Reduction of real power loss by upgraded red shaver swarm optimization algorithm

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ABSTRACT

In this paper, an upgraded Red Shaver swarm Optimization (RS) algorithm is proposed for solving reactive power problem. Under cockerel as group-mate Red Shaver explores food; also it prevents the same ones to eat their own food. Red Shaver would arbitrarily pinch the high-quality food which has been already found by other Red Shaver & always overriding other individuals to grab more food. In the Projected upgraded Red Shaver swarm Optimization (RS) algorithm additional parameters of cockerel, hens and chicks are eliminated, in order to upsurge the search towards global optimization solution. Proposed Upgraded Red Shaver swarm Optimization (RS) algorithm has been tested in standard IEEE 30 bus system. Simulation results show clearly the better performance of the proposed RS algorithm in reduction of real power loss.

1. INTRODUCTION

The main objective of optimal reactive power problem is to reduce the actual power loss. Various techniques [1-7] have been utilized but have the complexity in handling constraints. Different types of evolutionary algorithms [8-19] have been utilized in various stages to solve the problem. But many limitations have been found in Exploration & Exploitation. This paper proposes Upgraded Red Shaver swarm Optimization (RS) algorithm to solve reactive power problem. In this projected algorithm both exploration & exploitation has been augmented equally in order to reach near to global optimum solution. Red Shaver follows their cockerel to explore food. Overriding individuals have the lead to grab more food. In the region of the mother (hen [20]) Red Shaver always searches for food. In the Projected Upgraded Red Shaver swarm Optimization (RS) algorithm additional parameters of cockerel, hens and chicks are eliminated, in order to upsurge the search towards global optimization solution. Proposed Upgraded Red Shaver swarm Optimization (RS) algorithm has been tested in standard IEEE 30 bus system. & real power loss reduced with voltage profiles within the limits.

2. PROBLEM FORMULATION

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

\[ P_{\text{loss}} = \sum_{k=1}^{n} G_k (V_i^2 + V_j^2 - 2V_i V_j \cos \theta_{ij}) \]  

(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 \( \theta_{ij} \) is the voltage angle difference between bus i and bus j.

Minimization of Voltage Deviation

\[ \text{Minimize VD} = \sum_{k=1}^{nl} |V_k - 1.0| \]  

(2)

where nl is the number of load busses and \( V_k \) is the voltage magnitude at bus k.

System Constraints

Objective function has the following constraints as given below.

Load flow equality constraints:

\[ P_{Gi} - P_{Di} - V_{i, j}^{\text{nb}} \left[ G_{ij} \cos \theta_{ij} + B_{ij} \sin \theta_{ij} \right] = 0, \text{ } i = 1, 2, ..., \text{nb} \]  

(3)

\[ Q_{Gi} - Q_{Di} - V_{i, j}^{\text{nb}} \left[ G_{ij} \sin \theta_{ij} + B_{ij} \cos \theta_{ij} \right] = 0, \text{ } i = 1, 2, ..., \text{nb} \]  

(4)

Inequality constraints are:

\[ V_{\text{Gi}}^{\text{min}} \leq V_{Gi} \leq V_{\text{Gi}}^{\text{max}}, \text{ } i \in \text{ng} \]  

(5)

\[ V_{\text{Dj}}^{\text{min}} \leq V_{Dj} \leq V_{\text{Dj}}^{\text{max}}, \text{ } i \in \text{nl} \]  

(6)

\[ Q_{\text{Gi}}^{\text{min}} \leq Q_{Gi} \leq Q_{\text{Gi}}^{\text{max}}, \text{ } i \in \text{nc} \]  

(7)

\[ Q_{\text{Dj}}^{\text{min}} \leq Q_{Dj} \leq Q_{\text{Dj}}^{\text{max}}, \text{ } i \in \text{ng} \]  

(8)

\[ T_{i}^{\text{min}} \leq T_{i} \leq T_{i}^{\text{max}}, \text{ } i \in \text{nt} \]  

(9)

\[ S_{\text{Li}}^{\text{min}} \leq S_{Li} \leq S_{\text{Li}}^{\text{max}}, \text{ } i \in \text{nl} \]  

(10)

3. RED SHAVER SWARM OPTIMIZATION ALGORITHM

Red Shaver swarm Optimization based on the Red Shaver behaviour & it can be articulated mathematically as follows.
\[ y_{ij}^{t+1} = y_{ij}^t \cdot (1 + \text{Rand}(0, \sigma^2)) \]  
(11)

\[
\sigma^2 = \begin{cases} 
1 \cdot \exp\left(\frac{f_t - f_{l_i}}{|f_t + \varepsilon|}\right) & \text{if } f_t \leq f_{l_i} \\
0 & \text{otherwise} 
\end{cases} 
\quad k \in [1, N], k \neq 1 
\quad (12)
\]

where \(\text{Rand}(0, \sigma^2)\) is a Gaussian distribution with mean 0 and standard deviation \(\sigma^2\).

