Real Power Loss Reduction by Billfish and Red Mullet Optimization Algorithms

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Abstract

In this paper Billfish Optimization Algorithm (BOA) and Red Mullet Optimization (RMO) Algorithm has been designed for voltage stability enhancement and power loss reduction. Electrical Power is one among vital need in the society and also it plays lead role in formation of smart cities. Continuous power supply is essential and mainly quality of the power should be maintained in good mode. In this work real power loss reduction is key objective. Natural hunting actions of Billfish over pilchards are utilized to model the algorithm. Candidate solutions in the projected algorithm are Billfish and population in the exploration space is arbitrarily engendered. Movement of Billfish is high, it will attack the pilchards vigorously and it can't escape from the attack done by the group of Billfish. Then in this paper Red Mullet Optimization (RMO) Algorithm is proposed to solve optimal reactive power problem. Projected RMO algorithm modeled based on the behavior and characteristics of red mullet. As a group they hunt for the prey and in each group there will be chaser and blocker. When the prey approaches any one of the blocker red mullet then automatically it will turn as new chaser. So roles will interchangeable and very much flexible. At any time chaser will become blocker and any of the blocker will become a chaser with respect to prey position and conditions. Then in that particular area when all the preys are hunted completed then red mullet group will change the area. So there

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will be flexibility and changing the role quickly with respect to prey position. Alike to that with reference to the fitness function the particle will be chosen as chaser. By means of considering L (voltage stability) - index BOA, and RMO algorithms verified in IEEE 30- bus system. Then without L-index BOA and RMO algorithms is appraised in 30 bus test systems. Both BOA and RMO algorithms condensed the power loss proficiently with improvement in voltage stability and minimization of voltage deviation.

Keywords: Optimal reactive power, transmission loss, Billfish, Red Mullet.

Nomenclature

OBF – Minimization of the Objective function.
L and M – control and dependent variables of the optimal reactive power problem
r – Consist of control variables
(Q_c) – Reactive power compensators
T – Dynamic tap setting of transformers
(V_g) – Level of the voltage in the generation units
u – consist of dependent variables
PG_{slack} – Slack generator
V_L – Voltage on transmission lines
Q_G – Generation unit's reactive power
S_L – Apparent power
NTL – Number of transmission line indicated by conductance of the transmission line between the ith and jth buses, $Ø_{ij}$. Phase angle between buses i and j
V_{Lk} – Load voltage in k^{th} load bus
$V_{Lk}^{desired}$ – Voltage desired at the k^{th} load bus,
Q_{GK} – Reactive power generated at k^{th} load bus generators,
Q_{KG}^{Lim} – Reactive power limitation,
N_{LB} and Ng – number load and generating units
Tt – Transformer tap
Gen volt – Generator Voltage
DE – Differential evolution
GSA – Gravitational search algorithm
APOPSO – Adapted Particle Swarm Optimization
MPSO – Modified Particle Swarm Optimization

PSO – Particle Swarm Optimization
EP – Evolutionary programming
SARGA – self-adaptive real coded Genetic algorithm
CGA – Canonical Genetic algorithm
AGA – Adaptive Genetic algorithm
IPSO – Improved Particle Swarm Optimization
CLPSO – Comprehensive learning Particle Swarm Optimization
CSA – Cuckoo search optimization algorithm

1 Introduction

Power loss minimization and voltage stability augmentation are the prime objectives of this work. One among the Back bone of the society is electrical power. To maintain the quality of power in better mode reduction of power loss plays a key role. To build a society it's very essential to supply electrical power in continuous mode. Interior point, quadratic programming, Newton's method, [1–6] are applied, and many unable to handle constraints. Then Evolutionary algorithms such latter stages ant colony, wolf search, frog leaping, organism explore algorithms [7–41] are utilized to solve the problem [62–67]. Balancing exploration and exploitation is huge task in evolutionary and swarm based algorithm. First in this paper Billfish Optimization Algorithm (BOA) has been applied to solve optimal reactive power problem. Billfish is predatory and fast moving fish in the ocean which can hunt through groups, towards pilchards. Movement of Billfish is high, it will attack the pilchards vigorously and it can't escape from the attack done by the group of Billfish. Pilchard's school is intermingled in Billfish Optimization Algorithm and in the exploration space it also swimming [42]. Sporadically superior solutions can be mislaid when modernizing the position of exploration agents and new positions may be feeble one than the previous positions so superior selection is engaged. Superiority engages to copy the unaffected fittest solution to subsequent generation. Secondly in this work Red Mullet Optimization (RMO) Algorithm is applied to solve optimal reactive power problem. Projected RMO algorithm has been modeled based on the behavior and characteristics of red mullet which has been found in the Mediterranean Sea, Black sea and in East North Atlantic Ocean [43, 44]. They possess sensory barbells which can also find the prey like small fish etc even in the sediments. Red mullets own the cooperative hunting characteristics [16, 17]. As a group they hunt for the prey and each group will have special characters like allocating the roles themselves to trap the prey. One red mullet will run or chase behind the prey and the remaining red mullets will act as blocker for the prey such that the prey won't find any way to escape. The exploration space is formed on the basis of hunting space. An individual will imitate the set of fish. Depending on the spatial distribution of the individual's population and sub groups are formed in the projected algorithm. The whole population (R) will be divided into sub population or otherwise known as clusters; such that groups are formed for united hunting. During hunting there will be one Chaser Red Mullet and its position will be altered which depends on the location and movement of the prey. Choosing the Chaser Red Mullet among the group will be based on the prey position and also at any moment when the prey approaches the any one blocker (red mullet) whish surrounded them then that particular red mullet will be new chaser. If one area has been completely exploited (hunted all prey) means then immediately there will be change of area will occur. With and without L-index BOA, RMO algorithms are verified in IEEE 30, bus system. Real power loss and voltage deviation are minimized. Voltage stability index improvement has been achieved.

