[1.]Kanagasabai LENIN

# ACTIVE POWER LOSS REDUCTION BY ENRICHED BAT ALGORITHM

[1.]Department EEE, Prasad V. Potluri Siddhartha Institute of Technology, Kanuru, Vijayawada, Andhra Pradesh, INDIA

**Abstract:** In this work Enriched Bat Algorithm (EBA) is projected to solve optimal reactive power problem. Bat algorithm based on swarm intelligence and stimulated from the echolocation behavior of bats. In this projected algorithm the directional attribute of echolocation is applied. Progression of bats is directed by superior bats, local schedule are advanced by calculating the step sizes. Pulse emission and loudness are customized to augment the performance of the algorithm. In the Enriched Bat Algorithm (EBA) in the region of two bats when the food is definite then the present bat shift to a direction at the neighboring neighborhood the two bats where the food is believed to be ample. When it is not possible then it moves toward the most excellent bat. Proposed Enriched Bat Algorithm (EBA) has been tested in standard IEEE 14, 30, 57,118,300 bus test systems and simulation results show the projected algorithm reduced the real power loss comprehensively.

**Keywords:** optimal reactive power, Transmission loss, Bat algorithm

## 1. INTRODUCTION

Reactive power problem plays an important role in secure and economic operations of power system. Numerous types of methods [1–6] have been utilized to solve the optimal reactive power problem. However many scientific difficulties are found while solving problem due to an assortment of constraints. Evolutionary techniques [7–16] are applied to solve the reactive power problem. This paper proposes Enriched Bat Algorithm (EBA) to solve optimal reactive power problem. Proposed algorithm Imitate the deeds of the Bat actions and it uses sonar echoes to notice and stay away from obstacle. Time delay is used from emission to reflection and employing it for direction–finding. Echolocation used as main part to sense the distance and for other activities. With velocity $\vartheta_i$ at position $x_i$ with a set frequency $f_{min}$, changeable wavelength $\lambda$ and loudness $A_0$ Bats fly arbitrarily to look for the prey. Wavelength can be adjusted automatically and can regulate the rate of pulse emission $r \in [0; 1]$, depend on the propinquity of the target. In this projected algorithm the directional attribute of echolocation is applied. Progression of bats is directed by superior bats, local schedule are advanced by calculating the step sizes. Pulse emission and loudness are customized to augment the performance of the algorithm. In the Enriched Bat Algorithm (EBA) in the region of two bats when the food is definite then the present bat shift to a direction at the neighboring neighborhood of the two bats where the food is believed to be ample. When it is not possible then it moves toward the most excellent bat. Proposed Enriched Bat Algorithm (EBA) has been tested in standard IEEE 14, 30, 57,118,300 bus test systems and simulation results show the projected algorithm reduced the real power loss comprehensively.

## 2. PROBLEM FORMULATION

Objective of the problem is to reduce the true power loss:

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

Voltage deviation given as follows:

$$F = P_L + \omega_v \times \text{Voltage Deviation} \tag{2}$$

Voltage deviation given by:

$$\text{Voltage Deviation} = \sum_{i=1}^{Npq} |V_i - 1| \tag{3}$$

Constraint (Equality)

$$P_G = P_D + P_L \tag{4}$$

Constraints (Inequality)

$$P_{gslack}^{min} \le P_{gslack} \le P_{gslack}^{max} \tag{5}$$

$$Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max}, i \in N_g \tag{6}$$

$$V_i^{min} \le V_i \le V_i^{max}, i \in N \tag{7}$$

$$T_i^{min} \le T_i \le T_i^{max}, i \in N_T \tag{8}$$

$$Q_c^{min} \le Q_c \le Q_C^{max}, i \in N_C \tag{9}$$

## 3. ENRICHED BAT ALGORITHM

Bat algorithm imitated the deeds of the Bat actions and it uses sonar echoes to notice and stay away from obstacle. Time delay is used from emission to reflection and employing it for direction–finding. Echolocation used as main part to sense the distance and for other activities. With velocity $\vartheta_i$ at position $x_i$ with a set frequency $f_{min}$, changeable wavelength $\lambda$ and loudness $A_0$ Bats fly arbitrarily to look for the prey. Wavelength can be adjusted automatically and can regulate the rate of pulse emission r ∈ [0; 1], depend on the propinquity of the target [17]. Loudness assumed to vary from a large (positive) $A_0$ to minimum constant value $A_{min}$. New solutions engendered by,

$$Q_i^{(t)} = Q_{min} + (Q_{max} - Q_{min}) \cup (0,1), \tag{10}$$

$$v_i^{(t+1)} = v_i^t + (x_i^t - best) Q_i^{(t)}, \tag{11}$$

$$x_i^{(t+1)} = x_i^{(t)} + v_i^{(t)} \tag{12}$$

For local search a capricious walk with direct exploitation is used to modernize the present most excellent solution by:

