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ACTIVE POWER LOSS DIMINUTION & VOLTAGE STABILITY ENHANCEMENT BY RED WOLF OPTIMIZATION ALGORITHM

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Abstract

In this paper optimal reactive power dispatch problem (ORPD), has been solved by Enriched Red Wolf Optimization (ERWO) algorithm. Projected ERWO algorithm hybridizes the wolf optimization (WO) algorithm with swarm based algorithm called as particle swarm optimization (PSO) algorithm. In the approach each Red wolf has a flag vector, and length is equivalent to the whole sum of numbers which features in the dataset of the wolf optimization (WO). Exploration capability of the projected Red wolf optimization algorithm has been enriched by hybridization of both WO with PSO. Efficiency of the projected Enriched Red wolf optimization (ERWO) evaluated in standard IEEE 30 bus test system. Simulation study indicates Enriched Red wolf optimization (ERWO) algorithm performs well in tumbling the actual power losses& particularly voltage stability has been enriched.

Keywords: Reactive Power; Dispatch; Loss; Red 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 [7-15]. For last twenty years various types of programming and probabilistic based approach [16-20] has been used to solve the problem. In this work Enriched Red wolf optimization (ERWO) algorithm has been implemented to work out the problem. Both Exploration & Exploitation has been improved. In basic Wolf optimization algorithm (WO) [21], 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) [22] has good feature of exploration ability and it has been hybridized with Wolf optimization algorithm (WO) to produce an Enriched version called as Enriched Red wolf

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optimization (ERWO). PSO will aid to form better preliminary population to WO. In standard IEEE 30 bus test system efficiency of Enriched Red wolf optimization (ERWO) algorithm has been evaluated. Results indicate that Enriched Red wolf optimization (ERWO) algorithm performs well in tumbling the actual power losses& particularly margin index value of voltage stability has been improved.

2. Voltage Stability Evaluation

2.1. Modal Analysis for Voltage Stability Evaluation

Power flow equations of the steady state system is given by,

$$\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix} = \begin{bmatrix} J_{p\theta} & J_{pv} \\ J_{q\theta} & J_{QV}\end{bmatrix} \begin{bmatrix}\Delta\theta\\ \Delta V\end{bmatrix} \quad (1)$$

Where
ΔP = bus real power change incrementally.
ΔQ = bus reactive Power injection change incrementally.
Δθ = bus voltage angle change incrementally.
ΔV = bus voltage Magnitude change incrementally.
Jpθ , JPV , JQθ , JQV are sub-matrixes of the System voltage stability in jacobian matrix and both P and Q get affected by this.

Presume ΔP = 0, then equation (1) can be written as,

$$\Delta Q = [J_{QV} - J_{Q\theta} J_{P\theta^{-1}} J_{PV}]\Delta V = J_R \Delta V \quad (2)$$

$$\Delta V = J^{-1} - \Delta Q \quad (3)$$

Where

$$J_R = (J_{QV} - J_{Q\theta} J_{P\theta^{-1}} JPV) \quad (4)$$

J_R Denote the reduced Jacobian matrix of the system.

2.2. Modes of Voltage Instability

Voltage Stability characteristics of the system have been identified through computation of the Eigen values and Eigen vectors.

$$J_R = \xi \wedge \eta \quad (5)$$

Where,
ξ denote the right eigenvector matrix of JR, η denote the left eigenvector matrix of JR, ∧ denote the diagonal eigenvalue matrix of JR.

$$J_{R^{-1}} = \xi \wedge^{-1} \eta \quad (6)$$

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From the equations (5) and (6),

$$\Delta V = \xi \wedge^{-1} \eta \Delta Q \tag{7}$$

or

$$\Delta V = \sum_I \frac{\xi_i \eta_i}{\lambda_i} \Delta Q \tag{8}$$

ξi denote the ith column right eigenvector & η is the ith row left eigenvector of JR.
λi indicate the ith Eigen value of JR.

reactive power variation of the ith modal is given by,

$$\Delta Q_{mi} = K_i \xi_i \tag{9}$$

where,

$$K_i = \sum_j \xi_{ij^2} - 1 \tag{10}$$

Where ξji is the jth element of ξi
ith modal voltage variation is mathematically given by,

$$\Delta V_{mi} = [1/\lambda_i] \Delta Q_{mi} \tag{11}$$

When the value of | λi | =0 then the ith modal voltage will get collapsed.

