

# Enriched Lamprey Optimization Algorithm for Power Loss Diminution

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**Abstract**— In this paper Enriched Lamprey Optimization Algorithm (LOA) has been utilized to solve the optimal reactive power problem. Bubble net hunting tactic has been imitated to form the Lamprey Algorithm (LOA). Modernized solution is mainly depended on the current best candidate solution in Lamprey optimization algorithm (LOA). An inertia weight is introduced into Lamprey optimization algorithm alike in particle swarm optimization algorithm, to acquire the Enriched Lamprey optimization algorithm (LOA). Roulette wheel selection method has been used to perk up the convergence rate of proposed enriched Lamprey optimization algorithm (LOA). Humpback Lampreys will impulse within a recoil circle and spiral-shaped path concurrently. To model this concurrent performance, it has been assumed that there is a probability of 50% to select between either the recoil surrounding mechanism otherwise the spiral model to modernize the position of Lamprey during optimization. The proposed LOA has been tested in standard 30 bus system and simulation results show clearly about the better performance of the proposed algorithm in reducing the real power loss.

**Keywords**— Optimal reactive power, Transmission loss, Lamprey Optimization

## I. INTRODUCTION

Real power loss minimization problem and voltage stability enhancement are the key objectives of this work. Newton's method, interior point method; successive quadratic programming method [1-6] and Evolutionary algorithms like gravitational search, particle swarm optimization, symbiotic organism search algorithm [7-39] are already solved the problem. This paper propose Enriched Lamprey optimization algorithm (LOA) for solving reactive power problem. Lamprey algorithm (LOA) is inspired by the bubble-net hunting strategy of Lamprey. In Lamprey optimization algorithm, the modernized solution is mainly depended on the current best candidate solution. Algorithm describes the special hunting behaviour of Lamprey, and bubbles which causes the creation of '9-shaped path' while encircling prey during hunting. Lamprey went down in water roughly 10-16 meters and then it start to produce bubbles in a spiral shape encircles prey and then through the bubbles and it moves towards upward of the surface. Alike to Particle Swarm Optimization algorithm, an inertia weight  $\omega \in [1, 0]$  is introduced into Lamprey optimization algorithm to obtain the Enriched Lamprey optimization algorithm (LOA). Projected LOA approach utilizes roulette wheel selection method to improve the speed of convergence.

Proposed enriched Lamprey algorithm (LOA) algorithm has been evaluated on standard IEEE 30 bus system. The simulation results show that the proposed approach reduced the real power loss effectively.

## II. OBJECTIVE FUNCTION

Objective function of the problem is mathematically defined in general mode by,

$$\text{Minimization } \tilde{F}(\bar{x}, \bar{y}) \quad (1)$$

Subject to

$$E(\bar{x}, \bar{y}) = 0 \quad (2)$$

$$I(\bar{x}, \bar{y}) = 0 \quad (3)$$

$$x = [VG_1, \dots, VG_{Ng}; QC_1, \dots, QC_{Nc}; T_1, \dots, T_{NT}] \quad (4)$$

$$y = [PG_{stack}; VL_1, \dots, VL_{N_{Load}}; QG_1, \dots, QG_{Ng}; SL_1, \dots, SL_{NT}] \quad (5)$$

The fitness function ( $OF_1$ ), ( $OF_2$ ) and ( $OF_3$ ) is defined with respect to reduction of power loss, Minimization of Voltage deviation, voltage stability index (L-index) as follows,

$$OF_1 = P_{Min} = \text{Min} \left[ \sum_m^{NTL} G_m [V_i^2 + V_j^2 - 2 * V_i V_j \cos \theta_{ij}] \right] \quad (6)$$

$$OF_2 = \text{Min} \left[ \sum_{i=1}^{N_{LB}} |V_{Lk} - V_{Lk}^{desired}|^2 + \sum_{i=1}^{Ng} |Q_{GK} - Q_{KG}^{Lim}|^2 \right] \quad (7)$$

$$OF_3 = \text{Min} L_{Max} \quad (8)$$

$$L_{Max} = \text{Max} [L_j]; j = 1; N_{LB} \quad (9)$$

$$\text{And } \begin{cases} L_j = 1 - \sum_{i=1}^{NPV} F_{ji} \frac{V_i}{V_j} \\ F_{ji} = -[Y_1]^{-1}[Y_2] \end{cases} \quad (10)$$