$$x^{(t)} = best + \epsilon A_i^{(t)} (2U(0,1) - 1) \tag{13}$$

$\epsilon$ – scaling factor, $A_i^{(t)}$ – loudness. Depending on the pulse rate $r_i$ and new–fangled solutions are accepted with some proximity local search will be commenced. When bat finds a prey rate of pulse emission $r_i$ augments and loudness Ai diminished, which mathematically written by,

$$A_i^{(t+1)} = \alpha A_i^{(t)}, r_i^{(t)} = r_i^{(0)} [1 - \exp(-\gamma\epsilon)] \tag{14}$$

In the Enriched Bat Algorithm (EBA) in the region of two bats when the food is definite then the present bat shift to a direction at the neighbouring neighbourhood of the two bats where the food is believed to be ample. When it is not possible then it moves toward the most excellent bat. The arithmetical equation for the movement of the bats is given by,

$$\begin{cases} x_i^{t+1} = x_i^t + (x^* - x_i^t) f_1 + (x_k^t - x_i^t) f_2 & \left(\text{if } F(x_k^t) < F(x_i^t)\right) \\ x_i^{t+1} = x_i^t + (x^* - x_i^t) f_1 & \text{otherwise} \end{cases} \tag{15}$$

Projected movement in Eq. (7) has the capability to spread the progress directions which can augment the exploration aptitude, chiefly at the preliminary phase of iterations, and can thus keep away from early convergence.

Frequencies are updated by,

$$\begin{cases} f_1 = f_{minimum} + (f_{maximum} - f_{minimum}) \text{ random1} \\ f_2 = f_{minimum} + (f_{maximum} - f_{minimum}) \text{ random2} \end{cases} \tag{16}$$

Normally in the standard Bat algorithm, bats are allowed to shift from their present positions to novel arbitrary positions by a local capricious walk. Local search mechanisms are modified in the projected algorithm by,

$$x_i^{t+1} = x_i^t + < A^t > \varepsilon w_i^t \tag{17}$$

$w_i$ is a factor which control the balance of the exploration when iterative process proceed,

$$w_i^t = \left(\frac{w_{io} - w_{i\infty}}{1 - t_{maximum}}\right)(t - t_{maximum}) + w_{i\infty} \tag{18}$$

$$w_{io} = (Ub_i - Lb_i)/4 \tag{19}$$

$$w_{i\infty} = w_{io}/100 \tag{20}$$

Commencement of the iterative procedure $w_i$ begins with a huge value and the bats to shift capriciously so as to augment the exploration capability of the algorithm, so entire exploration space will be explored efficiently. Value of $w$ diminishes, during end period of the iterative procedure, it will condense the explore region around the most excellent solution, and thus the exploitation ability of the algorithm is also improved.

Pulse rate and loudness are increased, decreased by:

$$r^t = \left(\frac{r_o - r_\infty}{1 - t_{max}}\right)(t - t_{max}) + r_\infty \tag{21}$$

$$A^t = \left(\frac{A_o - A_\infty}{1 - t_{max}}\right)(t - t_{max}) + A_\infty \tag{22}$$

When iterations move towards the conclusion, large value will be assigned to the pulse rate such that exploitation takes over from exploration. Pulse rate and loudness: r0 = 0.1, r∞ = 0.7, A0 = 0.9 and A∞ = 0.6.

