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TRUE POWER LOSS REDUCTION BY WOLF OPTIMIZATION ALGORITHM

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Abstract

In this paper wolf optimization algorithm (WOA) has been applied for solving reactive power problem. In order to enhance the search procedure the basic qualities of particle swarm optimization has been intermingled to improve the capability of the search to reach a global solution. Efficiency of the projected wolf optimization algorithm (WOA) is tested in standard IEEE 30 bus test system. Simulation study indicates wolf optimization algorithm (WOA) performs well in tumbling the actual power losses& particularly voltage stability has been enriched.

Keywords: Reactive Power; Real Power Loss; Wolf Optimization; Swarm Optimization.

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1. Introduction

Reactive power problem plays major role in improving secure & economic of power system operation & control. A variety of methodologies [1-6] have been implemented to solve the problem, but difficulty found in handling the constraints. Now days various types of Evolutionary algorithms implemented to solve problem [7-19]. For last twenty years various types of programming and probabilistic based approach has been used to solve the problem. In this work wolf optimization algorithm (WOA) has been implemented to work out the problem. Both Exploration & Exploitation has been improved. In basic Wolf optimization algorithm (WO) [20], exploration spaces are missing the diversity and the high-quality diversity is needed to upgrade the performance of the algorithm to find an optimal solution. Particle swarm optimization (PSO) [21] has good feature of exploration ability and it has been hybridized with Wolf optimization algorithm (WO). PSO will aid to form better preliminary population to WO. In standard IEEE 30 bus test system efficiency of wolf optimization algorithm (WOA) has been evaluated. Actual power losses are reduced & particularly voltage margin within the limits.

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2. Problem Formulation

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

$$P_{loss}=\sum_{k=(i,j)}^{n}{}_{k=1}\, g_k\left(V_i^2+V_j^2-2V_i\, V_{j\ \cos\theta_{ij}}\right) \tag{1}$$

Voltage deviation magnitudes (VD) is stated as follows,

$$\text{Minimize VD} = \sum_{k=1}^{nl}|V_k - 1.0| \tag{2}$$

Load flow equality constraints:

$$P_{Gi} - P_{Di} - V_{i\sum_{j=1}^{nb} V_j}\begin{bmatrix} G_{ij} & \cos\theta_{ij} \\ +B_{ij} & \sin\theta_{ij}\end{bmatrix} = 0, i = 1,2 \ldots., nb \tag{3}$$

$$Q_{Gi} - Q_{Di} - V_{i\sum_{j=1}^{nb} V_j}\begin{bmatrix} G_{ij} & \sin\theta_{ij} \\ +B_{ij} & \cos\theta_{ij}\end{bmatrix} = 0, i = 1,2 \ldots., nb \tag{4}$$

Inequality constraints are:

$$V_{Gi}^{min} \leq V_{Gi} \leq V_{Gi}^{max}, i \in ng \tag{5}$$

$$V_{Li}^{min} \leq V_{Li} \leq V_{Li}^{max}, i \in nl \tag{6}$$

$$Q_{Ci}^{min} \leq Q_{Ci} \leq Q_{Ci}^{max}, i \in nc \tag{7}$$

$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max}, i \in ng \tag{8}$$

$$T_i^{min} \leq T_i \leq T_i^{max}, i \in nt \tag{9}$$

$$S_{Li}^{min} \leq S_{Li}^{max}, i \in nl \tag{10}$$

3. Wolf Optimization Algorithm

Wolf optimization imitates the common activity and hunting actions of wolves in nature. There are three fittest candidate solutions assumed as α,β and γ to lead the population toward promising regions of the exploration space in each iteration of wolf optimization. φ is named for the rest of wolves and it will assist α,β and γ to encircle, hunt, and attack prey, that is, to find Enriched solutions. In order to scientifically replicate the encompassing behavior of wolves, the following equations are proposed:

$$\vec{G} = \left|\vec{F}.\overrightarrow{Y_P}(t) - \vec{Y}(t)\right|,$$
$$\vec{Y}(t+1) = \overrightarrow{Y_P}(t) - \vec{H}.\vec{G} \tag{11}$$

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Where t indicates the current iteration $\vec{H} = 2\vec{b}.\vec{r_1} - \vec{b}$, $\vec{F} = 2.\vec{r_2}$, $\widehat{Y_P}$ the position vector of the prey, $\vec{Y}$ is the position vector of a wolf, $\vec{b}$ is linearly decreased from 2.0 to 0, and $\vec{r_1}$ and $\vec{r_2}$ are arbitrary vectors in [0, 1].

Hunting behavior of wolves are mathematically simulated by following equations,

$$\overrightarrow{G_\alpha} = \left|\overrightarrow{F_1}, \overrightarrow{Y_\alpha} - \vec{Y}\right|$$
$$\overrightarrow{G_\beta} = \left|\overrightarrow{F_2}, \overrightarrow{Y_\beta} - \vec{Y}\right| \quad (13)$$

$$\overrightarrow{G_\gamma} = \left|\overrightarrow{F_3}, \overrightarrow{Y_\gamma} - \vec{Y}\right|$$
$$\overrightarrow{Y_1} = \overrightarrow{Y_\alpha} - \overrightarrow{H_1} \ .\overrightarrow{G_\alpha}$$
$$\overrightarrow{Y_2} = \overrightarrow{Y_\beta} - \overrightarrow{H_2} \ .\overrightarrow{G_\beta} \quad (14)$$

$$\overrightarrow{Y_3} = \overrightarrow{Y_\gamma} - \overrightarrow{H_3} \ .\overrightarrow{G_\gamma}$$
$$\vec{Y}(t+1) = \frac{\overrightarrow{Y_1}+\overrightarrow{Y_2}+\overrightarrow{Y_3}}{3} \quad (15)$$

Position of a wolf was updated by equation (15) & the following equation is used to discrete the position.

$$flag_{i,j} = \begin{cases} 1 & Y_{i,j} > 0.50 \\ 0 & otherwise \end{cases} \quad (16)$$

Where i, indicates the jth position of the ith wolf, $flag_{i,j}$ is features of the wolf.