Such that

$$L_{Max} = \text{Max} \left[ 1 - [Y_1]^{-1}[Y_2] \times \frac{V_i}{V_j} \right] \quad (11)$$

Then the equality constraints are

$$0 = PG_i - PD_i - V_i \sum_{j \in N_B} V_j \left[ G_{ij} \cos[\theta_i - \theta_j] + B_{ij} \sin[\theta_i - \theta_j] \right] \quad (12)$$

$$0 = QG_i - QD_i - V_i \sum_{j \in N_B} V_j \left[ G_{ij} \sin[\theta_i - \theta_j] + B_{ij} \cos[\theta_i - \theta_j] \right] \quad (13)$$

Inequality constraints

$$P_{gslack}^{\min} \leq P_{gslack} \leq P_{gslack}^{\max} \quad (14)$$

$$Q_{gi}^{\min} \leq Q_{gi} \leq Q_{gi}^{\max}, i \in N_g \quad (15)$$

$$VL_i^{\min} \leq VL_i \leq VL_i^{\max}, i \in N_L \quad (16)$$

$$T_i^{\min} \leq T_i \leq T_i^{\max}, i \in N_T \quad (17)$$

$$Q_c^{\min} \leq Q_c \leq Q_c^{\max}, i \in N_C \quad (18)$$

$$|SL_i| \leq S_{Li}^{\max}, i \in N_{TL} \quad (19)$$

$$VG_i^{\min} \leq VG_i \leq VG_i^{\max}, i \in N_g \quad (20)$$

Then the multi objective fitness (MOF) function has been defined by,

$$MOF = OF_1 + x_i OF_2 + y OF_3 = OF_1 + \left[ \sum_{i=1}^{NL} x_v [VL_i - VL_i^{\min}]^2 + \sum_{i=1}^{NG} x_g [QG_i - QG_i^{\min}]^2 \right] + x_f OF_3 \quad (21)$$

$$VL_i^{\min} = \begin{cases} VL_i^{\max}, VL_i > VL_i^{\max} \\ VL_i^{\min}, VL_i < VL_i^{\min} \end{cases} \quad (22)$$

$$QG_i^{\min} = \begin{cases} QG_i^{\max}, QG_i > QG_i^{\max} \\ QG_i^{\min}, QG_i < QG_i^{\min} \end{cases} \quad (23)$$

### III. LAMPREY ALGORITHM

It inspired from the bubble-net hunting strategy of Lamprey. Algorithm describes the special hunting behaviour of Lamprey, and bubbles which causes the creation of '9-shaped path' while encircling prey during hunting. Lamprey went down in water roughly 10-16 meters and then it start to produce bubbles in a

spiral shape encircles prey and then through the bubbles and it moves towards upward of the surface. Mathematic model of approach given as follows, Encompassing prey equation Lamprey enfolds the prey then appraises its position towards the optimum solution over the sequence of swelling number of iteration from start to a maximum number of iteration,

$$\vec{E} = |F \cdot \vec{Y} * (t) - Y(t)| \quad (24)$$

$$\vec{Y}(t+1) = \vec{Y} * (t) - \vec{B} \cdot \vec{E} \quad (25)$$

Where  $\vec{B}, \vec{E}$  are coefficient vectors, t is a present iteration,  $\vec{y} * (t)$  is position vector of the optimum solution and  $Y(t)$  is position vector.

