

## Enhanced whale optimization algorithm for active power loss diminution

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### ABSTRACT

In this paper Enhanced whale Optimization Algorithm (EWO) proposed to solve the optimal reactive power problem. Whale optimization algorithm is modeled by Bubble-net hunting tactic. In the projected optimization algorithm an inertia weight  $\omega \in [1, 0]$  has been introduced to perk up the search ability. Whales are commonly moving 10-16 meters down then through the bubbles which are created artificially then they encircle the prey and move upward towards the surface of sea. Proposed Enhanced whale optimization algorithm (EWO) is tested in standard IEEE 57 bus systems and power loss reduced considerably.

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## 1. INTRODUCTION

In this work minimization of real power loss is key goal. A variety of conventional techniques has been already solved the problem [1-6] but many techniques underwent complexity in managing the in-equality constraints. Subsequently evolutionary techniques [7-15] have been successfully solved the problem. In this work Enhanced whale Optimization Algorithm (EWO) is applied to solve the optimal reactive power problem. Whale algorithm modelled by Bubble-net hunting strategy of whale [16] and with respect to current excellent candidate, solution will be obtained. Alike to Particle Swarm Optimization algorithm, an inertia weight;  $\omega \in [1, 0]$  is introduced into whale optimization algorithm to augment the search and called as Enhanced whale optimization algorithm. Projected EWO algorithm evaluated in standard IEEE 57 bus systems and power loss has been reduced powerfully.

## 2. PROBLEM FORMULATION

Reduction real power loss is the key goal of this work and it has been written as follows:

$$F = P_L = \sum_{k \in N_{br}} g_k (V_i^2 + V_j^2 - 2V_i V_j \cos \theta_{ij}) \quad (1)$$

$$F = P_L + \omega_v \times \text{Voltage Deviation} \quad (2)$$

$$\text{Voltage Deviation} = \sum_{i=1}^{N_{pq}} |V_i - 1| \quad (3)$$

Constraint (Equality)

$$P_G = P_D + P_L \quad (4)$$

Constraints (Inequality)

$$P_{gslack}^{\min} \leq P_{gslack} \leq P_{gslack}^{\max} \quad (5)$$

$$Q_{gi}^{\min} \leq Q_{gi} \leq Q_{gi}^{\max}, i \in N_g \quad (6)$$

$$V_i^{\min} \leq V_i \leq V_i^{\max}, i \in N \quad (7)$$

$$T_i^{\min} \leq T_i \leq T_i^{\max}, i \in N_T \quad (8)$$

$$Q_c^{\min} \leq Q_c \leq Q_c^{\max}, i \in N_c \quad (9)$$

### 3. ENHANCED WHALE OPTIMIZATION ALGORITHM

Projected algorithm has been modelled through Bubble-net hunting strategy of whale. Normally bubbles form a ‘9-shaped path’ through that whale encircle the prey during hunting. Whales normally move 10-16 meters down the sea then through the bubbles which created artificially in spiral shape by that it encircles the prey and move upward towards the surface of sea.

Encompassing prey equation after enclosing the prey whale evaluate its position,

$$\vec{M} = |\vec{F} \cdot \vec{Y} * (t) - Y(t)| \quad (10)$$

$$\vec{Y}(t+1) = \vec{Y} * (t) - \vec{D} \cdot \vec{M} \quad (11)$$

$$\vec{D} = 2\vec{k} * \text{random} - \vec{k} \quad (12)$$

$$\vec{M} = 2 * \text{random} \quad (13)$$

Diminishing encircling method; it is done by reducing the value of ‘k’ from 2.0 to 0.0. Then the capricious value of vector  $\vec{D}$  will range from [-1, 1].

Modernization of spiral position; In this phase whale and prey position will be in helix-shaped then the movement is described by,

$$\vec{Y}(t+1) = \vec{H}' * e^{bt} * \cos(2\pi l) + \vec{Y} * (t) \quad (14)$$

$$\vec{M}' = |\vec{Y} * (t) - Y(t)| \quad (15)$$

In (15) describe the distance between “i” th whale to the prey and it point out the premium solution obtained so far. Movement of the whale in enclosed path or logarithmic path mode is described as,

$$\vec{Y}(t+1) = \begin{cases} \vec{Y} * \vec{D} \vec{M}' & \text{if } p < 0.50 \\ \vec{M}' * e^{bt} * \cos(2\pi l) + \vec{Y} * (t) & \text{if } p \geq 0.50 \end{cases} \quad (16)$$

Prey exploration;  $\vec{D}$  for prey exploration and value will be “1” or less than -1. With reference to the condition’s exploration is done in the search,

$$\vec{M} = |\vec{F} \cdot \vec{X}_{\text{random}} - \vec{Y}| \quad (17)$$

$$Y(t+1) = \vec{X}_{\text{random}} - \vec{D} \cdot \vec{M} \quad (18)$$

$|\vec{D}| > 1$  ; For finding the global optimum.