Dominant hens competing for food highly & formulated mathematically as follows,

\[ y_{ij}^{t+1} = y_{ij}^t + G1 \cdot \text{Rand} \cdot \left( y_{ij}^* - y_{ij}^t \right) + G2 \cdot \text{Rand} \cdot \left( y_{ij}^t - y_{ij}^* \right) \]

(13)

\[ G1 = \exp\left(\frac{f_{l_i} - f_t}{|f_{l_i} + \varepsilon|}\right) \]

(14)

\[ G2 = \exp(f_{t_i} - f_t) \]

(15)

where Rand is a uniform random number over \([0, 1]\), is an index of the cockerel, which is the ith hen’s group-mate, while \(r^2 \in [0, 1]\), is an index of the Red Shaver, which is arbitrarily chosen from the swarm \(r^1 \neq r^2\).

Around the mother, chicks move to forage for food & formulated by,

\[ y_{ij}^{t+1} = y_{ij}^t + FL \cdot \left( y_{m_j}^t - y_{ij}^t \right) \]

(16)

where \(y_{m_j}^t\) stands for the position of the i-th chick’s mother in \([1, N]\). FL[FL \in (0, 2)].

### 4. UPGRADED RED SHAVER SWARM OPTIMIZATION ALGORITHM

In the upgradation of the Red Shaver optimization algorithm the parameters are tuned in the Exploration & Exploitation Step. It will augment the search & lead to a better solution.

**Initialization of Population**

Red Shaver swarm population are initialized by,

\[ y_{ij} = lb + \text{Rand}(ub - lb) \]

(17)

In exploration space, \(lb\) and \(ub\) are lower bound and upper bound.

**Exploration Step**

Each individual of Red Shaver population revamp their position and it formulated as,

\[ y_{ij}(s) = y_{ij} + G1 \cdot \text{Rand} \cdot \left( y_{ij} - y_{ij} \right) + G2 \cdot \text{Rand} \cdot \left( y_{n_j} - y_{ij} \right) \]

(18)

With

\[ G1 = \exp\left(\frac{f_{l_i} - f_t}{|f_{l_i} + \varepsilon|}\right) \]

(19)

\[ G2 = \exp(f_{t_i} - f_t) \]

(20)

\[ y_t, y_n \in [1, N] \text{ is arbitrarily chosen form Red Shaver swarm with } y_t \neq y_i \neq y_n. \]

Based on most excellent fitness value best individual of the global population is found & termed as \(y_{ij}(g)\).

**Exploitation Step**

The first step in Local optimum search is reduction of cockerel formula as follows.

\[ y_{ij}(**) = y_{ij} + \text{Rand}(0, \sigma^2) \]

(21)

\[ \sigma^2 = \begin{cases} 
1 \cdot \exp\left(\frac{f_t - f_{l_i}}{|f_t + \varepsilon|}\right) & \text{if } f_t \leq f_{l_i} \\
0 & \text{otherwise} 
\end{cases} \quad l \in [1, N] \quad (12) \]

Most excellent fitness value solution is chosen as best individual & called as Local population

\[ I\left(y_{ij}(l_1)\right). \]

In concluding step of upgraded Red Shaver swarm optimization is to find more local optimum values as follows:

\[ y_{ij}(**) = y_{ij}(l_1) + C \cdot \left( y_{n_j}(l_1) - y_{ij}(l_1) \right) \]

(23)

\[ y_n \in [1, N] \text{ is arbitrarily chosen from the local population } I \text{ with } y_t \neq y_n \text{ and } C(C \in (0, 2)). \]

Solution which has most outstanding fitness value is chosen as best individual & called as local population \(I(y_{ij}(l_2))\).

Until the stopping criterion is met this population is used as the preliminary population for the ensuing iterations.

Upgraded Red Shaver swarm Optimization (RS) algorithm for solving reactive power problem

a. By using equation (17) Initialize a population of \( N \) Red Shaver

b. \( N \) Red Shaver fitness value has been evaluated; \( t = 0 \)

c. While \( t < G \)

d. For \( i = 1; N \)

aa. By equation (18) explore the global optimum & individual best global population \(y_{ij}(g)\)

bb. Local optimum has been exploit.

aaa. By equation (21) find first local optimum & individual best local population \(I(y_{ij}(l_1))\)

bbb. By equation (23) find second local optimum & individual best local population \(I(y_{ij}(l_2))\)

e. End For

**End While**

### 5. SIMULATION RESULTS

Validity of the proposed Upgraded Red Shaver swarm Optimization (RS) algorithm has been verified by testing in standard IEEE 30-bus without considering Voltage stability evaluation. In Table 1 Control variables limits are given. In Table 2 gives the power limits of generator buses. Table 3 shows the values of control variables. Table 4 narrates the performance of the proposed algorithm. Overall comparison of real power loss is given in Table 5.
### Table 1. Primary variable limits (PU)

