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Chaotic based Pteropus algorithm for solving optimal reactive power problem

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ABSTRACT

In this work, a Chaotic based Pteropus algorithm (CPA) has been proposed for solving optimal reactive power problem. Pteropus algorithm imitates deeds of the Pteropus. Normally Pteropus while flying it avoid obstacles by using sonar echoes, particularly utilize time delay. To the original Pteropus algorithm chaotic disturbance has been applied and the optimal capability of the algorithm has been improved in search of global solution. In order to augment the population diversity and prevent early convergence, adaptively chaotic disturbance is added at the time of stagnation. Furthermore, exploration and exploitation capability of the proposed algorithm has been improved. Proposed CPA technique has been tested in standard IEEE 14,300 bus systems & real power loss has been considerably reduced.

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1. INTRODUCTION

To have secure & economic, operations of the power system optimal reactive power problem plays a prime role. Numerous conventional methods [1-6] have been successfully solved the problem. But difficulty found in handling the inequality constraints. Various types of evolutionary algorithms [7-18] applied to solve the problem. This paper projects chaotic Pteropus algorithm (CPA) for solving reactive power problem. Pteropus algorithm is designed based on the actions of Pteropus. while flying it avoid obstacles by using sonar echoes, particularly utilize time delay; happened while release and reflection of echo which has been utilized during the period of for course-plotting. In Projected algorithm echolocation feature is utilized in the algorithm and chaos theory intermingled in the flowing process. In order to augment the population diversity and prevent early convergence, adaptively chaotic disturbance P_c is added at the time of stagnation. Projected CPA algorithm has been tested in standard IEEE 14,300 bus systems & simulation study show the best performance of the projected algorithm in reducing the real power loss.

2. PROBLEM FORMULATION

The key objective of the reactive power problem is to minimize the system real power loss & given as,

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

Voltage deviation magnitudes (VD) is stated as follows,

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

Load flow equality constraints:

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

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

Inequality constraints are:

$$V_{Gi}^{min} \leq V_{Gi} \leq V_{Gi}^{max}, i \in ng \quad (5)$$

$$V_{Li}^{min} \leq V_{Li} \leq V_{Li}^{max}, i \in nl \quad (6)$$

$$Q_{Ci}^{min} \leq Q_{Ci} \leq Q_{Ci}^{max}, i \in nc \quad (7)$$

$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max}, i \in ng \quad (8)$$

$$T_{i}^{min} \leq T_{i} \leq T_{i}^{max}, i \in nt \quad (9)$$

$$S_{Li}^{min} \leq S_{Li}^{max}, i \in nl \quad (10)$$

3. PTEROPUS ALGORITHM

Pteropus algorithm imitates deeds of the Pteropus. Normally Pteropus while flying it avoid obstacles by using sonar echoes, particularly utilize time delay; happened while release and reflection of echo which has been utilized during the period of for course-plotting. Generalized rules for Pteropus algorithm are:

a. To sense the distance- all Pteropus use echolocation
b. In arbitrarily mode Pteropus fly with velocity ϑ_i at position y_i with a fixed frequencyf_{min}, varying wavelength λ and loudness A_0 to search for prey. They can robotically adjust the frequency of their released pulses and regulate the rate of pulse emission r ∈ [0; 1], with reference to the propinquity of the goal.
c. Loudness will vary from a large (positive) A_0 to a minimum constant value A_{min}.