$|\vec{D}| < 1$  ; For updating the search agent position.

#### 4. ENHANCED WHALE OPTIMIZATION ALGORITHM

An inertia weight  $\omega \in [1, 0]$  has been introduced in the whale optimization algorithm and by this modernized methodology surrounding of prey is defined by,

$$\vec{M} = |\vec{G} \cdot \omega \vec{Y}^*(t) - \vec{Y}(t)| \quad (19)$$

$$\vec{Y}(t+1) = \overrightarrow{Y_{\text{random}}} - \vec{D} \cdot \vec{M} \quad (20)$$

In phase of modernization of spiral position helix shaped sequence created by whale and described as:

$$\vec{Y}(t+1) = \vec{M}' * e^{bt*} \cos(2\pi l) + \omega \vec{Y}^*(t) \quad (21)$$

$$M' = |\omega Y^*(t) - Y(t)| \quad (22)$$

Recoil circling produced by the whale is defined by,

$$\vec{Y}(t+1) = \begin{cases} \omega \vec{Y} * \vec{H} \vec{D} & \text{if } p < 0.50 \\ \vec{H}' * e^{bt*} \cos(2\pi l) + \omega \vec{Y}^*(t) & \text{if } p \geq 0.50 \end{cases} \quad (23)$$

- Initialization of whale population
- Fitness of  $\vec{Y}_i = (1, 2, \dots, n)$ , is computed best  $Y^*$  is found.
- Alter the exploration when  $|\vec{D}| < 1$  for every  $\vec{Y}_i = (1, 2, \dots, n)$ , and modernization of position is done by  $\vec{M} = |\vec{G} \cdot \omega \vec{Y}^*(t) - \vec{Y}(t)|$
- When  $|\vec{D}| > 1$ , position modernizing is done by  $Y(t+1) = \overrightarrow{Y_{\text{random}}} - \vec{D} \cdot \vec{M}$
- When  $p \geq 0.50$ , modernize the position by,  $\vec{Y}(t+1) = \vec{M}' * e^{bt*} \cos(2\pi l) + \omega \vec{Y}^*(t)$
- Ensure if any explore agent goes away from the exploration and if so amend it.
- Calculate the fitness of  $\vec{Y}_i = (1, 2, \dots, n)$ , and find best  $\vec{Y}^*$ .
- $t = t + 1$ ,
- Revisit the excellent solution  $\vec{Y}^*$  and premium fitness values.

#### 5. SIMULATION RESULTS

Proposed enhanced Whale Optimization Algorithm (EWO) is tested in IEEE 57 Bus system [17]. Table 1 show control variables, Table 2 gives the reactive power generators, comparison of results is given in Table 3. Figure 1 shows the comparison of Real Power Loss and Figure 2 indicate about the Real power loss reduction in percentage.

Table 1. Constraints of control variables

Parameter	Minimum value (PU)	Maximum value (PU)
Generator Voltage	0.95	1.10
Transformer Tap	0.90	1.10
VAR Source	0.00	0.20

Table 2. Constrains of reactive power generators

BUS	Q Minimum (PU)	Q Maximum (PU)
1	-140.00	200.00
2	-17.00	50.00
3	-10.00	60.00
6	-8.00	25.00
8	-140.00	200.00
9	-3.00	9.00
12	-150.00	155.00

