{x}_i = (x_{i1}, x_{i2}, .., x_{iD})$, which represents a reasonable solution for an optimal problem in the *D* dimensional search space *S*. In HO, each position vector $\vec{x}_i$ represents a hill with a linked quality which is represented as *fit* $(\vec{x}_i)$. The fitness value models sum of pheromones which are deposited on the hill. At first, number of the Hodotermitidae, and utmost number of iterations, $Iter_{max}$, are determined. After that, at the commence time of the algorithm all of the Hodotermitidae are located arbitrarily in the exploration space:

$$\vec{x}_i(0) = Init\ (i, s)\ 1 \le i \le N \tag{10}$$

Where Init (i, S) is the initialization function which associates an arbitrary position to the Hodotermitidae *i* in the exploration space *S*. After initialization, the Hodotermitidae utilize the following progression to adjust their positions throughout iterations until the termination condition is met.

At each progression of the algorithm, the fitness value of each Hodotermitidae is calculated. The fitness value is used for computation of pheromone content at each position of Hodotermitidae. The pheromone content at the *j*-th location is computed based on the following equation:

$$\tau_i(t) = (1 - \rho)\tau_i(t - 1) + 1/(fit(x_i) + 1) \tag{11}$$

Where, ρ is the evaporation rate that is taken in range of [0..1], $\tau_i(t-1)$ and $\tau_i(t)$ respectively are the pheromone level at the current and earlier locations of *i*-th Hodotermitidae.

After calculating the pheromone levels at the locations of Hodotermitidae, each Hodotermitidae alter its trajectory based on local information and moves to new-fangled position. The Hodotermitidae movement is a function of pheromone level at the visited position and the distance between a Hodotermitidae position and the visited positions. Based on these, two different movement patterns introduced for Hodotermitidae. A local region around each Hodotermitidae has been considered, and the amount of visited position in the neighbourhood of the Hodotermitidae has been calculated. If there is no visited position in the neighbourhood of a Hodotermitidae, it moves arbitrarily in its own nearby regions. Hodotermitidae with one or more visited positions in their neighbourhood may select a more profitable position and move toward that position. A part of Hodotermitidae employs an arbitrary movement pattern in order to find more gainful regions. The arbitrary walk is performed by the Hodotermitidae in a region with radius τ. The exploration region is centred at existing position of the Hodotermitidae. So the subsequent position of a Hodotermitidae is modernized using the following equation:

$$\vec{x}_i(t) = \vec{x}_i(t - 1) + Rw\left(\tau, \vec{x}_i(t - 1)\right) \tag{12}$$

Where $\vec{x}_i(t-1)$ represents the earlier position of the Hodotermitidae, Rw is a random walk function that depends on the current position of the Hodotermitidae and the radius search τ

. The initial value of radius τ is defined as a percentage of $|X_{max} - X_{min}|$, where $X_{\max}$ and $X_{\min}$ respectively represent the maximum and minimum values of the search space along a dimension. The value of τ is linearly reduced from τ max to τ min throughout iterations. The Hodotermitidae adjust their walking based on the τ . The large value of τ at the first iterations enables Hodotermitidae walking with large step size to travel around wide regions in the exploration space. While the small values of τ in the last iterations support the scout Hodotermitidae to walk more precisely within small regions.

The locally observed pheromones provide the ability for a Hodotermitidae to use a selection procedure in order to alter its trajectories towards one of these pheromone gradients. In other words, the Hodotermitidae estimates the provided pheromone information, and alter its trajectory towards a position with the highest level of pheromone. A Hodotermitidae *i* considers the local best position $(\vec{b}_i)$ as its own promising position and move towards that if its existing position has smaller level of pheromone compared to the most excellent local position. The movement trajectory of the Hodotermitidae *i* is controlled by using the following equation:

$$\vec{x}_i(t) = \vec{x}_i(t-1) + \omega_b r_b \left(\vec{b}_i - \vec{x}_i(t-1)\right) \quad if \left(\tau_i(t-1) < \tau_{b_i}(t-1)\right) \tag{13}$$

Where $1 < w_b < 2$ & $0 < r_b < 1$ probabilistically controls the attraction of the Hodotermitidae towards local best position.