Coefficient vectors  $\vec{B}, \vec{E}$  are computed as follows:

$$\vec{B} = 2\vec{g} * rand - \vec{g} \quad (26)$$

$$\vec{E} = 2 * rand \quad (27)$$

Where  $\vec{g}$  is a variable linearly decrease from 2 to 0 over the sequence of iteration and rand is an arbitrary number [0, 1]. Bubble-net deeds of Lamprey are modelled by following methods,

This process is engaged by reducing linearly the value of 'g' from 2 to 0. Arbitrary value of vector  $\vec{B}$  is range between [-1, 1]. Scientific spiral equation for position modernizing between Lamprey and prey was helix-shaped movement & is given as follows,

$$\vec{Y}(t+1) = \vec{E}' * e^{bt} \cos(2\pi l) + \vec{Y} * (t) \quad (28)$$

Where l is an arbitrary number [-1, 1], b is constant defines the logarithmic shape,  $\vec{E}' = |\vec{Y} * (t) - Y(t)|$  expresses the distance between i<sup>th</sup> Lamprey to the prey mean the finest solution so far. 50-50% probability of Lamprey will either follow the dwindling enclosing path or logarithmic path during optimization. Arithmetically it modelled as follows:

$$\vec{Y}(t+1) = \begin{cases} \vec{Y} * \vec{B}\vec{E} & \text{if } p < 0.50 \\ \vec{E}' * e^{bt} \cos(2\pi l) + \vec{Y} * (t) & \text{if } p \geq 0.50 \end{cases} \quad (29)$$

The vector  $\vec{B}$  can be used for exploration to search for prey; vector  $\vec{B}$  also takes the values greater than one or less than -1. Exploration follows two conditions,

$$\vec{E} = |\vec{F} \cdot \vec{Y}_{random} - \vec{Y}| \quad (30)$$

$$\vec{Y}(t + 1) = \overrightarrow{Y_{random}} - \vec{B} \cdot \vec{E} \tag{31}$$

IV. ENRICHED LAMPREY OPTIMIZATION ALGORITHM

In Lamprey optimization algorithm (LOA), the modernized solution is mainly depended on the current best candidate solution. Alike to Particle Swarm Optimization algorithm, an inertia weight  $\omega \in [1, 0]$  is introduced into Lamprey optimization algorithm to obtain the Enriched Lamprey Optimization Algorithm (LOA). In surrounding prey, the modernized method is symbolized by the following equations:

$$\vec{E} = |\vec{G} \cdot \omega \vec{Y}^*(t) - \vec{Y}(t)| \tag{32}$$

$$\vec{Y}(t + 1) = \overrightarrow{Y_{random}} - \vec{B} \cdot \vec{E} \tag{33}$$

Where t is the present iteration,  $\vec{Y}$  is the location vector,  $\vec{G}$  is coefficient vectors,  $||$  is the complete value, G is the coefficient vectors,  $*$  an element-by-element multiplication  $\vec{Y}^*$  the location vector of the finest solution attained so far. In Spiral modernizing position, a spiral equation is formed between the location of Lamprey and prey to imitate the helix-shaped progression of humpback Lamprey as follows:

$$\vec{Y}(t + 1) = \vec{E}' \cdot e^{bt} \cos(2\pi l) + \vec{\omega Y}^*(t) \tag{34}$$

Where  $E' = |\omega Y^*(t) - Y(t)|$  and indicates the distance of the  $i^{th}$  Lamprey to the prey (most excellent solution attained so far), b is a stable for defining the outline of the logarithmic spiral, l is an arbitrary number in  $[-1,1]$ . Humpback Lampreys will impulse within a recoil circle and spiral-shaped path concurrently. To model this concurrent performance, it has been assumed that there is a probability of 50% to select between either the recoil surrounding mechanism otherwise the spiral model to modernize the position of Lamprey during optimization.

The mathematical model is as follows:

$$\vec{Y}(t + 1) = \begin{cases} \omega \vec{Y} * \vec{B} \vec{E} & \text{if } p < 0.50 \\ \vec{E}' \cdot e^{bt} \cos(2\pi l) + \omega \vec{Y}^*(t) & \text{if } p \geq 0.50 \end{cases} \tag{35}$$

Where “p” is an arbitrary number in  $[0, 1]$ . In addition to the bubble-net method, the humpback Lamprey explore for prey arbitrarily.