Projected EBA approach will modernize the global best position each time when the bat's arbitrary walk generate a solution with a superior fitness value although if it was not established to modernize the bat's position.

```
a. Initialize a population
b. Set $x_{pi}^* = x_i (i = 1,.., M)$ and most excellent present solution has to be found $x^*$
c. While t ≤ Iteration maximum do
d. For i = 1 to M do
e. For j = 1 to n do
f. Modify the velocity of each bat by
   $Q_i^{(t)} = Q_{min} + (Q_{max} - Q_{min}) \cup (0,1)$ ;   $v_i^{t+1} = \omega * v_i^t + \left(x_i^t - \frac{x^* + x_{pi}^*}{2}\right) * f_i$
g. Modify the position of each bat by $x_i^{(t+1)} = x_i^{(t)} + v_i^{(t)}$
h. End for
```

```
i.   If random > $r_i$ then choose a solution amongst of the most excellent solutions
j.   Produce frequencies; $\begin{cases} f_1 = f_{minimum} + (f_{maximum} - f_{minimum})\ random1 \\ f_2 = f_{minimum} + (f_{maximum} - f_{minimum})\ random2 \end{cases}$
k.   Engender local solution in the region of most excellent solution;
         $\begin{cases} x_i^{t+1} = x_i^t + (x^* - x_i^t)f_1 + (x_k^t - x_i^t)f_2 & \left(\text{if } F(x_k^t) < F(x_i^t)\right) \\ x_i^{t+1} = x_i^t + (x^* - x_i^t)f_1 & \text{otherwise} \end{cases}$
l.   End if
m.   if random $< A_i$ and $f(x_i) < f(x^*)$
n.   fix $x^* = x_i$
o.   Augment the value of $r_i$, diminish the value of $A_i$.
p.   End if
q.   If $f(x_i) < f(x_{pi}^*)$
r.   $x_{pi}^* = x_i$ then fix $L_i = 0$
s.   Or Else fix $L_i = L_i + 1$
t.   End if
u.   End for
v.   For i = 1 to M do
w.   if $L_i = L$ then by $\begin{cases} x_i^{t+1} = x_i^t + (x^* - x_i^t)f_1 + (x_k^t - x_i^t)f_2 & \left(\text{if } F(x_k^t) < F(x_i^t)\right) \\ x_i^{t+1} = x_i^t + (x^* - x_i^t)f_1 & \text{otherwise} \end{cases}$
     engender novel position & swap $x_i$
x.   Recognize the new–fangled solution
y.   Augment ri by $r^t = \left(\frac{r_0 - r_\infty}{1 - t_{max}}\right)(t - t_{max}) + r_\infty$
z.   Diminish $A_i$ by $A^t = \left(\frac{A_0 - A_\infty}{1 - t_{max}}\right)(t - t_{max}) + A_\infty$
aa.  End if
bb.  $\left(\text{if } F(x_k^t) < F(x^*)\right)$
cc.  Modernize the most excellent solution $x^*$
dd.  End
ee.  End while
ff.  Output the results
```

## 4. SIMULATION RESULTS

At first in standard IEEE 14 bus system the validity of the proposed Enriched Bat Algorithm (EBA) has been tested, Table 1 shows the constraints of control variables Table 2 shows the limits of reactive power generators and comparison results are presented in Table 3.

Table 1 – constraints of control variables

| System | Variables | Minimum (PU) | Maximum (PU) |
|---|---|---|---|
| IEEE 14 Bus | Generator Voltage | 0.95 | 1.1 |
| | Transformer Tap | 0.9 | 1.1 |
| | VAR Source | 0 | 0.20 |

Table 2: Constrains of reactive power generators

| System | Variables | Q Minimum (PU) | Q Maximum (PU) |
|---|---|---|---|
| IEEE 14 Bus | 1 | 0 | 10 |
| | 2 | −40 | 50 |
| | 3 | 0 | 40 |
| | 6 | −6 | 24 |
| | 8 | −6 | 24 |

Table 3: Simulation results of IEEE -14 system

| Control variables | Base case | MPSO [19] | PSO [19] | EP [19] | SARGA [19] | EBA |
|---|---|---|---|---|---|---|
| $VG$-1 | 1.060 | 1.100 | 1.100 | NR* | NR* | 1.021 |
| $VG$-2 | 1.045 | 1.085 | 1.086 | 1.029 | 1.060 | 1.034 |
| $VG$-3 | 1.010 | 1.055 | 1.056 | 1.016 | 1.036 | 1.020 |
| $VG$-6 | 1.070 | 1.069 | 1.067 | 1.097 | 1.099 | 1.034 |
| $VG$-8 | 1.090 | 1.074 | 1.060 | 1.053 | 1.078 | 1.010 |
| $Tap$ 8 | 0.978 | 1.018 | 1.019 | 1.04 | 0.95 | 0.900 |
| $Tap$ 9 | 0.969 | 0.975 | 0.988 | 0.94 | 0.95 | 0.921 |
| $Tap$ 10 | 0.932 | 1.024 | 1.008 | 1.03 | 0.96 | 0.949 |
| $QC$-9 | 0.19 | 14.64 | 0.185 | 0.18 | 0.06 | 0.152 |
| $PG$ | 272.39 | 271.32 | 271.32 | NR* | NR* | 271.62 |
| $QG$ (Mvar) | 82.44 | 75.79 | 76.79 | NR* | NR* | 74.86 |
| Reduction in PLoss (%) | 0 | 9.2 | 9.1 | 1.5 | 2.5 | 19.35 |
| Total PLoss (Mw) | 13.550 | 12.293 | 12.315 | 13.346 | 13.216 | 10.928 |

NR* – Not reported.

