Timber Wolf Optimization Algorithm for Real Power Loss Diminution

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Abstract: *In this paper Timber Wolf optimization (TWO) algorithm is proposed to solve optimal reactive power problem. Timber Wolf optimization (TWO) algorithm is modeled based on the social hierarchy and hunting habits of Timber wolf towards finding prey. Based on their fitness values social hierarchy has been replicated by classifying the population of exploration agents. Exploration procedure has been modeled by imitating the hunting actions of timber wolf by using searching, encircling, and attacking the prey. There are three fittest candidate solutions embedded as α, β and γ to lead the population toward capable regions of the exploration space in each iteration of Timber Wolf optimization. Proposed Timber Wolf optimization (TWO) algorithm has been tested in standard IEEE 14, 30 bus test systems and simulation results show the projected algorithm reduced the real power loss efficiently.*

Keywords: *optimal reactive power, Transmission loss, Timber Wolf optimization (TWO) algorithm*

1. Introduction

For efficient and better operation of power system Reactive power problem play a lead role. Numerous types of methods [1-6] have been utilized to solve the optimal reactive power problem. However many scientific difficulties are found while solving problem due to an assortment of constraints. Evolutionary techniques [7-16] are applied to solve the reactive power problem. This paper proposes Timber Wolf optimization (TWO) algorithm to solve optimal reactive power problem. Timber Wolves will hunt and move in packs. Normally pack consists of one male, female and their younger ones. Almost 10 wolves per pack, although packs as huge as 30 have been witnessed. Every Pack have a head, which known as the "α" male. Against the interloper each pack safeguards its boundary and if needed will kill other timber wolves which are not in the part of the pack. Timber Wolves are nocturnal in nature and hunt for food at night and almost sleep during the daytime. Hunting procedure of the wolf is designed to formulate the algorithm. There are three fittest candidate solutions embedded as α, β and γ to lead the population toward capable regions of the exploration space in each iteration of Timber Wolf optimization. Adaptive value of parameters "a", "A" determines the exploration, exploitation operation. When the value of "A" is located in [–1, 1] capriciously, which indicate the procedure of local search perceptibly in this phase the wolves attack towards the prey. Adaptive cross-over, mutation operation of genetic algorithm has been utilized to perk up the exploitation capability of the algorithm also it augments the diversity of the wolves, these activities will avoid to get trap in local solution and premature convergence. Proposed Timber Wolf optimization (TWO) algorithm has been tested in standard IEEE 14, 30, bus test systems and simulation results show the projected algorithm reduced the real power loss effectively.

2. Problem Formulation

Objective of the problem is to reduce the true power loss:

$$F = P_L = \sum_{k \in Nbr} g_k \left(V_i^2 + V_j^2 - 2V_i V_j \cos\theta_{ij} \right) \tag{1}$$

Voltage deviation given as follows:

$$F = P_L + \omega_v \times \text{Voltage Deviation} \tag{2}$$

Voltage deviation given by:

$$\text{Voltage Deviation} = \sum_{i=1}^{Npq} \left| V_i - 1 \right| \tag{3}$$

Constraint (Equality)

$$P_G = P_D + P_L \tag{4}$$

Constraints (Inequality)

$$P_{gslack}^{min} \le P_{gslack} \le P_{gslack}^{max} \tag{5}$$

$$Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max}, i \in N_g \tag{6}$$

$$V_i^{min} \le V_i \le V_i^{max}, i \in N \tag{7}$$

$$T_i^{min} \le T_i \le T_i^{max}, i \in N_T \tag{8}$$

$$Q_c^{min} \le Q_c \le Q_C^{max}, i \in N_C \tag{9}$$

3. Timber Wolf Optimization

Timber Wolf optimization (TWO) algorithm is based on the natural behavior of the Timber Wolf. The deeds of the timber wolf have been emulated to formulate the algorithm. Timber Wolves will hunt and move in packs. Normally pack consists of one male, female and their younger ones. Almost 10 wolves per pack, although packs as huge as 30 have been witnessed. Every Pack have a head, which known as the "α" male. Against the interloper each pack safeguards its boundary and if needed will kill other timber wolves which are not in the part of the pack. Timber Wolves are nocturnal in nature and hunt for food at night and almost sleep during the daytime. Hunting procedure of the wolf is designed to formulate the algorithm. There are three fittest candidate solutions embedded as α, β and γ to lead the population toward capable regions of the exploration space in each iteration of Timber Wolf optimization. φ is named for the rest of Timber Wolves and it will assist α, β and γ to to encircle, hunt, and attack prey; to find improved solutions. In order to technically imitate the encircling deeds of Timber wolves, the following equations are projected:

$$\vec{U} = \left| \vec{I} \cdot \overrightarrow{Q_P}(t) - \vec{Q}(t) \right| \tag{10}$$

$$\vec{Q}(t+1) = \overrightarrow{Q_P}(t) - \vec{G} \cdot \vec{U} \tag{11}$$

In order to scientifically imitate the hunting deeds of Timber wolf, the following equations are projected,

$$\overrightarrow{U_\alpha} = \left| \overrightarrow{I_1}, \overrightarrow{Q_\alpha} - \vec{Q} \right|$$