Step1. Initialize the Lamprey population  $\vec{Y}_i = (1,2,\dots,n)$  and Max gen - maximum number of iterations. Assume “t” = 1.

Step2. Compute the fitness of  $\vec{Y}_i = (1,2,\dots,n)$ , and find the most excellent explore solution  $Y^*$ .

Step3. Repeat the following: For every  $\vec{Y}_i = (1,2,\dots,n)$ , modernize the search if  $|\vec{B}| < 1$ , then modernize the location of the present explore agent by the Eq.(18) and if  $|\vec{B}| > 1$ , modernize the location of the existing exploration agent by the Eq.(17). If  $p \geq 0.50$ , modernize the position of the current search by the Eq.(20). Ensure if any explore agent goes beyond the exploration and modify it. Compute the fitness of  $\vec{Y}_i = (1,2,\dots,n)$ , and if there is a superior solution, find the best search solution  $\vec{Y}^*$ . Let  $t = t + 1$ , Until “t” accomplish Maximum generations, then the algorithm is completed. Step 4. Revisit the most excellent optimization solution  $\vec{Y}^*$  and the finest optimization value of fitness values.

V. SIMULATION RESULTS

Projected Enriched Lamprey Optimization Algorithm (LOA) has been tested in standard IEEE 30 bus system [40]. It has a sum of active and reactive power consumption of 2.834 and 1.262 per unit on 100 MVA base. Table 1,2,3,4 gives the comparison with reference to real power loss, voltage stability improvement, Voltage Deviation Minimization Multi – objective formulation. PLoss (base case) is 5.66 MW and Base case for VD is 0.58217 PU. Figures – 1to 4 gives graphical comparison between the methodologies with reference to power loss, voltage stability improvement, voltage deviation and multi- objective problem formulation.

Table 1.Comparison of real power loss with different metaheuristic algorithms

| Parameter    | DE [41] | GSA [42] | APOPSO [43] | LOA    |
|--------------|---------|----------|-------------|--------|
| PLoss (MW)   | 4.555   | 4.5143   | 4.398       | 4.216  |
| VD (PU)      | 1.9589  | 0.87522  | 1.047       | 1.032  |
| L-index (PU) | 0.5513  | 0.14109  | 0.1267      | 0.1204 |

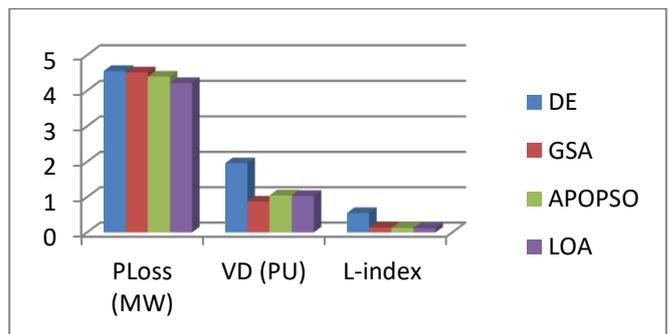


Fig 1. Comparison of Real Power Loss, VD, L-index between methodologies

Table 2. Comparison of different algorithms with reference to voltage stability improvement

| Parameter              | DE [41] | GSA [42] | APOPSO [43] | LOA    |
|------------------------|---------|----------|-------------|--------|
| P <sub>Loss</sub> (MW) | 6.4755  | 6.9117   | 5.698       | 5.413  |
| VD (PU)                | 0.0911  | 0.0676   | 0.087       | 0.064  |
| L-index (PU)           | 0.14352 | 0.1349   | 0.1377      | 0.1339 |

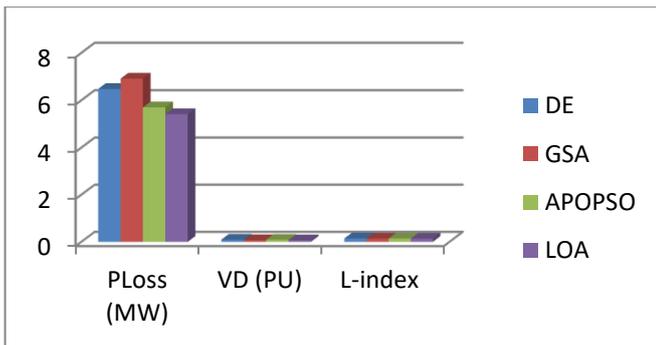


Fig 2. Comparison of Real Power Loss, VD, L-index between methodologies with reference to voltage stability improvement