Then the proposed Enriched Bat Algorithm (EBA) has been tested, in IEEE 30 Bus system. Table 4 shows the constraints of control variables, Table 5 shows the limits of reactive power generators and comparison results are presented in Table 6. Then the proposed Enriched Bat Algorithm (EBA) has been tested, in IEEE 57 Bus system. Table 7 shows the constraints of control variables, Table 8 shows the limits of reactive power generators and comparison results are presented in Table 9.

Table 4 – constraints of control variables

| System | Variables | Minimum (PU) | Maximum (PU) |
|---|---|---|---|
| IEEE 30 Bus | Generator Voltage | 0.95 | 1.1 |
| | Transformer Tap | o.9 | 1.1 |
| | VAR Source | 0 | 0.20 |

Table 5: Constrains of reactive power generators

| System | Variables | Q Minimum (PU) | Q Maximum (PU) |
|---|---|---|---|
| IEEE 30 Bus | 1 | 0 | 10 |
| | 2 | −40 | 50 |
| | 5 | −40 | 40 |
| | 8 | −10 | 40 |
| | 11 | −6 | 24 |
| | 13 | −6 | 24 |

Table 6: Simulation results of IEEE -30 system

| Control variables | Base case | MPSO [19] | PSO [19] | EP [19] | SARGA [19] | EBA |
|---|---|---|---|---|---|---|
| $VG$-1 | 1.060 | 1.101 | 1.100 | NR* | NR* | 1.038 |
| $VG$-2 | 1.045 | 1.086 | 1.072 | 1.097 | 1.094 | 1.026 |
| $VG$-5 | 1.010 | 1.047 | 1.038 | 1.049 | 1.053 | 1.051 |
| $VG$-8 | 1.010 | 1.057 | 1.048 | 1.033 | 1.059 | 1.024 |
| $VG$-12 | 1.082 | 1.048 | 1.058 | 1.092 | 1.099 | 1.062 |
| VG–13 | 1.071 | 1.068 | 1.080 | 1.091 | 1.099 | 1.058 |
| Tap11 | 0.978 | 0.983 | 0.987 | 1.01 | 0.99 | 0.912 |
| Tap12 | 0.969 | 1.023 | 1.015 | 1.03 | 1.03 | 0.928 |
| Tap15 | 0.932 | 1.020 | 1.020 | 1.07 | 0.98 | 0.912 |
| Tap36 | 0.968 | 0.988 | 1.012 | 0.99 | 0.96 | 0.909 |
| QC10 | 0.19 | 0.077 | 0.077 | 0.19 | 0.19 | 0.090 |
| QC24 | 0.043 | 0.119 | 0.128 | 0.04 | 0.04 | 0.124 |
| $PG$ (MW) | 300.9 | 299.54 | 299.54 | NR* | NR* | 298.91 |
| $QG$ (Mvar) | 133.9 | 130.83 | 130.94 | NR* | NR* | 130.12 |
| Reduction in PLoss (%) | 0 | 8.4 | 7.4 | 6.6 | 8.3 | 14.58 |
| Total PLoss (Mw) | 17.55 | 16.07 | 16.25 | 16.38 | 16.09 | 14.99 |

NR* – Not reported.

Table 7 – constraints of control variables

| System | Variables | Minimum (PU) | Maximum (PU) |
|---|---|---|---|
| IEEE 57 Bus | Generator Voltage | 0.95 | 1.1 |
| | Transformer Tap | o.9 | 1.1 |
| | VAR Source | 0 | 0.20 |

Table 8: Constrains of reactive power generators

| System | Variables | Q Minimum (PU) | Q Maximum (PU) |
|---|---|---|---|
| IEEE 57 Bus | 1 | −140 | 200 |
| | 2 | −17 | 50 |
| | 3 | −10 | 60 |
| | 6 | −8 | 25 |
| | 8 | −140 | 200 |
| | 9 | −3 | 9 |
| | 12 | −150 | 155 |