In equation (8), when ΔQ = ek is assumed , then ek has all its elements zero except the kth one being 1. Then ΔV can be formulated as follows,

$$\Delta V = \sum_i \frac{\eta_{1k}\ \xi_1}{\lambda_1} \tag{12}$$

η_{1k} is k th element of η_1
At bus k V –Q sensitivity is given by,

$$\frac{\partial V_K}{\partial Q_K} = \sum_i \frac{\eta_{1k}\ \xi_1}{\lambda_1} = \sum_i \frac{P_{ki}}{\lambda_1} \tag{13}$$

3. Problem Formulation

Minimization of actual power loss and augmentation of static voltage stability margin index (SVSM) is main key to solve optimal reactive power dispatch problem. Voltage stability evaluation has been done through modal analysis method.

3.1. Minimization of Real Power Loss

Real power loss (Ploss) minimization is given as,

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$$P_{loss}= \sum_{\substack{k=1 \\ k=(i,j)}}^{n} g_{k}(V_i^2+V_j^2-2V_i V_j \cos\theta_{ij}) \quad (14)$$

Where n is the number of transmission lines, gk is the conductance of branch k, Vi and Vj are voltage magnitude at bus i and bus j, and θij is the voltage angle difference between bus i and bus j.

3.2. Minimization of Voltage Deviation

Formula for reducing the voltage deviation magnitudes (VD) is derived as follows,

$$\text{Minimize VD} = \sum_{k=1}^{nl} |V_k - 1.0| \quad (15)$$

Where nl is the number of load busses and Vk is the voltage magnitude at bus k.

3.3. System Constraints

Load flow equality constraints:

$$P_{Gi} - P_{Di} - V_{i} \sum_{j=1}^{nb} V_j \begin{bmatrix} G_{ij} & \cos\theta_{ij} \\ +B_{ij} & \sin\theta_{ij} \end{bmatrix} = 0, i = 1,2 \ldots, nb \quad (16)$$

$$Q_{Gi} - Q_{Di} - V_{i} \sum_{j=1}^{nb} V_j \begin{bmatrix} G_{ij} & \sin\theta_{ij} \\ +B_{ij} & \cos\theta_{ij} \end{bmatrix} = 0, i = 1,2 \ldots, nb \quad (17)$$

where, nb is the number of buses, P_G and Q_G are the real and reactive power of the generator, P_D and Q_D are the real and reactive load of the generator, and G_{ij} and B_{ij} are the mutual conductance and susceptance between bus i and bus j.

$$V_{Gi}^{min} \leq V_{Gi} \leq V_{Gi}^{max}, i \in ng \quad (18)$$

$$V_{Li}^{min} \leq V_{Li} \leq V_{Li}^{max}, i \in nl \quad (19)$$

$$Q_{Ci}^{min} \leq Q_{Ci} \leq Q_{Ci}^{max}, i \in nc \quad (20)$$

$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max}, i \in ng \quad (21)$$

$$T_{i}^{min} \leq T_{i} \leq T_{i}^{max}, i \in nt \quad (22)$$

$$S_{Li}^{min} \leq S_{Li}^{max}, i \in nl \quad (23)$$

4. Red Wolf Optimization

Red wolf optimization mimics the communal management and hunt deeds of Red wolves in nature. There are three fittest candidate solutions assumed as α,β and γ to lead the population toward

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promising regions of the exploration space in each iteration of red wolf optimization. φ is named for the rest of Red 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 Red wolves, the following equations are proposed:

$$\vec{G} = \left|\vec{F}.\vec{Y_P}(t) - \vec{Y}(t)\right|,$$
$$\vec{Y}(t+1) = \vec{Y_P}(t) - \vec{H}.\vec{G} \tag{24}$$