Pteropus algorithm

```
Initialize the population
Pulse frequency defined in the range of $G_i \in [Q_{min}, G_{max}]$
$r_i$ ,$A_i$ are defined
While (t <$T_{maximum}$)
By adjustment of frequency new solutions are generated
Obtained Solution & velocity are updated
If (random (0; 1) > $r_i$ )
Form the solution best one is selected
Around the best solution – a local solution will be engendered
End if
In arbitrary mode new solutions are generated
If (random (0; 1) < $A_i$ and f ($y_i$) < f(y))
New solutions are formed
$r_i$ and $A_i$ values are increased
End if
Current best is found by ranking the Pteropus in order
End while
Output the optimized results
Virtual Pteropus are moved to form new solutions by the following,
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$$\mathrm{G}_{\mathrm{i}}^{(\mathrm{t})} = \mathrm{G}_{\min} + (\mathrm{G}_{\max} - \mathrm{G}_{\min}) \cup (0,1), \tag{11}$$

$$\mathrm{l}_{\mathrm{i}}^{(\mathrm{t}+1)} = \mathrm{l}_{\mathrm{i}}^{\mathrm{t}} + (\mathrm{y}_{\mathrm{i}}^{\mathrm{t}} - \mathrm{best})\mathrm{G}_{\mathrm{i}}^{(\mathrm{t})}, \tag{12}$$

$$\mathrm{y}_{\mathrm{i}}^{(\mathrm{t}+1)} = \mathrm{y}_{\mathrm{i}}^{(\mathrm{t})} + \mathrm{l}_{\mathrm{i}}^{(\mathrm{t})} \tag{13}$$

Existing finest solution has been modified by the following,

$$\mathrm{y}^{(\mathrm{t})} = \mathrm{best} + \epsilon \mathrm{A}_{\mathrm{i}}^{(\mathrm{t})}(2\mathrm{U}(0,1) - 1), \tag{14}$$

When ri increases, Ai will decrease; when a Pteropus finds a prey & it mathematically written as follows,

$$\mathrm{A}_{\mathrm{i}}^{(\mathrm{t}+1)} = \alpha \mathrm{A}_{\mathrm{i}}^{(\mathrm{t})}, \mathrm{r}_{\mathrm{i}}^{(\mathrm{t})} = \mathrm{r}_{\mathrm{i}}^{(0)}[1 - \exp(-\gamma\epsilon)], \tag{15}$$

To improve the Pteropus algorithm chaotic disturbance [19-21] is introduced. Here, variance σ^2 demonstrates the converge degree of all particles.

$$\sigma^2 = \sum_{i=1}^{N}\left[\left(f_i - f_{avg}\right)/f\right]^2 \tag{16}$$

$$f = max\left\{1, max\left\{\left|f_i - f_{avg}\right|\right\}\right\} \tag{17}$$

$$y_{id}(t+1) = \mu y_{id}(t)\left(1 - y_{id}(t)\right) \tag{18}$$

In order to augment the population diversity and prevent early convergence, adaptively chaotic disturbance P_c is added at the time of stagnation. Thus, $P_c\ is\ modified\ as\ P_c'$.

$$E_{cd}'(t+1) = p_{cd}(t) + Z_{id}\left(2_{yid}(t) - 1\right) \tag{19}$$

$$Z_{id} = \beta\left|p_{cd}(t) - E_{id}(t)\right| \tag{20}$$

Chaotic based Pteropus Algorithm

```
Initialize the population
Pulse frequency defined in the range of $G_i \in [G_{min}, G_{max}]$
$r_i$ ,$A_i$ are defined
While (t <$T_{maximum}$)
By adjustment of frequency new solutions are generated
Obtained Solution & velocity are updated
Using the equations update the velocities and locations
$G_i^{(t)} = G_{min} + (G_{max} - G_{min}) \cup (0,1),$
$l_i^{(t+1)} = l_i^t + (y_i^t - best)G_i^{(t)},$
$y_i^{(t+1)} = y_i^{(t)} + l_i^{(t)}$
If (random (0; 1) > $r_i$ )
Form the solution best one is selected
Around the best solution – a local solution will be engendered
End if
In arbitrary mode new solutions are generated
If (random (0; 1) < $A_i$ and f ($y_i$) < f(y))
New solutions are formed
$r_i$ and $A_i$ values are increased
End if
Current best is found by ranking the Pteropus in order
End while
Output the optimized results
```

4. SIMULATION RESULTS

Proposed Chaotic based Pteropus algorithm (CPA) has been tested in standard IEEE 14,300 bus systems and comparison has been done with standard algorithms. Simulation output clearly indicates about the efficiency of the proposed algorithm in reducing the real power loss.

At first in standard IEEE 14 bus system the validity of the proposed CPA algorithm has been tested & comparison results are presented in Table 1.

Table 1. Comparison results

Control variables	ABCO [22]	IABCO [22]	Projected CPA
V1	1.06	1.05	1.03
V2	1.03	1.05	1.00
V3	0.98	1.03	1.01
V6	1.05	1.05	1.00
V8	1.00	1.04	0.99
Q9	0.139	0.132	0.129
T56	0.979	0.960	0.969
T47	0.950	0.950	0.948
T49	1.014	1.007	1.002
Ploss (MW)	5.92892	5.50031	5.49842

Then IEEE 300 bus system [23] is used as test system to validate the performance of the proposed CPA algorithm. Table 2 shows the comparison of real power loss obtained after optimization. Real power loss has been considerably reduced when compared to the other standard reported algorithms.

Table 2 comparison of real power loss

Parameter	Method EGA [24]	Method EEA [24]	Method CSA [25]	Projected CPA
PLOSS (MW)	646.2998	650.6027	635.8942	627.1564

5. CONCLUSION

In this paper, chaotic based Pteropus algorithm (CPA) has been successfully solved the optimal reactive power problem. Natural actions of Pteropus has been effectively imitated and modelled to solve the problem. An adaptive chaotic disturbance P_c is added at the time of stagnation Performance of the Pteropus algorithm has been improved and better-quality solutions have been obtained. In addition, exploration and exploitation capability of the proposed algorithm has been enhanced. Proposed CPA technique has been tested in standard IEEE 14,300 bus systems & real power loss has been considerably reduced.

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