Table 9: Simulation results of IEEE -57 system

| Control variables | Base case | MPSO [19] | PSO [19] | CGA [19] | AGA [19] | EBA |
|---|---|---|---|---|---|---|
| $VG$ 1 | 1.040 | 1.093 | 1.083 | 0.968 | 1.027 | 1.024 |
| $VG$ 2 | 1.010 | 1.086 | 1.071 | 1.049 | 1.011 | 1.018 |
| $VG$ 3 | 0.985 | 1.056 | 1.055 | 1.056 | 1.033 | 1.032 |
| $VG$ 6 | 0.980 | 1.038 | 1.036 | 0.987 | 1.001 | 1.019 |
| $VG$ 8 | 1.005 | 1.066 | 1.059 | 1.022 | 1.051 | 1.031 |
| $VG$ 9 | 0.980 | 1.054 | 1.048 | 0.991 | 1.051 | 1.012 |
| $VG$ 12 | 1.015 | 1.054 | 1.046 | 1.004 | 1.057 | 1.042 |
| $Tap$ 19 | 0.970 | 0.975 | 0.987 | 0.920 | 1.030 | 0.956 |
| $Tap$ 20 | 0.978 | 0.982 | 0.983 | 0.920 | 1.020 | 0.932 |
| $Tap$ 31 | 1.043 | 0.975 | 0.981 | 0.970 | 1.060 | 0.927 |
| $Tap$ 35 | 1.000 | 1.025 | 1.003 | NR* | NR* | 1.012 |
| $Tap$ 36 | 1.000 | 1.002 | 0.985 | NR* | NR* | 1.000 |
| $Tap$ 37 | 1.043 | 1.007 | 1.009 | 0.900 | 0.990 | 1.002 |
| $Tap$ 41 | 0.967 | 0.994 | 1.007 | 0.910 | 1.100 | 0.990 |
| $Tap$ 46 | 0.975 | 1.013 | 1.018 | 1.100 | 0.980 | 1.010 |
| $Tap$ 54 | 0.955 | 0.988 | 0.986 | 0.940 | 1.010 | 0.972 |
| $Tap$ 58 | 0.955 | 0.979 | 0.992 | 0.950 | 1.080 | 0.960 |
| $Tap$ 59 | 0.900 | 0.983 | 0.990 | 1.030 | 0.940 | 0.969 |
| $Tap$ 65 | 0.930 | 1.015 | 0.997 | 1.090 | 0.950 | 1.000 |
| $Tap$ 66 | 0.895 | 0.975 | 0.984 | 0.900 | 1.050 | 0.952 |
| $Tap$ 71 | 0.958 | 1.020 | 0.990 | 0.900 | 0.950 | 1.004 |
| $Tap$ 73 | 0.958 | 1.001 | 0.988 | 1.000 | 1.010 | 1.000 |
| $Tap$ 76 | 0.980 | 0.979 | 0.980 | 0.960 | 0.940 | 0.968 |
| $Tap$ 80 | 0.940 | 1.002 | 1.017 | 1.000 | 1.000 | 1.000 |
| $QC$ 18 | 0.1 | 0.179 | 0.131 | 0.084 | 0.016 | 0.171 |
| $QC$ 25 | 0.059 | 0.176 | 0.144 | 0.008 | 0.015 | 0.169 |
| $QC$ 53 | 0.063 | 0.141 | 0.162 | 0.053 | 0.038 | 0.141 |
| $PG$ (MW) | 1278.6 | 1274.4 | 1274.8 | 1276 | 1275 | 1267.92 |
| $QG$ (Mvar) | 321.08 | 272.27 | 276.58 | 309.1 | 304.4 | 271.01 |
| Reduction in PLoss (%) | 0 | 15.4 | 14.1 | 9.2 | 11.6 | 20.92 |
| Total PLoss (Mw) | 27.8 | 23.51 | 23.86 | 25.24 | 24.56 | 21.982 |

NR* – Not reported.

Then the proposed Enriched Bat Algorithm (EBA) has been tested, in IEEE 118 Bus system. Table 10 shows the constraints of control variables and comparison results are presented in Table 11.

Table 10. Constraints of control variables

| System | Variables | Minimum (PU) | Maximum (PU) |
|---|---|---|---|
| IEEE 118 Bus | Generator Voltage | 0.95 | 1.1 |
| | Transformer Tap | o.9 | 1.1 |
| | VAR Source | 0 | 0.20 |