2 Problem Formulation

Power loss minimization is defined by

$$Min\ \widetilde{OBF}(\overline{r}, \overline{u}) \tag{1}$$

Subject to

$$L(\overline{r}, \overline{u}) = 0 \tag{2}$$

$$M(\overline{r}, \overline{u}) = 0 \tag{3}$$

$$r = [VLG_1, \ldots, VLG_{Ng}; QC_1, \ldots, QC_{Nc}; T_1, \ldots, T_{N_T}] \tag{4}$$

$$u = [PG_{slack}; VL_1, \ldots, VL_{N_{Load}}; QG_1, \ldots, QG_{Ng}; SL_1, \ldots, SL_{N_T}] \tag{5}$$

The fitness function (F_1, F_2, F_3) is designed [61] for power loss (MW) reduction, Voltage deviation, voltage stability index (L-index) is defined by,

$$F_1 = P_{Minimize}$$
$$= Minimize \left[\sum_{m}^{NTL} G_m \left[V_i^2 + V_j^2 - 2 * V_i V_j cos Ø_{ij} \right] \right] \tag{6}$$

$$F_2 = Minimize\left[\sum_{i=1}^{N_{LB}}\left|V_{Lk}-V_{Lk}^{desired}\right|^2+\sum_{i=1}^{Ng}\left|Q_{GK}-Q_{KG}^{Lim}\right|^2\right] \tag{7}$$

$$F_3 = Minimize\ L_{MaxImum} \tag{8}$$

$$L_{Maximum} = Maximum[L_j]; j = 1; N_{LB} \tag{9}$$

And

$$\begin{cases} L_j = 1-\sum_{i=1}^{NPV} F_{ji}\frac{V_i}{V_j} \\ F_{ji} = -[Y_1]^1\,[Y_2] \end{cases} \tag{10}$$

$$L_{Maximum} = Maximum\left[1-[Y_1]^{-1}\,[Y_2]\times\frac{V_i}{V_j}\right] \tag{11}$$

Equality constraints

$$0 = PG_i - PD_i - V_i\sum_{j\in N_B} V_j\left[G_{ij}cos\left[Ø_i - Ø_j\right] + B_{ij}sin\left[Ø_i - Ø_j\right]\right] \tag{12}$$

$$0 = QG_i - QD_i - V_i\sum_{j\in N_B} V_j[G_{ij}sin[Ø_i - Ø_j] + B_{ij}cos[Ø_i - Ø_j]] \tag{13}$$

Inequality constraints

$$\mathbf{P_{gslack}^{minimum} \leq P_{gslack} \leq P_{gslack}^{maximum}} \tag{14}$$

$$\mathbf{Q_{gi}^{minimum} \leq Q_{gi} \leq Q_{gi}^{maximum}, i \in N_g} \tag{15}$$

$$\mathbf{VL_i^{minimum} \leq VL_i \leq VL_i^{maximum}, i \in NL} \tag{16}$$

$$\mathbf{T_i^{minimum} \leq T_i \leq T_i^{maximum}, i \in N_T} \tag{17}$$

$$\mathrm{Q_c^{minimum} \leq Q_c \leq Q_C^{maximum},\ i \in N_C} \tag{18}$$

$$|SL_i| = S_{L_i}^{maximum},\ \mathrm{i \in N_{TL}} \tag{19}$$

$$\mathrm{VG_i^{minimum} \leq VG_i \leq VG_i^{maximum},\ i \in N_g} \tag{20}$$

Multi objective fitness (MOF) function has been defined by,

$$MOF = F_1 + r_i F_2 + u F_3$$
$$= F_1 + \left[\sum_{i=1}^{NL} x_v \left[VL_i - VL_i^{min} \right]^2 + \sum_{i=1}^{NG} r_g \left[QG_i - QG_i^{min} \right]^2 \right]$$
$$+ r_f F_3 \tag{21}$$

$$VL_i^{minimum} = \begin{cases} VL_i^{max}, \; VL_i > VL_i^{max} \\ VL_i^{min}, VL_i < VL_i^{min} \end{cases} \tag{22}$$

$$QG_i^{minimum} = \begin{cases} QG_i^{max}, \; QG_i > QG_i^{max} \\ QG_i^{min}, QG_i < QG_i^{min} \end{cases} \tag{23}$$

3 Billfish Optimization Algorithm

Billfish is predatory and fast moving fish in the ocean which can hunt through groups, towards pilchards. Movement of Billfish is high, it will attack the pilchards vigorously and it can't escape from the attack done by the group of Billfish. The natural deeds of Billfish have been imitated to model the Billfish Optimization Algorithm (BOA) to solve the optimal reactive power dispatch problem.