Table 3. Comparison with reference to Voltage Deviation Minimization

| Parameter              | DE [41] | GSA [42] | APOPSO [43] | LOA    |
|------------------------|---------|----------|-------------|--------|
| P <sub>Loss</sub> (MW) | 7.0733  | 4.9752   | 4.478       | 4.226  |
| VD (PU)                | 1.419   | 0.21579  | 1.8579      | 1.8209 |
| L-index (PU)           | 0.1246  | 0.13684  | 0.1227      | 0.1164 |

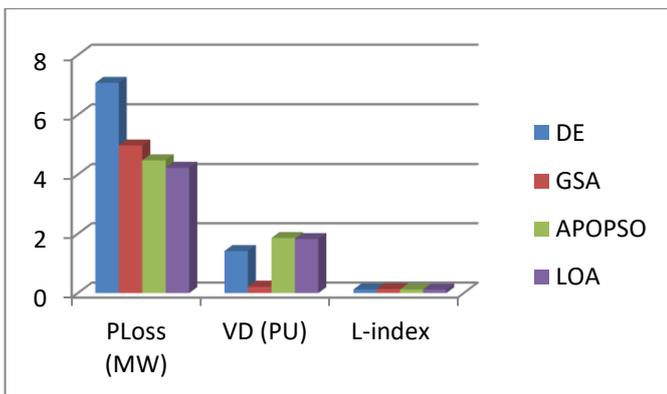


Fig 3. Comparison of Real Power Loss, VD, L-index between methodologies with reference to Voltage Deviation Minimization

Table 4. Comparison of values with reference to Multi – objective formulation

| Parameter              | APOPSO [43] | LOA    |
|------------------------|-------------|--------|
| P <sub>Loss</sub> (MW) | 4.842       | 4.734  |
| VD (PU)                | 1.009       | 1.003  |
| L-index (PU)           | 0.1192      | 0.1185 |

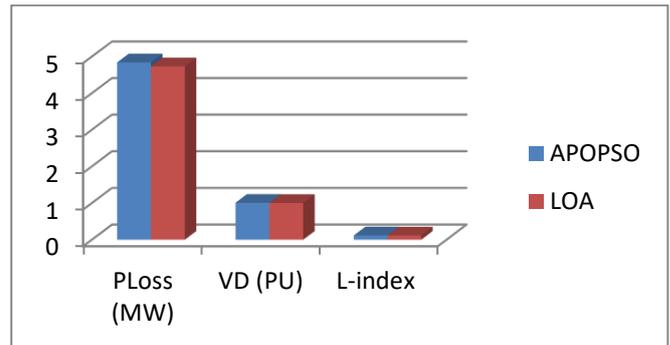


Fig 4. Comparison of Real Power Loss, VD, L-index between methodologies with reference to Multi – objective formulation.

## VI. CONCLUSION

In this paper, Enriched Lamprey optimization Algorithm (LOA) has been effectively applied to solve Optimal Reactive Power Dispatch problem. Alike to Particle Swarm Optimization algorithm, an inertia weight is introduced into Lamprey optimization algorithm to obtain the Enriched Lamprey optimization algorithm (LOA). In this algorithm roulette wheel selection method has been used to improve the convergence rate. Humpback Lampreys will impulse within a recoil circle and spiral-shaped path concurrently. To model this concurrent performance, it has been assumed that there is a probability of 50% to select between either the recoil surrounding mechanism otherwise the spiral model to modernize the position of Lamprey during optimization. The proposed LOA algorithm has been tested in the standard IEEE 30 bus system. Simulation results show the heftiness of projected Enriched Lamprey optimization algorithm in declining the real power loss. The control variables obtained after the optimization by LOA are well within the limits.

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