Table 11: Simulation results of IEEE -118 system

| Control variables | Base case | MPSO [19] | PSO [19] | PSO [19] | CLPSO [19] | EBA |
|---|---|---|---|---|---|---|
| $VG$ 1 | 0.955 | 1.021 | 1.019 | 1.085 | 1.033 | 1.012 |
| $VG$ 4 | 0.998 | 1.044 | 1.038 | 1.042 | 1.055 | 1.046 |
| $VG$ 6 | 0.990 | 1.044 | 1.044 | 1.080 | 0.975 | 1.029 |
| $VG$ 8 | 1.015 | 1.063 | 1.039 | 0.968 | 0.966 | 1.003 |
| $VG$ 10 | 1.050 | 1.084 | 1.040 | 1.075 | 0.981 | 1.012 |
| $VG$ 12 | 0.990 | 1.032 | 1.029 | 1.022 | 1.009 | 1.024 |
| $VG$ 15 | 0.970 | 1.024 | 1.020 | 1.078 | 0.978 | 1.031 |
| $VG$ 18 | 0.973 | 1.042 | 1.016 | 1.049 | 1.079 | 1.042 |
| $VG$ 19 | 0.962 | 1.031 | 1.015 | 1.077 | 1.080 | 1.031 |
| $VG$ 24 | 0.992 | 1.058 | 1.033 | 1.082 | 1.028 | 1.012 |
| $VG$ 25 | 1.050 | 1.064 | 1.059 | 0.956 | 1.030 | 1.036 |
| $VG$ 26 | 1.015 | 1.033 | 1.049 | 1.080 | 0.987 | 1.051 |
| $VG$ 27 | 0.968 | 1.020 | 1.021 | 1.087 | 1.015 | 0.901 |
| $VG$31 | 0.967 | 1.023 | 1.012 | 0.960 | 0.961 | 0.904 |
| $VG$ 32 | 0.963 | 1.023 | 1.018 | 1.100 | 0.985 | 0.912 |
| $VG$ 34 | 0.984 | 1.034 | 1.023 | 0.961 | 1.015 | 1.001 |
| $VG$ 36 | 0.980 | 1.035 | 1.014 | 1.036 | 1.084 | 1.004 |
| $VG$ 40 | 0.970 | 1.016 | 1.015 | 1.091 | 0.983 | 0.961 |
| $VG$ 42 | 0.985 | 1.019 | 1.015 | 0.970 | 1.051 | 1.002 |
| $VG$ 46 | 1.005 | 1.010 | 1.017 | 1.039 | 0.975 | 1.003 |
| $VG$ 49 | 1.025 | 1.045 | 1.030 | 1.083 | 0.983 | 1.000 |
| $VG$ 54 | 0.955 | 1.029 | 1.020 | 0.976 | 0.963 | 0.924 |
| $VG$ 55 | 0.952 | 1.031 | 1.017 | 1.010 | 0.971 | 0.961 |
| $VG$56 | 0.954 | 1.029 | 1.018 | 0.953 | 1.025 | 0.954 |
| $VG$ 59 | 0.985 | 1.052 | 1.042 | 0.967 | 1.000 | 0.965 |
| $VG$ 61 | 0.995 | 1.042 | 1.029 | 1.093 | 1.077 | 0.972 |
| $VG$ 62 | 0.998 | 1.029 | 1.029 | 1.097 | 1.048 | 0.989 |
| $VG$ 65 | 1.005 | 1.054 | 1.042 | 1.089 | 0.968 | 1.000 |
| $VG$ 66 | 1.050 | 1.056 | 1.054 | 1.086 | 0.964 | 1.006 |
| $VG$ 69 | 1.035 | 1.072 | 1.058 | 0.966 | 0.957 | 1.050 |
| $VG$ 70 | 0.984 | 1.040 | 1.031 | 1.078 | 0.976 | 1.036 |
| $VG$ 72 | 0.980 | 1.039 | 1.039 | 0.950 | 1.024 | 1.024 |
| $VG$ 73 | 0.991 | 1.028 | 1.015 | 0.972 | 0.965 | 1.019 |
| $VG$ 74 | 0.958 | 1.032 | 1.029 | 0.971 | 1.073 | 1.010 |
| $VG$ 76 | 0.943 | 1.005 | 1.021 | 0.960 | 1.030 | 1.004 |
| $VG$ 77 | 1.006 | 1.038 | 1.026 | 1.078 | 1.027 | 1.001 |
| $VG$ 80 | 1.040 | 1.049 | 1.038 | 1.078 | 0.985 | 1.005 |
| $VG$ 85 | 0.985 | 1.024 | 1.024 | 0.956 | 0.983 | 1.012 |