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Candidate solutions in the projected algorithm are Billfish and population in the exploration space is arbitrarily engendered. In the searching space present position of the ith member $BF_{i,k} \in R(i = 1, 2, \ldots, m)$. Variables position during optimization is given by,

$$BF_{position} = \begin{bmatrix} BF_{1,1} & BF_{1,2} & \cdots & BF_{1,d} \\ BF_{2,1} & BF_{2,2} & \cdots & BF_{2,d} \\ \vdots & \vdots & \cdots & \vdots \\ BF_{m,1} & BF_{m,2} & \cdots & BF_{m,d} \end{bmatrix} \tag{24}$$

Solution fitness value calculated by,

$$BF_{position} = \begin{bmatrix} f(BF_{1,1} & BF_{1,2} & \cdots & BF_{1,d}) \\ f(BF_{2,1} & BF_{2,2} & \cdots & BF_{2,d}) \\ \vdots & \vdots & \ldots & \vdots \\ f(BF_{m,1} & BF_{m,2} & \cdots & BF_{m,d}) \end{bmatrix} = \begin{bmatrix} F_{BF1} \\ F_{BF2} \\ \vdots \\ F_{BFm} \end{bmatrix} \quad (25)$$

Pilchard's school is intermingled in Billfish Optimization Algorithm (BOA) and in the exploration space it also swimming. Then the Pilchard's position and fitness found by,

$$P_{position} = \begin{bmatrix} P_{1,1} & P_{1,2} & \cdots & P_{1,d} \\ P_{2,1} & P_{2,2} & \cdots & P_{2,d} \\ \vdots & \vdots & \ldots & \vdots \\ P_{m,1} & P_{m,2} & \cdots & P_{m,d} \end{bmatrix} \quad (26)$$

$$P_{position} = \begin{bmatrix} f(P_{1,1} & P_{1,2} & \cdots & P_{1,d}) \\ f(P_{2,1} & P_{2,2} & \cdots & P_{2,d}) \\ \vdots & \vdots & \ldots & \vdots \\ f(P_{m,1} & P_{m,2} & \cdots & P_{m,d}) \end{bmatrix} = \begin{bmatrix} F_{P1} \\ F_{P2} \\ \vdots \\ F_{Pm} \end{bmatrix} \quad (27)$$

Sporadically superior solutions can be mislaid when modernizing the position of exploration agents and new positions may be feeble one than the previous positions so superior selection is engaged. Superiority engages to copy the unaffected fittest solution to subsequent generation. The position of the superior Billfish and the injured Pilchards which possess the supreme fitness value in the ith iteration is specified as $Y^i_{superior\_BF}$ and $Y^i_{injured\_P}$.

In the projected Billfish Optimization Algorithm (BOA) the new position of Billfish indicated by,

$$Y^i_{new_{BF}} = Y^i_{superior\_BF} - \lambda_i \times \left(random(0,1) \times \left(\frac{Y^i_{superior\_BF} + Y^i_{injured\_P}}{2} \right) - Y^i_{previous\ BF} \right) \quad (28)$$

$$\lambda_i = 2 \times random(0,1) \times prey\ density - prey\ density \quad (29)$$

$$prey\ density = 1 - \left(\frac{number\ of\ Billfish}{number\ if\ Billfish + number\ of\ Pilchard} \right) \quad (30)$$

During the hunting the new position of the pilchard is given by,

$$Y^i_{new\_P} = random\ number \times (Y^i_{superior\_BF} - Y^i_{previous\_P} + Billfish\ attack\ power) \quad (31)$$

$$Attack\ power = l \times (2 \times iteration \times \varepsilon) \quad (32)$$

By utilizing the "attack power parameter" number of pilchard's will modernize the position (α), variables number (β) given by,

$$\alpha = number\ of\ pilchard\text{'}s\ \times attack\ power \quad (33)$$

$$\beta = number\ of\ variables\ \times attack\ power \quad (34)$$

Chances of Billfish to hunt new prey (Pilchard) is defined by,

$$Y^i_{BF} = Y^i_P\ if\ f(P_i) < f(BF_i) \quad (35)$$

Start
Population of the Billfish, Pilchard generated randomly
Parameters values of attack force ε are chosen
Fitness values of Billfish, Pilchard are calculated
Most excellent Billfish, Pilchard are chosen as superior Billfish and injured Pilchard
While the end condition not satisfied
For every Billfish; λ_i calculated by $\lambda_i = 2 \times random(0,1) \times prey\ density - prey\ density$
Billfish position is modernized by

$$Y^i_{new_{BF}} = Y^i_{superior\_BF} - \lambda_i \times \left(random(0,1) \times \left(\frac{Y^i_{superior\_BF} + Y^i_{injured\_P}}{2} \right) - Y^i_{previous\ BF} \right)$$