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 Red 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 Red wolves are mathematically simulated by following equations,

$$\vec{G_\alpha} = \left|\vec{F_1}, \vec{Y_\alpha} - \vec{Y}\right|$$
$$\vec{G_\beta} = \left|\vec{F_2}, \vec{Y_\beta} - \vec{Y}\right| \tag{25}$$

$$\vec{G_\gamma} = \left|\vec{F_3}, \vec{Y_\gamma} - \vec{Y}\right|$$
$$\vec{Y_1} = \vec{Y_\alpha} - \vec{H_1}\ .\vec{G_\alpha}$$
$$\vec{Y_2} = \vec{Y_\beta} - \vec{H_2}\ .\vec{G_\beta} \tag{26}$$

$$\vec{Y_3} = \vec{Y_\gamma} - \vec{H_3}\ .\vec{G_\gamma}$$
$$\vec{Y}(t+1) = \frac{\vec{Y_1}+\vec{Y_2}+\vec{Y_3}}{3} \tag{27}$$

In this work, a new Enriched Red wolf optimization (ERWO) algorithm is proposed to solve reactive power dispatch problem & the position of a Red wolf was updated by equation (27) & the following equation is used to discrete the position.

$$flag_{i,j} = \begin{cases} 1 & Y_{i,j} > 0.50 \\ 0 & otherwise \end{cases} \tag{28}$$

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

5. Particle Swarm Optimization

In Particle swarm optimization (PSO) algorithm [22] the positions and velocities of the Particles are modernized as follows:

$$v_{t+1}^{i} = \omega_t . v_t^{i} + cg_1 . Rm_1 . \left(m_t^{i} - y_t^{i}\right) + cg_2 . Rm_2 . \left(m_t^{g} - y_t^{i}\right) \tag{29}$$

$$y_{t+1}^{i} = y_t^{i} + v_{t+1}^{i} \tag{30}$$

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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

$$\omega_t = (\omega_{max} - \omega_{min}).\frac{(t_{max}-t)}{t_{max}} + \omega_{min} \tag{31}$$

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.

6. Enriched Red Wolf Optimization (ERWO) Algorithm for Solving Optimal Reactive Power Dispatch Problem

In this approach red wolves α,β and γ determine the position of the prey. $\vec{H} = 2\vec{b}.\vec{r_1} - \vec{b}$ Directs the exploration & exploitation process by reducing the value from 2 to 0.When $|\vec{H}| < 1$ it converged towards the prey & If $|\vec{H}| > 1$ diverged away. 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.

Commence
Initialize the parameters
Initialize b, $\vec{H}$ and $\vec{F}$; beginning positions of Red wolves has been stimulated.
i = 1: population size
j = 1: n
When (i, j) > 0.500
(i) = 1;
Else
(j) = 0;
End if
End for
Work out the maximum fitness of Red wolves as follows,
Primary maximum fitness of the Red wolf is designated as “α”
Second maximum fitness of the Red wolf is designated as “β”
Third maximum fitness of the Red wolf is designated as “γ”
While k < maximum iteration
For i = 1: population size
Exact Location of the existing Red 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
End for

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Sporadically revise the values of b, $\overrightarrow{H}$ and $\vec{F}$;
At this stage Fitness of Red wolves has been calculated
The assessment of red wolves "α","β" and " γ" has to be revised
k=k+1;
End while
Re-examine the value of" α "as the optimal characteristic division;
End

7. Simulated Outcomes

The efficiency of the proposed Enriched Red Wolf Optimization (ERWO) algorithm is demonstrated by testing it on standard IEEE-30 bus system, it has 41 transmission lines of which four branches are (6-9), (6-10) , (4-12) , 6 generator buses, 24 load buses , (28-27) - are with the tap setting transformers. Optimal values of the control variables are given arte given in Table 1.