Hodotermitidae Optimization (HO) algorithm delivers a colony of Hodotermitidae with two movement patterns. This heterogeneity result an effective population based algorithm for optimal reactive problem. The arbitrary pattern is used by a part of Hodotermitidae that cannot use social information provided by the other Hodotermitidae. The HO algorithm utilizes this prototype control miscellany and stochastic of the behaviours of the Hodotermitidae in the colony. Usually, rising diversity of population is used as a way to lessen stagnation problem. In HO algorithm, diversity of the colony is efficiently controlled by a part of Hodotermitidae with arbitrary walk. The planned approach undyingly encourages the population to exit from stagnation state by exploring the nearby regions using random Hodotermitidae. The second movement pattern is used by the other part of Hodotermitidae. These Hodotermitidae utilize the social information about more gainful regions and adjust their trajectories towards these regions. This pattern enhances the swarm to strongly control the searching and convergence towards global optimum. Also, it eases premature convergence and stagnation that may occur due to solid constriction on the movement trajectories of the individuals of a population.

3.1. Hodotermitidae Optimization (HO) algorithm for solving reactive power problem

Initialization:

```
    Determine N,τ and $Iter_{max}$
    For i = 1 to N
    $\vec{x}_i(0) = Init(i, s)\ 1 \le i \le N$
    Next i
    Do
    Estimate fitness of the Hodotermitidae
    For i = 1 to N
    $\tau_i(t) = (1-\rho)\tau_i(t-1) + 1/(fit(x_i) + 1)$
    Next i
    For i = 1 to N
    Discover the neighbour positions for Hodotermitidae i
    Choose best neighbour position $\vec{b}_i$
    If Hodotermitidae i has neighbours Then
    If $\left(\tau_i(t-1) < \tau_{b_i}(t-1)\right)$ Then
    $\vec{x}_i(t) = \vec{x}_i(t-1) + \omega_b r_b \left(\vec{b}_i - \vec{x}_i(t-1)\right)$
    End If
    Else
    $\vec{x}_i(t) = \vec{x}_i(t-1) + Rw\left(\tau, \vec{x}_i(t-1)\right)$
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End If
Next i
Regulate radius $\tau$ and step size s
Until iter< $Iter_{max}$
```

4. Simulation Results

At first Hodotermitidae Optimization (HO) 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} = 12.122 p.u. Q_{load} = 3.060 p.u.

The total initial generations and power losses are obtained as follows:

$\sum P_G$ = 12.471 p.u. $\sum Q_G$ = 3.3160 p.u.

P_{loss} = 0.25870 p.u. Q_{loss} = -1.2071 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	**HO**
V1	1.1
V2	1.034
V3	1.036
V6	1.023
V8	1.021
V9	1.004
V12	1.017
Qc18	0.0660
Qc25	0.200
Qc53	0.0471
T4-18	1.004
T21-20	1.043
T24-25	0.861
T24-26	0.870
T7-29	1.051
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 [22]	0.25902	0.30854	0.27858
2	CGA [22]	0.25244	0.27507	0.26293
3	AGA [22]	0.24564	0.26671	0.25127
4	PSO-w [22]	0.24270	0.26152	0.24725
5	PSO-cf [22]	0.24280	0.26032	0.24698
6	CLPSO [22]	0.24515	0.24780	0.24673
7	SPSO-07 [22]	0.24430	0.25457	0.24752
8	L-DE [22]	0.27812	0.41909	0.33177
9	L-SACP-DE [22]	0.27915	0.36978	0.31032
10	L-SaDE [22]	0.24267	0.24391	0.24311
11	SOA [22]	0.24265	0.24280	0.24270
12	LM [23]	0.2484	0.2922	0.2641
13	MBEP1 [23]	0.2474	0.2848	0.2643
14	MBEP2 [23]	0.2482	0.283	0.2592
15	BES100 [23]	0.2438	0.263	0.2541
16	BES200 [23]	0.3417	0.2486	0.2443
17	Proposed HO	0.22097	0.23012	0.22278

Then Hodotermitidae Optimization (HO) algorithm has been tested in standard IEEE 118-bus test system [24].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 Hodotermitidae Optimization (HO) algorithm in reducing the real power loss.

Table 5. Comparison results

Active power loss (MW)	BBO [25]	ILSBBO/ strategy1 [24]	ILSBBO/ strategy1 [25]	Proposed HO
Min	128.77	126.98	124.78	118.92
Max	132.64	137.34	132.39	120.74
Average	130.21	130.37	129.22	119.96

5. Conclusion

In this paper, the Hodotermitidae Optimization (HO) algorithm has been successfully implemented to solve Optimal Reactive Power Dispatch problem. The main advantage of the Hodotermitidae Optimization (HO) algorithm is easily handling of non-linear constraints. The proposed Hodotermitidae Optimization (HO) algorithm has been tested in the standard IEEE 57,118 bus systems to minimize the active power loss. The optimal setting of control variables are well within the limits. The results were compared with the other heuristic methods and proposed HO demonstrated its efficiency and heftiness in minimizing the real power loss.

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