End for
Compute the value of attack power by,

$$Attack\ power = l \times (2 \times iteration \times \varepsilon)$$

$when\ attack\ power < 0.5$, then calculate α, β by

$$\alpha = number\ of\ pilchard's\ \times attack\ power$$

$$\beta = number\ of\ variables\ \times attack\ power$$

Based on the value of α, β choose the set of Pilchard
The position of chosen Pilchard is modernized by,

$$Y^i_{new\_P} = random\ number \times (Y^i_{superior\_BF} - Y^i_{previous\_P} + Billfish\ attack\ power)$$

Or else
Modernize the position of all Pilchards' by

$$Y^i_{new\_P} = random\ number \times (Y^i_{superior\_BF} - Y^i_{previous\_P} + Billfish\ attack\ power)$$

End if
Compute fitness value of all Pilchards
When there is better Pilchard population found then swap a Pilchard with injured Pilchard by using,

$$Y^i_{BF} = Y^i_P\ if\ f(P_i) < f(BF_i)$$

Then form the population eliminate the hunted Pilchard
Modernize the most excellent Billfish, pilchard
End if
End while
Return best Billfish

4 Red Mullet Optimization Algorithm

In this work Red Mullet Optimization (RMO) Algorithm has been modeled based on the behavior and characteristics of red mullet which has been found in the Mediterranean Sea, Black sea and in East North Atlantic Ocean. They possess sensory barbels which can also find the prey like small fish etc even in the sediments. Red mullets own the cooperative hunting characteristics. As a group they hunt for the prey means then they themselves will form the main group (main population) and sub group (sub-population). Naturally there won't be any internal clash within the group. Each group will have special characters like allocating the roles themselves to trap the prey. One red mullet will run or chase behind the prey and the remaining red mullets will act as blocker for the prey such that the prey won't find any way to escape. When the prey approaches any one of the blocker red mullet then automatically it will turn as new chaser. So roles will interchangeable and very much flexible. At any time chaser will become blocker and any of the blocker will become a chaser with respect to prey position and conditions. Then in that particular area when all the preys are hunted completed then red mullet group will change the area.

The exploration space is formed on the basis of hunting space. An individual will imitate the set of fish. Depending on the spatial distribution of the individual's population and sub groups are formed in the projected algorithm.

Population of "m" red mullets (individuals) is $\{R_1, R_2, \ldots, R_m\}$ has been arbitrarily engendered in the exploration space with specified boundaries $boundary^{max}$ and $boundary^{min}$. With decision variables $R_i \in R;\ R_i = \{R_i^1, R_i^2, \ldots, R_i^n\}$, then

$$R_i^j = random \cdot (boundary_j^{max} - boundary_j^{min}) + boundary_j^{min};$$
$$i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n \tag{36}$$

The whole population (R) will be divided into sub population or otherwise known as clusters; such that groups are formed for united hunting. In the projected algorithm in each $cluster_{kr}$ will possess ϕ_{cr} (chaser red mullet) and φ_{br} (blocker red mullet).

The data set will be formed on the basis of the population of Red mullet (R), then the data points $\{R_1, R_2, \ldots, R_n\}$ and squared error μ_{lr} in the cluster c_{lr} is determined by,

$$e(c_{lr}) = \sum_{R_g \in c_{lr}} \|R_g - \mu_{lr}\|^2;\ g = 1, 2, \ldots, h;\ lr = 1, 2, \ldots, k \tag{37}$$

In this work the problem's objective function is minimization of power loss for over all $cluster_{kr}$ the sum of squared error is defined by,

$$E(c) = \sum_{lr=1}^{k} e(c_{lr}) \tag{38}$$

During hunting there will be one Chaser Red Mullet and its position will be altered which depends on the location and movement of the prey. Choosing the Chaser Red Mullet among the group will be based on the prey position and also at any moment when the prey approaches the any one blocker (red mullet) whish surrounded them then that particular red mullet will be new chaser. So there will be flexibility and changing the role quickly with respect to prey position. Alike to that with reference to the fitness function the particle will be chosen as chaser. Then the new location of the chaser Red mullet is given by,

$$new\ position(R_{cr}^{t+1}) = existing\ position(R_{cr}^{t}) + \alpha \oplus levy(\beta)$$
$$0 < \beta = 2 \qquad (39)$$

In this proposed approach β is utilized for the control of the step size the vale will be increased linearly form 1.9 to 2.0. For balancing the exploration and exploitation; levy flights, β will be utilized in appropriate manner to enhance the search in the exploration space.