| $VG$ 87 | 1.015 | 1.019 | 1.022 | 0.964 | 1.088 | 1.010 |
| $VG$ 89 | 1.000 | 1.074 | 1.061 | 0.974 | 0.989 | 1.042 |
| $VG$ 90 | 1.005 | 1.045 | 1.032 | 1.024 | 0.990 | 1.039 |
| $VG$ 91 | 0.980 | 1.052 | 1.033 | 0.961 | 1.028 | 1.001 |
| $VG$ 92 | 0.990 | 1.058 | 1.038 | 0.956 | 0.976 | 1.032 |
| $VG$ 99 | 1.010 | 1.023 | 1.037 | 0.954 | 1.088 | 1.000 |
| $VG$ 100 | 1.017 | 1.049 | 1.037 | 0.958 | 0.961 | 1.002 |
| $VG$ 103 | 1.010 | 1.045 | 1.031 | 1.016 | 0.961 | 1.012 |
| $VG$ 104 | 0.971 | 1.035 | 1.031 | 1.099 | 1.012 | 1.009 |
| $VG$ 105 | 0.965 | 1.043 | 1.029 | 0.969 | 1.068 | 1.052 |
| $VG$ 107 | 0.952 | 1.023 | 1.008 | 0.965 | 0.976 | 1.019 |
| $VG$ 110 | 0.973 | 1.032 | 1.028 | 1.087 | 1.041 | 1.010 |
| $VG$ 111 | 0.980 | 1.035 | 1.039 | 1.037 | 0.979 | 1.002 |
| $VG$ 112 | 0.975 | 1.018 | 1.019 | 1.092 | 0.976 | 1.091 |
| $VG$ 113 | 0.993 | 1.043 | 1.027 | 1.075 | 0.972 | 1.006 |
| $VG$ 116 | 1.005 | 1.011 | 1.031 | 0.959 | 1.033 | 1.001 |
| $Tap$ 8 | 0.985 | 0.999 | 0.994 | 1.011 | 1.004 | 0.940 |
| $Tap$ 32 | 0.960 | 1.017 | 1.013 | 1.090 | 1.060 | 1.000 |
| $Tap$ 36 | 0.960 | 0.994 | 0.997 | 1.003 | 1.000 | 0.950 |
| $Tap$ 51 | 0.935 | 0.998 | 1.000 | 1.000 | 1.000 | 0.932 |
| $Tap$ 93 | 0.960 | 1.000 | 0.997 | 1.008 | 0.992 | 1.002 |
| $Tap$ 95 | 0.985 | 0.995 | 1.020 | 1.032 | 1.007 | 0.972 |
| $Tap$ 102 | 0.935 | 1.024 | 1.004 | 0.944 | 1.061 | 1.005 |
| $Tap$ 107 | 0.935 | 0.989 | 1.008 | 0.906 | 0.930 | 0.952 |
| $Tap$ 127 | 0.935 | 1.010 | 1.009 | 0.967 | 0.957 | 1.000 |
| $QC$ 34 | 0.140 | 0.049 | 0.048 | 0.093 | 0.117 | 0.006 |
| $QC$ 44 | 0.100 | 0.026 | 0.026 | 0.093 | 0.098 | 0.023 |
| $QC$ 46 | 0.100 | 0.117 | 0.118 | 0.089 | 0.026 | 0.129 |
| $QC$ 48 | 0.150 | 0.056 | 0.056 | 0.118 | 0.028 | 0.040 |
| $QC$ 74 | 0.120 | 0.120 | 0.120 | 0.046 | 0.005 | 0.118 |
| $QC$ 82 | 0.200 | 0.180 | 0.180 | 0.164 | 0.194 | 0.152 |
| $QC$ 83 | 0.100 | 0.166 | 0.166 | 0.096 | 0.069 | 0.126 |
| $QC$ 105 | 0.200 | 0.189 | 0.190 | 0.089 | 0.090 | 0.152 |
| $QC$ 107 | 0.060 | 0.128 | 0.129 | 0.050 | 0.049 | 0.134 |
| $QC$ 110 | 0.060 | 0.014 | 0.014 | 0.055 | 0.022 | 0.009 |
| PG(MW) | 4374.8 | 4359.3 | 4361.4 | NR* | NR* | 4381.6 |
| QG(MVAR) | 795.6 | 604.3 | 653.5 | * NR* | NR* | 612.4 |
| Reduction in PLOSS (%) | 0 | 11.7 | 10.1 | 0.6 | 1.3 | 12.92 |
| Total PLOSS (Mw) | 132.8 | 117.19 | 119.34 | 131.99 | 130.96 | 115.64 |