In Particle swarm optimization (PSO) algorithm [21] the positions and velocities of the Particles are modernized as follows:

$$v_{t+1}^i = \omega_t . v_t^i + cg_1 . Rm_1 . \left(m_t^i - y_t^i\right) + cg_2 . Rm_2 . \left(m_t^g - y_t^i\right) \quad (17)$$

$$y_{t+1}^i = y_t^i + v_{t+1}^i \quad (18)$$

The current position of particle is y_t^i & search velocity is v_t^i . Global best-found position is. m_t^g. In uniformly distributed interval (0, 1) Rm_1 & Rm_2 are arbitrary numbers. Where cg_1 and cg_2 are scaling parameters.ω_t is the particle inertia. The variable ω_t is modernized as

$$\omega_t = (\omega_{max} - \omega_{min}).\frac{(t_{max} - t)}{t_{max}} + \omega_{min} \quad (19)$$

Maximum and minimum of ω_t is represented by ω_{max} and ω_{min} ; maximum number of iterations is given by t_{max}. Until termination conditions are met this process will be repeated.

The first best Minimum loss and variables are accumulated as "α" position, score & as like second best, third best accumulated as "β" and " γ" position & score.

Initialize the parameters
Initialize b, $\overrightarrow{H}$ and $\vec{F}$;
i = 1: population size; j = 1: n
When (i, j) > 0.500; (i) = 1;
Else; (j) = 0;
End if
Wolf is designated as "α" - Primary maximum fitness; Wolf is designated as "β" - Second maximum fitness Wolf is designated as "γ" - Third maximum fitness
While k < maximum number of iteration; for i = 1: population size
Exact Location of the present wolf has been revised periodically
End for
For i = 1: population size; For i=1:n;If (i, j) > 0.500
(j) = 1;
Else
(j) = 0;
End if
Modify the values of b, $\overrightarrow{H}$ and $\vec{F}$; Fitness of wolves has been calculated
Value of wolves "α","β" and " γ" has to be modified
k=k+1;
End while
Value of" α "has to be analyzed
End

4. Simulated Outcomes

Validity of proposed wolf optimization algorithm (WOA) has been verified by testing it in standard IEEE 30-bus system. Control variables limits are given in Table 1.

Table 1: Key Variable Limits (Pu)

List of Variables	Minimum Limit	Maximum Limit	Class
Generator Bus	0.9500	1.100	Continuous
Load Bus	0.9500	1.0500	Continuous
Transformer-Tap	0.900	1.100	Discrete
Shunt Reactive Compensator	-0.1100	0.3100	Discrete

In Table 2 Generators power limits are listed.

Table 2: Generators Power Limits

Bus	Pg	Pg minimum	Pg maximum	Qg minimum	Qg maximum
1	96.000	49.000	200.000	0.000	10.000
2	79.000	18.000	79.000	-40.000	50.000
5	49.000	14.000	49.000	-40.000	40.000
8	21.000	11.000	31.000	-10.000	40.000
11	21.000	11.000	28.000	-6.000	24.000
13	21.000	11.000	39.000	-6.000	24.000

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Table 3 gives the control variables obtained after optimization. Table 4 presents the performance of the proposed ERWO. Table 5 list out the overall comparison of real power loss

Table 3: Control variables values after optimization

List of Control Variables	**WOA**
Voltage at 1	1.022000
Voltage at 2	1.053200
Voltage at 5	1.046400
Voltage at 8	1.020000
Voltage at 11	1.080100
Voltage at 13	1.040000
T;4,12	0.0000
T;6,9	0.0000
T;6,10	0.9000
T;28,27	0.9000
Q;10	0.1000
Q;24	0.1000
Real power loss (MW)	4.2282
Voltage deviation	0.9080

Table 4: Narration of projected WOA algorithm

No. of Iterations	**31**
Time taken	9.62
Real power loss (MW)	4.2282

Table 5: evaluation of outcome

List of Techniques	**Real power loss (MW)**
Method SGA [22]	4.98
Method PSO [23]	4.9262
Method LP [24]	5.988
Method EP [24]	4.963
Method CGA [24]	4.980
Method AGA [24]	4.926
Method CLPSO [24]	4.7208
Method HSA [25]	4.7624
Method BB-BC [26]	4.690
Method MCS [27]	4.87231
Proposed WOA	4.2282

5. Conclusion

Wolf optimization approach effectively solved the problem. Exploration & Exploitation has been considerably improved through the proposed methodology. Proposed technique has been tested in

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standard IEEE 30 bus test system. Comparison of the real power loss has been done & proposed methodology reduced the actual power loss considerably & voltage margin within limits.

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