$$\beta = 1.9 + \frac{0.001t}{t_{max}/10} \qquad (40)$$

Then levy is applied as,

$$Random\ step(S) = \alpha \oplus levy(\beta) \sim \alpha \left(\frac{u}{|v|^{1/\beta}}\right) \cdot (\mathrm{R}_{\mathrm{ir}}^{\mathrm{t}} - \mathrm{R}_{\mathrm{best}}^{\mathrm{t}}) \qquad (41)$$

$$\mathrm{u} \sim \mathrm{N}(0, s_{\mathrm{u}}^2)\mathrm{v} \sim \mathrm{N}(0, s_{\mathrm{v}}^2) \qquad (42)$$

$$\sigma_{\mathrm{u}} = \left\{\frac{\Gamma(1+\beta)\sin(\pi\beta/2)}{\Gamma[(1+\beta)/2]\beta 2^{(\beta-1)/2}}\right\}^{1/\beta},\ \sigma_{\mathrm{v}} = 1 \qquad (43)$$

Based on the levy distribution, the new-fangled position of the chaser Red mullet is given by,

$$new\ position(\phi_{cr}^{t+1}) = \phi_{lr}^{t} + Random\ step\ (S) \qquad (44)$$

Also with reference to the global best the new fangled position of chaser Red mullet is given by,

$$\phi_{best}^{t+1} = \phi_{best}^{t} + S' \qquad (45)$$

$$S' = \alpha\left(\frac{u}{|v|^{1/\beta}}\right) \qquad (46)$$

In the strategy of the hunting the φ_{br} (blocker red mullet $\varphi_{br} \in R$) will surround the prey all the ways which is possible for the prey will be blocked. Then with respect to the position of the prey, the new fangled position of the ϕ_{br}^{t+1} (blocker red mullet) is defined by,

$$\phi_{br}^{t+1} = D_{br} \cdot e^{bp} \cdot \cos 2\pi\rho + \phi_{cr} \tag{47}$$

Then the present distance between blocker Red mullet and chaser Red mullet is defined by,

$$D_{br} = |random\ number \cdot \phi_{cr} - \phi_{br}^{t}| \tag{48}$$

$$\{\phi_{cr}, \phi_{br}^{t}\} \in c_{lr} \tag{49}$$

At any moment the chaser red mullet will become a blocker red mullet and vice versa. It depends on the fitness value of the function. If one area has been completely exploited (hunted all prey) means then immediately there will be change of area will occur.

$$R_{m}^{t+1} = \frac{\phi_{best} + R_{m}^{t}}{2} \tag{50}$$

a. Start
b. Input: m, kr, t maximum and S
c. Population $R = \{R_1, R_2, \ldots, R_m\}$ has been initialized
d. Fitness value of the each particle will be computed
e. ϕ_{best} will be recognized
f. Into cluster's $\{cluster_1, cluster_2, \ldots cluster_{kr}\}$ the population "R" will be spited
g. For each cluster recognize ϕ_{cr} (chaser red mullet) and φ_{br} (blocker red mullet)
h. While ($t < t$ maximum)
i. For each $cluster_{kr}$
j. Implement hunting schedule for chaser fish
k. Implement blocking schedule for blocker Red mullet
l. For every Red mullet Compute the fitness value
m. If φ_{br} (blocker red mullet) has enhanced fitness than ϕ_{cr} (chaser red mullet)
n. Then swap over the roles by modernizing ϕ_{cr} (chaser red mullet)
o. End If
p. When ϕ_{cr} (chaser red mullet) has enhanced fitness value than ϕ_{best}

q. Then modernize ϕ_{best}
r. End If
s. When ϕ_{cr} (chaser red mullet) fitness value not improved then,
t. $q \leftarrow q + 1$
u. End If
v. If $q > \lambda$
w. Implement a schedule for altering the area
x. $q \leftarrow 0$
y. End If
z. End For
aa. $t \leftarrow t + 1$
bb. End While
cc. Output ϕ_{best}

5 Simulation Results and Discussion

Billfish Optimization Algorithm (BOA) is based on Billfish deeds and is predatory and fast moving fish in the ocean which hunt through groups, towards pilchards. Pilchard's school is intermingled in Billfish Optimization Algorithm and in the exploration space it also swimming. Intermittently better-quality solutions can be misplaced when modernizing the position of exploration agents and new positions may be feeble one than the previous positions so superior selection is engaged. Projected Red Mullet Optimization (RMO) Algorithm has been modeled based on the behavior and characteristics of red mullet which has been found in the Mediterranean Sea, Black sea and in East North Atlantic Ocean. As a group they hunt for the prey and each group will have special characters like allocating the roles themselves to trap the prey. The exploration space is formed on the basis of hunting space.

Projected BOA, RMO algorithms has been tested in standard IEEE 30 bus system [60]. Table 1 shows the optimal solutions of power loss, voltage deviation (VD) and voltage stability index value (VSI). In Table 2 shows the loss comparison, Table 3 shows the voltage deviation comparison and Table 4 gives the L-index comparison. Figures – 1 to 3 gives graphical comparison between the methodologies with reference to power loss, voltage stability improvement, voltage deviation.

Then BOA, RMO algorithms verified in IEEE 30 bus test system without L- index. Loss comparison is shown in Tables 5 to 9. Figures 4 to 8 gives graphical comparison between the methodologies with reference to power loss.