Table 1: Results of ERWO – ORPD optimal control variables

List of Control variables	Variable setting values
V1	1.04120
V2	1.04020
V5	1.04000
V8	1.03020
V11	1.00260
V13	1.03020
T11	1.0000
T12	1.0000
T15	1.0100
T36	1.0100
Qc10	2
Qc12	3
Qc15	2
Qc17	0
Qc20	2
Qc23	2
Qc24	3
Qc29	2
Real power loss	4.2096
SVSM	0.2484

Table 2 indicates the optimal values of the control variables & there is no limit violations in state variables. Static voltage stability margin (SVSM) has increased from 0.2484 to 0.2496. contingency analysis was conducted using the control variable setting obtained in case 1 and case 2 to determine the voltage security of the system. In Table 3 the Eigen values equivalent to contingencies are given. In Table 4Eigen value has been improved for all contingencies. Limit Violation Checking Of State Variables. Comparisons of results are shown in Table 5.

Table 2: Results of ERWO -Voltage Stability Control Reactive Power Dispatch Optimal Control Variables

List of Control Variables	Variable Setting values
V1	1.04420
V2	1.04040
V5	1.04120
V8	1.03040
V11	1.00320
V13	1.03200
T11	0.0900
T12	0.0900
T15	0.0900
T36	0.0900
Qc10	3
Qc12	3
Qc15	3
Qc17	3
Qc20	0
Qc23	2
Qc24	2
Qc29	3
Real power loss	4.9890
SVSM	0.2496

Table 3: Voltage Stability under Contingency State

Sl.No	Contingency	Optimal Reactive Power Dispatch Setting values	Voltage Stability Control Reactive Power Dispatch Setting values
1	28-27	0.1412	0.1423
2	4-12	0.1644	0.1652
3	1-3	0.1762	0.1765
4	2-4	0.2021	0.2054

Table 4: Limit Violation Checking of State Variables

State variables	limits		Optimal Reactive Power Dispatch Setting values	Voltage Stability Control Reactive Power Dispatch Setting values
	Lower	Upper		
Q1	-20.00	152.00	1.34220	-1.32690
Q2	-20.00	61.00	8.99000	9.82320
Q5	-15.00	49.920	25.9200	26.0010
Q8	-10.00	63.520	38.8200	40.8020
Q11	-15.00	42.00	2.93000	5.0020
Q13	-15.00	48.00	8.10250	6.0330
V3	0.950	1.050	1.03720	1.03920

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V4	0.950	1.050	1.03070	1.03280
V6	0.950	1.050	1.02820	1.02980
V7	0.950	1.050	1.01010	1.01520
V9	0.950	1.050	1.04620	1.04120
V10	0.950	1.050	1.04820	1.04980
V12	0.950	1.050	1.04000	1.04660
V14	0.950	1.050	1.04740	1.04430
V15	0.950	1.050	1.04570	1.04130
V16	0.950	1.050	1.04260	1.04050
V17	0.950	1.050	1.03820	1.03960
V18	0.950	1.050	1.03920	1.04000
V19	0.950	1.050	1.03810	1.03940
V20	0.950	1.050	1.01120	1.01940
V21	0.950	1.050	1.04350	1.02430
V22	0.950	1.050	1.04480	1.03960
V23	0.950	1.050	1.04720	1.03720
V24	0.950	1.050	1.04840	1.03720
V25	0.950	1.050	1.01420	1.01920
V26	0.950	1.050	1.04940	1.04220
V27	0.950	1.050	1.04720	1.04520
V28	0.950	1.050	1.02430	1.02830
V29	0.950	1.050	1.04390	1.04190
V30	0.950	1.050	1.04180	1.03970

Table 5: Comparison of Real Power Loss

Method	**Minimum loss**
Evolutionary programming [23]	5.0159
Genetic algorithm [24]	4.665
Real coded GA with Lindex as SVSM[25]	4.568
Real coded genetic algorithm [26]	4.5015
projected ERWO	4.2096

8. Conclusion

Enriched Red wolf optimization (ERWO) approach effectively solved the problem. Exploration & Exploitation has been considerably improved through the proposed methodology. In standard IEEE 30 bus test system proposed technique has been tested, , comparison of the real power loss has been done & proposed methodology reduced the actual power loss considerably with augmentation of static voltage stability margin index.

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