<table>
<thead>
<tr>
<th>List of Variables</th>
<th>Minimum limit</th>
<th>Maximum limit</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator Bus</td>
<td>0.9500</td>
<td>1.1000</td>
<td>Continuous</td>
</tr>
<tr>
<td>Load Bus</td>
<td>0.9500</td>
<td>1.0500</td>
<td>Continuous</td>
</tr>
<tr>
<td>Transformer-Tap</td>
<td>0.9000</td>
<td>1.1000</td>
<td>Discrete</td>
</tr>
<tr>
<td>Shunt Reactive Compensator</td>
<td>-0.1100</td>
<td>0.3100</td>
<td>Discrete</td>
</tr>
</tbody>
</table>

### Table 2. Power limits of the generator buses

<table>
<thead>
<tr>
<th>Bus</th>
<th>Pg</th>
<th>Pgminimum</th>
<th>Pgmaximum</th>
<th>Qgminimum</th>
<th>Qgmaximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>96.000</td>
<td>49.00</td>
<td>200.00</td>
<td>0.00</td>
<td>10.0</td>
</tr>
<tr>
<td>2</td>
<td>79.000</td>
<td>18.00</td>
<td>79.00</td>
<td>-40.00</td>
<td>50.00</td>
</tr>
<tr>
<td>5</td>
<td>49.000</td>
<td>14.00</td>
<td>49.00</td>
<td>-40.00</td>
<td>40.00</td>
</tr>
<tr>
<td>8</td>
<td>21.000</td>
<td>11.00</td>
<td>31.00</td>
<td>-10.00</td>
<td>40.00</td>
</tr>
<tr>
<td>11</td>
<td>21.000</td>
<td>11.00</td>
<td>28.00</td>
<td>-6.000</td>
<td>24.00</td>
</tr>
<tr>
<td>13</td>
<td>21.000</td>
<td>11.00</td>
<td>39.00</td>
<td>-6.000</td>
<td>24.00</td>
</tr>
</tbody>
</table>

### Table 3. After optimization values of control variables

<table>
<thead>
<tr>
<th>List of Control Variables</th>
<th>RS</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>1.04320</td>
</tr>
<tr>
<td>V2</td>
<td>1.04200</td>
</tr>
<tr>
<td>V5</td>
<td>1.01920</td>
</tr>
<tr>
<td>V8</td>
<td>1.02840</td>
</tr>
<tr>
<td>V11</td>
<td>1.06920</td>
</tr>
<tr>
<td>V13</td>
<td>1.04340</td>
</tr>
<tr>
<td>T4,12</td>
<td>0.0000</td>
</tr>
<tr>
<td>T6,9</td>
<td>0.0100</td>
</tr>
<tr>
<td>T6,10</td>
<td>0.9000</td>
</tr>
<tr>
<td>T28,27</td>
<td>0.9100</td>
</tr>
<tr>
<td>Q10</td>
<td>0.1000</td>
</tr>
<tr>
<td>Q24</td>
<td>0.1000</td>
</tr>
<tr>
<td>Real power loss (MW)</td>
<td>4.2674</td>
</tr>
<tr>
<td>Voltage deviation</td>
<td>0.9070</td>
</tr>
</tbody>
</table>

### Table 4. Performance of RS algorithm

<table>
<thead>
<tr>
<th>Number of Iterations</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time taken in secs</td>
<td>9.68</td>
</tr>
<tr>
<td>Real power loss (MW)</td>
<td>4.2674</td>
</tr>
</tbody>
</table>

### Table 5. Comparison of Results

<table>
<thead>
<tr>
<th>List of Techniques</th>
<th>Real power loss (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGA [21]</td>
<td>4.98</td>
</tr>
<tr>
<td>PSO [22]</td>
<td>4.9262</td>
</tr>
<tr>
<td>LP [23]</td>
<td>5.988</td>
</tr>
<tr>
<td>EP [23]</td>
<td>4.963</td>
</tr>
<tr>
<td>CGA [23]</td>
<td>4.980</td>
</tr>
<tr>
<td>AGA [23]</td>
<td>4.926</td>
</tr>
<tr>
<td>CLPSO [23]</td>
<td>4.7208</td>
</tr>
<tr>
<td>HSA [24]</td>
<td>4.7624</td>
</tr>
<tr>
<td>MCS [26]</td>
<td>4.87231</td>
</tr>
<tr>
<td>Proposed RS</td>
<td>4.2674</td>
</tr>
</tbody>
</table>

### 6. CONCLUSION

Reactive power problem has been successfully solved by Upgraded Red Shaver swarm Optimization (RS) algorithm & it eliminated the additional parameters of cockerel, hens and chicks, also upsurges the exploration in reaching the global optimization solution. Proposed Upgraded Red Shaver swarm Optimization (RS) algorithm has been tested in standard IEEE 30 bus test system. Simulation results show the better performance of the RS algorithm in reduction of real power loss.

### REFERENCES