Table 1 Optimal solutions of the proposed algorithms

	Power Loss (BOA)	Power Loss (RMO)	VD (BOA)	VD (RMO)	VSI (BOA)	VSI (RMO)
VG1	1.1001	1.1003	1.0053	1.0054	1.0803	1.0801
VG2	1.0953	1.0954	1.0012	1.0013	1.0534	1.0533
VG5	1.0752	1.0750	1.0170	1.0171	1.0735	1.0734
VG8	1.0761	1.0759	1.0121	1.0120	1.0086	1.0087
VG11	1.0870	1.0872	1.0322	1.0323	1.0800	1.0809
VG13	1.0990	1.0994	1.0233	1.0235	1.0852	1.0850
T1	1.0501	1.0505	1.0501	1.0503	0.9000	0.9000
T2	0.9201	0.9206	0.9001	0.9004	0.9000	0.9000
T3	1.0101	1.0109	1.0001	1.0005	0.9000	0.9000
T4	0.9802	0.9806	0.9702	0.9706	0.9000	0.9000
Qc1	5.0000	5.0000	4.0000	4.0000	5.0000	5.0000
Qc2	5.0000	5.0000	2.0000	2.0000	5.0000	5.0000
Qc3	5.0000	5.0000	4.0000	4.0000	0.0000	0.0000
Qc4	5.0000	5.0000	3.0000	3.0000	0.0000	0.0000
Qc5	3.0000	3.0000	5.0000	5.0000	5.0000	5.0000
Qc6	5.0000	5.0000	3.0000	3.0000	3.0000	3.0000
Qc7	3.0000	3.0000	5.0000	5.0000	5.0000	5.0000
Qc8	4.0000	4.0000	5.0000	5.0000	5.0000	5.0000
Qc9	2.0000	2.0000	3.0000	3.0000	1.0000	1.0000

Table 6 shows the convergence characteristics of the proposed Billfish Optimization Algorithm (BOA) and Red Mullet Optimization (RMO) Algorithm. Figure 5 shows the graphical representation of the characteristics.

Discussion on Results

Both Billfish Optimization Algorithm (BOA) and Red Mullet Optimization (RMO) Algorithm reduced the power loss efficiently. Comparison of loss has been done with PSO, modified PSO, improved PSO, comprehensive learning

Table 2 Comparison of total power loss for IEEE 30 bus system

Method	Power loss (MW)
BPSO-TS [53]	4.5213
TS [53]	4.6862
BPSO [53]	4.6862
ALO [54]	4.5900
QO-TLBO [55]	4.5594
TLBO [55]	4.5629
SGA [56]	4.9408
BPSO [56]	4.9239
HAS [56]	4.9059
S-FS [57]	4.5777
IS-FS [57]	4.5142
SFS [59]	4.5275
BOA	4.5009
RMO	4.5015

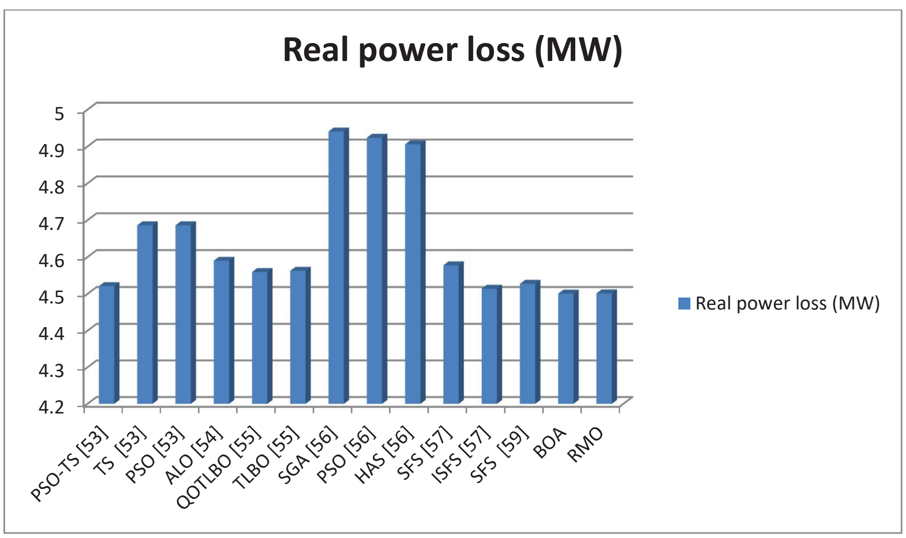

Figure 1 Comparison of real power loss.