Table 3. Simulation results of IEEE –57 system

Variable	Base case	MPSO [18]	PSO [18]	CGA [18]	AGA [18]	EWO
VG 1	1.040	1.093	1.083	0.968	1.027	1.014
VG 2	1.010	1.086	1.071	1.049	1.011	1.013
VG 3	0.985	1.056	1.055	1.056	1.033	1.020
VG 6	0.980	1.038	1.036	0.987	1.001	1.012
VG 8	1.005	1.066	1.059	1.022	1.051	1.024
VG 9	0.980	1.054	1.048	0.991	1.051	1.021
VG 12	1.015	1.054	1.046	1.004	1.057	1.030
Tap 19	0.970	0.975	0.987	0.920	1.030	0.910
Tap 20	0.978	0.982	0.983	0.920	1.020	0.912
Tap 31	1.043	0.975	0.981	0.970	1.060	0.903
Tap 35	1.000	1.025	1.003	NR*	NR*	1.002
Tap 36	1.000	1.002	0.985	NR*	NR*	1.014
Tap 37	1.043	1.007	1.009	0.900	0.990	1.011
Tap 41	0.967	0.994	1.007	0.910	1.100	0.910
Tap 46	0.975	1.013	1.018	1.100	0.980	1.022
Tap 54	0.955	0.988	0.986	0.940	1.010	0.934
Tap 58	0.955	0.979	0.992	0.950	1.080	0.923
Tap 59	0.900	0.983	0.990	1.030	0.940	0.941
Tap 65	0.930	1.015	0.997	1.090	0.950	1.055
Tap 66	0.895	0.975	0.984	0.900	1.050	0.914
Tap 71	0.958	1.020	0.990	0.900	0.950	1.024
Tap 73	0.958	1.001	0.988	1.000	1.010	1.023
Tap 76	0.980	0.979	0.980	0.960	0.940	0.930
Tap 80	0.940	1.002	1.017	1.000	1.000	1.012
QC 18	0.1	0.179	0.131	0.084	0.016	0.133
QC 25	0.059	0.176	0.144	0.008	0.015	0.142
QC 53	0.063	0.141	0.162	0.053	0.038	0.104
PG (MW)	1278.6	1274.4	1274.8	1276	1275	1272.21
QC (Mvar)	321.08	272.27	276.58	309.1	304.4	272.32
Reduction in PLoss (%)	0	15.4	14.1	9.2	11.6	23.93
Total PLoss (Mw)	27.8	23.51	23.86	25.24	24.56	21.146

NR\* - Not reported.

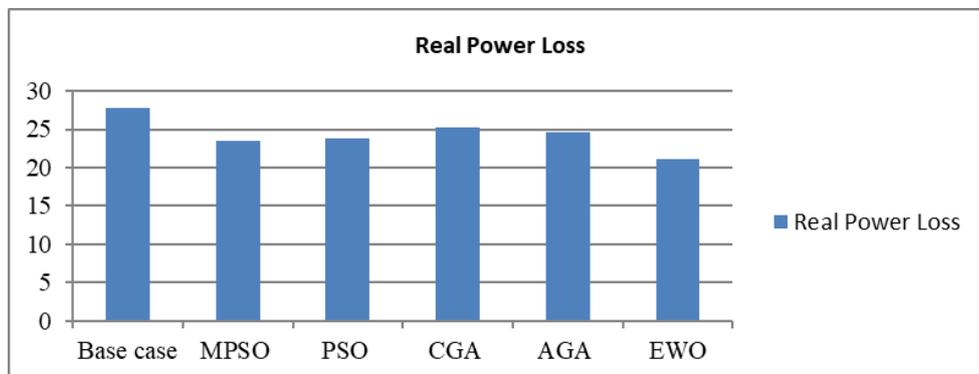


Figure 1. Comparison of real power loss

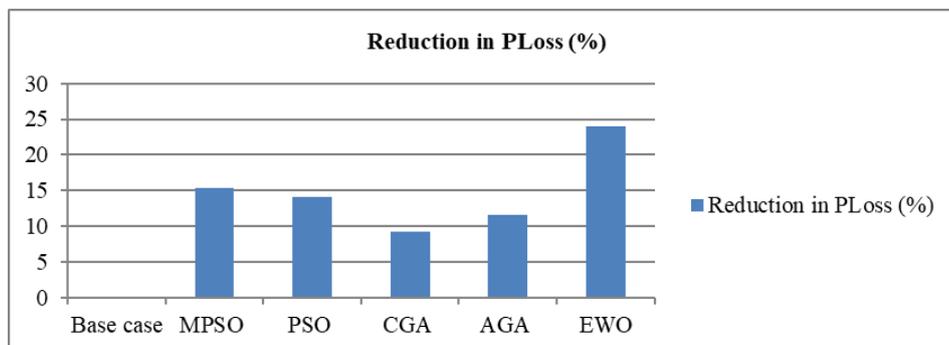


Figure 2. Real power loss reduction in percentage

## 6. CONCLUSION

Enhanced whale Optimization Algorithm (EWO) solved the optimal reactive power problem efficiently. To pick up the pace of convergence during the period of exploration an inertia weight  $\omega \in [0,1]$  has been applied. Bubble-net hunting stratagem is used for modelling and most excellent candidate solution has been attained. In standard IEEE 57 bus test system Enhanced whale Optimization Algorithm (EWO) is tested and results shows that the projected algorithm reduced the real power loss efficiently. Reduction of real power loss value is 23.93 % when compared to the base value.

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