NR* – Not reported.

Then IEEE 300 bus system [18] is used as test system to validate the performance of the Enriched Bat Algorithm (EBA). Table 12 shows the comparison of real power loss obtained after optimization.

Table 12. Comparison of Real Power Loss

| Parameter | Method EGA [21] | Method EEA [21] | Method CSA [20] | EBA |
|---|---|---|---|---|
| PLOSS (MW) | 646.2998 | 650.6027 | 635.8942 | 612.2682 |

## 5. CONCLUSION

In this Enriched Bat Algorithm (EBA) successfully solved the optimal reactive power problem. Normally in the standard Bat algorithm, bats are allowed to shift from their present positions to novel arbitrary positions by a local capricious walk. Progression of bats is directed by superior bats, local schedule are advanced by calculating the step sizes Local search mechanisms are modified in the projected algorithm. Proposed Enriched Bat Algorithm (EBA) has been tested in standard IEEE 14, 30, 57,118,300 bus test systems and simulation results show the projected algorithm reduced the real power loss comprehensively.

**References**

[1] K. Y. Lee.(1984). “Fuel–cost minimisation for both real and reactive–power dispatches,” Proceedings Generation, Transmission and Distribution Conference, vol/issue: 131(3), pp. 85–93.
[2] N. I. Deeb.(1998). “An efficient technique for reactive power dispatch using a revised linear programming approach,” Electric Power System Research, vol/issue: 15(2), pp. 121–134.
[3] M. R. Bjelogrlic, M. S. Calovic, B. S. Babic. (1990). “Application of Newton’s optimal power flow in voltage/reactive power control”, IEEE Trans Power System, vol. 5, no. 4, pp. 1447–1454.
[4] S. Granville.(1994). “Optimal reactive dispatch through interior point methods,” IEEE Transactions on Power System, vol/issue: 9(1), pp. 136–146
[5] N. Grudinin.(1998). “Reactive power optimization using successive quadratic programming method,” IEEE Transactions on Power System, vol/issue: 13(4), pp. 1219–1225
[6] Ng Shin Mei, R.; Sulaiman, M.H.; Mustaffa, Z.; Daniyal, H. (2017) “Optimal reactive power dispatch solution by loss minimization using moth–flame optimization technique”, Appl. Soft Comput. 2017, 59, 210–222.
[7] Chen, G.; Liu, L.; Zhang, Z.; Huang, S. (2017) “Optimal reactive power dispatch by improved GSA–based algorithm with the novel strategies to handle constraints” Appl. Soft Comput. 2017, 50, 58–70.
[8] Naderi, E.; Narimani, H.; Fathi, M.; Narimani, M.R, (2017) “A novel fuzzy adaptive configuration of particle swarm optimization to solve large–scale optimal reactive power dispatch”, Appl. Soft Comput. 2017, 53, 441–456.
[9] Heidari, A.A.; Ali Abbaspour, R.; Rezaee Jordehi, (2017) A. “Gaussian bare–bones water cycle algorithm for optimal reactive power dispatch in electrical power systems”, Appl. Soft Comput. 2017, 57, 657–671
[10] Mahaletchumi Morgan, Nor Rul Hasma Abdullah, Mohd Herwan Sulaiman, Mahfuzah Mustafa, Rosdiyana Samad.(2016). “Benchmark Studies on Optimal Reactive Power Dispatch (ORPD) Based Multi–objective Evolutionary Programming (MOEP) Using Mutation Based on Adaptive Mutation Adapter (AMO) and Polynomial Mutation Operator (PMO)”, Journal of Electrical Systems, 12–1.
[11] Rebecca Ng Shin Mei, Mohd Herwan Sulaiman, Zuriani Mustaffa, (2016). “Ant Lion Optimizer for Optimal Reactive Power Dispatch Solution”, Journal of Electrical Systems, "Special Issue AMPE2015", pp. 68–74.
[12] P. Anbarasan ; T. Jayabarathi,(2017) , “Optimal reactive power dispatch problem solved by symbiotic organism search algorithm”, Innovations in Power and Advanced Computing Technologies,
[13] Gagliano A., Nocera F. (2017). Analysis of the performances of electric energy storage in residential applications, International Journal of Heat and Technology , Vol. 35, Special Issue 1, pp. S41–S48.
[14] Caldera M., Ungaro P., Cammarata G., Puglisi G. (2018). Survey–based analysis of the electrical energy demand in Italian households, Mathematical Modelling of Engineering Problems, Vol. 5, No. 3, pp. 217–224
[15] M. Basu, “Quasi–oppositional differential evolution for optimal reactive power dispatch”, Electrical Power and Energy Systems, vol. 78, pp. 29–40, 2016.
[16] T. Weise, Global Optimization Algorithms – Theory and Application, Germany: it–weise.de (self–published), [Online]. Available: http://www.it–weise.de/, 2009.
[17] X.S. Yang. Bat algorithm for multi–objective optimisation. International Journal of Bio–Inspired Computation, 3(5):267– 274, 2011.
[18] IEEE, “The IEEE–test systems”, (1993), http://www.ee.washington.edu/trsearch/pstca/.
[19] Ali Nasser Hussain, Ali Abdulabbas Abdullah and Omar Muhammed Neda, (2018), “Modified Particle Swarm Optimization for Solution of Reactive Power Dispatch”, Research Journal of Applied Sciences, Engineering and Technology 15(8): 316–327, 2018
[20] S. Surender Reddy, “Optimal Reactive Power Scheduling Using Cuckoo Search Algorithm”, International Journal of Electrical and Computer Engineering, Vol. 7, No. 5, pp. 2349–2356. 2017.
[21] S.S. Reddy, et al., “Faster evolutionary algorithm based optimal power flow using incremental variables”, Electrical Power and Energy Systems, vol. 54, pp. 198–210, 2014.

5, Revolutiei, 331128, Hunedoara, ROMANIA
http://annals.fih.upt.ro