Table 3 Comparison of voltage deviation for IEEE 30 bus system

Method	Voltage Deviation (PU)
BPSO-TVIW [58]	0.1038
BPSO-TVAC [58]	0.2064
SPSO-TVAC [58]	0.1354
BPSO-CF [58]	0.1287
PG-PSO [58]	0.1202
SWT-PSO [58]	0.1614
PGSWT-PSO [58]	0.1539
MPG-PSO [58]	0.0892
QO-TLBO [55]	0.0856
TLBO [55]	0.0913
S-FS [57]	0.1220
ISFS [57]	0.0890
SFS [59]	0.0877
BOA	0.0870
RMO	0.0869

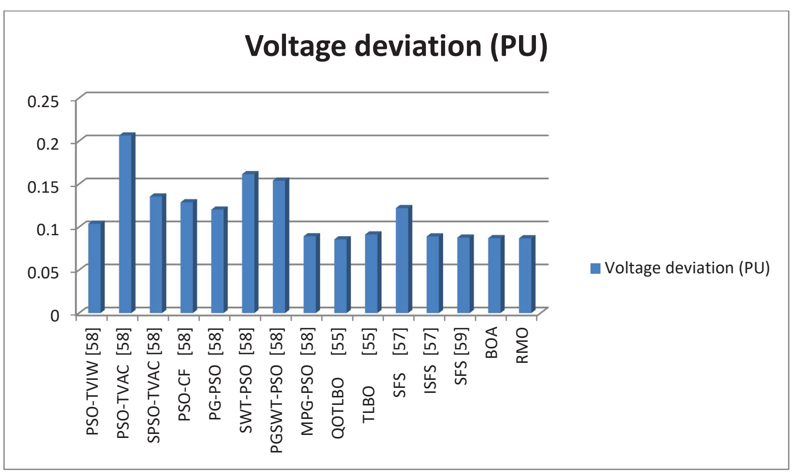

Figure 2 Comparison of Voltage deviation.

Table 4 Comparison of VSI for IEEE 30 bus system

Method	Voltage Deviation (PU)
Method	L-index (PU)
BPSO-TVIW [58]	0.1258
BPSO-TVAC [58]	0.1499
SPSO-TVAC [58]	0.1271
BPSO-CF [58]	0.1261
PG-PSO [58]	0.1264
SWT-PSO [58]	0.1488
PGSWT-PSO [58]	0.1394
MPG-PSO [58]	0.1241
QO-TLBO [55]	0.1191
TLBO [55]	0.1180
ALO [54]	0.1161
ABC [54]	0.1161
GWO [54]	0.1242
BA [54]	0.1252
S-FS [57]	0.1252
IS-FS [57]	0.1245
SFS [59]	0.1007
BOA	0.1004
RMO	0.1001

PSO, Adaptive genetic algorithm, Canonical genetic algorithm, enhanced genetic algorithm, Hybrid PSO-Tabu search (PSO-TS), Ant lion (ALO), quasi-oppositional teaching learning based (QOTBO), improved stochastic fractal search optimization algorithm (ISFS), harmony search (HS), improved pseudo-gradient search particle swarm optimization and cuckoo search algorithm. Power loss reduced efficiently and percentage of the power loss reduction has been improved. Mainly voltage stability enhancement achieved with minimized voltage deviation.

Table 5 Comparison of loss with reference to IEEE −30 system

	Base Case Value [65]	Modified-Particle Swarm Optimization [65]	Basic Particle Swarm Optimization [64]	Evolutionary Programming [63]	Self-adaptive Real Coded Genetic Algorithm [63]	BOA	RMO
Percentage of Reduction in Power Loss	0.0000	8.40000	7.4000	6.60000	8.30000	17.26	18.60
Real Power Loss in Mw	17.5500	16.0700	16.2500	16.3800	16.0900	14.52	14.284

Table 6 Convergence characteristics

IEEE 30 Bus System	Real Power Loss in MW (With L-index)	Real Power Loss in MW (Without L-index)	Time in Sec (With L-index)	Time in Sec (Without L-index)	Number of Iterations (With L-index)	Number of Iterations (Without L-index)
BOA	4.5009	14.52	18.84	14.97	25	21
RMO	4.5015	14.284	18.55	14.64	23	19

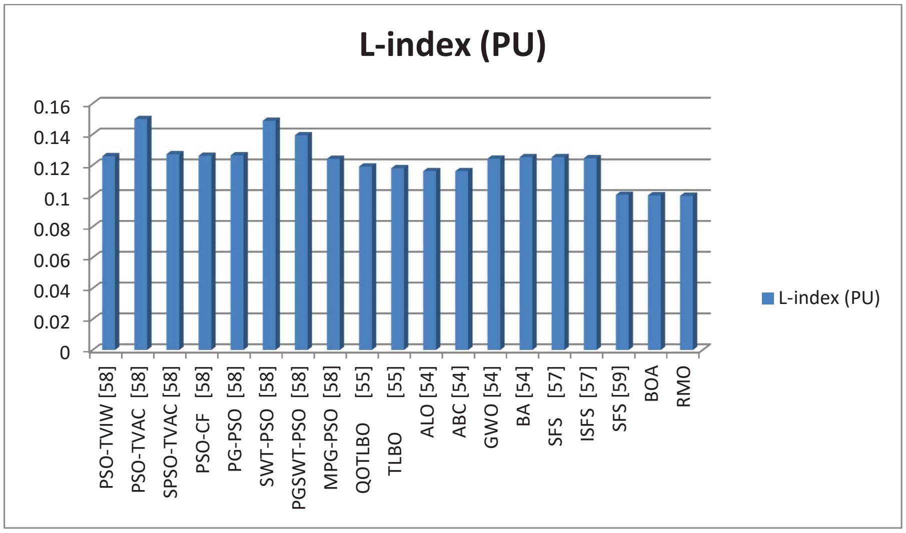

Figure 3 Comparison of voltage stability index.

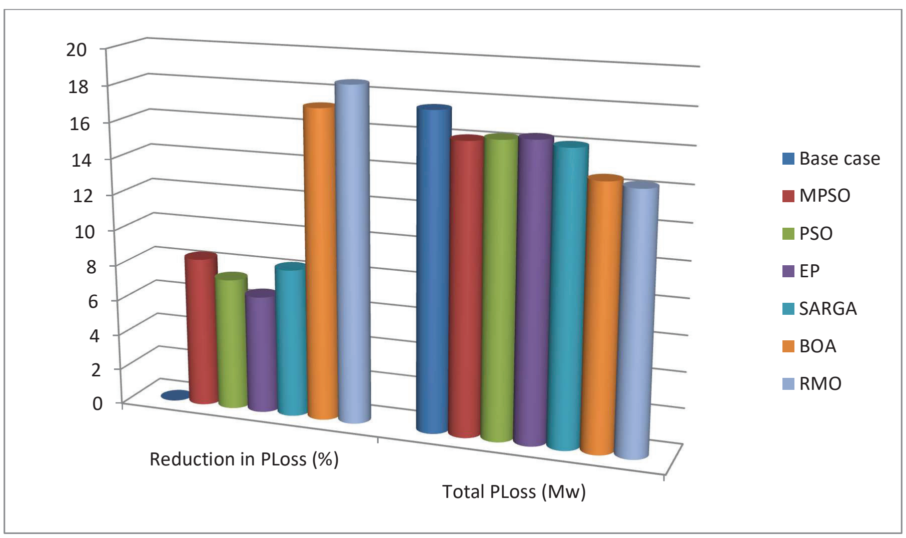

Figure 4 Comparison of Real Power Loss between methodologies (Tested in IEEE 30 bus system).

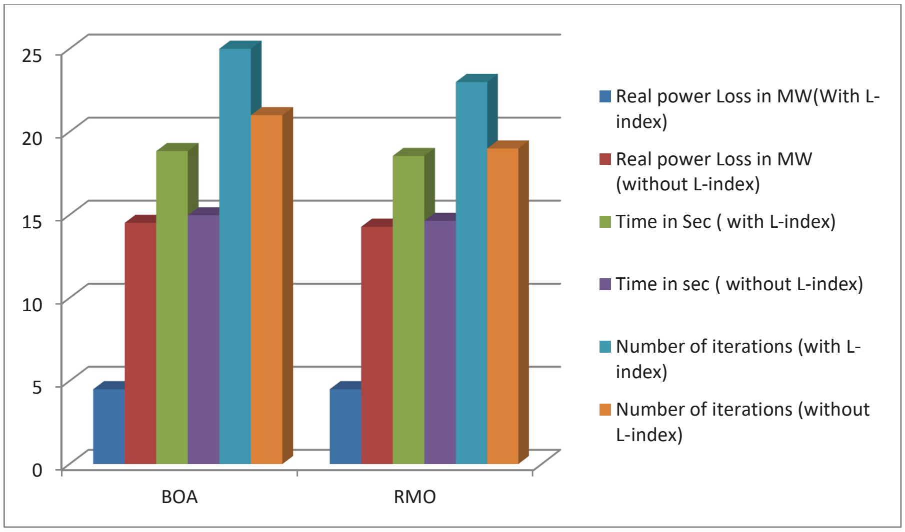

Figure 5 Convergence characteristics.

6 Conclusion

Both Billfish Optimization Algorithm (BOA) and Red Mullet Optimization (RMO) Algorithm reduced the power loss with enhancement of voltage. In BOA Billfish is predatory and fast moving fish in the ocean which can hunt through groups, towards pilchards. Hunting deeds of Billfish has been imitated successfully to formulate the projected algorithm. In RMO proposed approach β is utilized for the control of the step size the vale will be increased linearly form 1.9 to 2.0. For balancing the exploration and exploitation; levy flights, β has been utilized in appropriate manner to enhance the search in the exploration space. In the strategy of the hunting the φ_{br} (blocker red mullet $\varphi_{br} \in R$) will surround the prey all the ways which is possible for the prey will be blocked. At any moment the chaser red mullet will become a blocker red mullet and vice versa. It depends on the fitness value of the function. If one area has been completely exploited (hunted all prey) means then immediately there will be change of area will occur. BOA and RMO algorithms verified in IEEE 30- bus test system with L-index and devoid of L-index. All the three algorithms effectively reduced the power loss and percentage of real power loss reduction has been improved.

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c. • Acknowledgments; No funding
d. • Ethics statement
(human embryos/foetus, including human embryonic stem cells, human participants, human cells/tissues, animals) – Not involved
d. • Conflict of Interests
Author have no conflict

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