$$\overrightarrow{U_\beta} = \left| \overrightarrow{I_2}, \overrightarrow{Q_\beta} - \vec{Q} \right| \tag{12}$$

$$\overrightarrow{Q_1} = \overrightarrow{Q_\alpha} - \overrightarrow{G_1} \cdot \overrightarrow{U_\alpha} \tag{13}$$

$$\overrightarrow{Q_2} = \overrightarrow{Q_\beta} - \overrightarrow{Q_2} \cdot \overrightarrow{U_\beta}$$

$$\overrightarrow{Q_3} = \overrightarrow{Q_\gamma} - \overrightarrow{G_3} \cdot \overrightarrow{U_\gamma} \tag{14}$$

$$\vec{Q}(t+1) = \frac{\overrightarrow{Q_1} + \overrightarrow{Q_2} + \overrightarrow{Q_3}}{3}$$

The position of an Timber wolf is modernized and then the following equation is used to discrete the position of the wolf;

$$\text{flag}_{i,j} = \begin{cases} 1 & Q_{i,j} > 0.475 \\ 0 & \text{otherwise} \end{cases} \tag{15}$$

Where i, indicates the jth position of the ith Timber wolf, $\text{flag}_{i,j}$ is features of the Timber wolf.

The interactions of the Timber wolf among them is increased by,

$$\omega_i^d = q_i^d + \varphi_{id}\left(q_\pm^d - z_i^d\right) + \varphi_{id}\left(q_j^d - q_k^d\right) \tag{16}$$

The confined density of the Timber wolf is denoted by,

$$\rho_i = \sum_{j \in T/\{i\}} e^{-\left(\frac{d_{ij}}{dc}\right)^2} \tag{17}$$

Timber wolf is less than "dc" when the the Timber wolf's distance from the Qi , the greater than the confined density [17] of the Timber wolf. dij symbolize the Euclidean distance between the Qi, Qj of Timber wolf, φ_{id} is a arbitrary number in [0, 1], φ_{id} is a arbitrary number in [−1,1].

Adaptive value of parameters "a", "A" determines the exploration, exploitation operation. When the value of A are located in [−1, 1] capriciously, which indicate the procedure of local search perceptibly in this phase the wolves attack towards the prey. Wolves are forced to make a global search When | A | > 1. Through the parameter "a" fluctuation range of "A" can be decreased. Parameter "a" is linearly decreased from 2 to 0 during the augment of iterations according to;

$$A_i = 2a \cdot r_1 - a \tag{18}$$

$$C_i = 2 \cdot r_2 \tag{19}$$

$$a = 2 - 2t/t_{max} \tag{20}$$

In this work adaptive parameter "a" is adjusted in the nonlinear control parameter based on cosine function which has been given as,

$$a = 1 - \cos\left(\left(1 - \frac{t}{t_{max}}\right)^k \cdot \pi\right) \tag{21}$$

Adaptive cross-over, mutation operation of genetic algorithm has been utilized to perk up the exploitation capability of the algorithm also it augments the diversity of the wolves, these activities will avoid to get trap in local solution and premature convergence. Genetic operators adaptive probability makes certain to reach the global optimization and the outstanding individuals will be retained.

$$P_c = \begin{cases} 0.750 \quad - \dfrac{1}{\left|f_{best} - f_{mean}\right|}, & \left|f_{best} - f_{mean}\right| > \varepsilon_1 \\ 0.50 & \text{else} \end{cases} \tag{22}$$

$$P_m = \begin{cases} 0.0750 \quad - \dfrac{1}{\left|f_{best} - f_{mean}\right|}, & \left|f_{best} - f_{mean}\right| > \varepsilon_1 \\ 0.050 & \text{else} \end{cases} \tag{23}$$

New-fangled individuals will be engendered by,

$$Q' = \lambda_1 \cdot Q_a + (1 - \lambda_1) \cdot Q_b \tag{24}$$

With reference to the probability with whole population mutation obtained by,

$$Q'' = Q_i \cdot (1 + \lambda_2)^m \tag{25}$$

Where X" ; after the mutation operation positions of the engendered individual. λ_2 – Arbitrary parameter in [0, 1], "m" – control parameter.

a. Begin
b. Set the preliminary parameters, and engender the preliminary population arbitrarily
c. Compute the fitness value of each wolf
d. Fitness value of wolf will be compared, and find

out the present top three most excellent wolves

e. Modernize the value of a, A_i, C_i

f. Modernize the position of the present wolves by $\overrightarrow{U_\alpha} = \left|\overrightarrow{I_1}, \overrightarrow{Q_\pm} - \vec{Q}\right|;\ \overrightarrow{U_\beta} = \left|\overrightarrow{I_2}, \overrightarrow{Q_\beta} - \vec{Q}\right|;\ \overrightarrow{U_\gamma} = \left|\overrightarrow{I_3}, \overrightarrow{Q_\gamma} - \vec{Q}\right|$

g. Apply adaptive parameter "a" is adjusted in the nonlinear control parameter based on cosine function by $a = 1 - \cos\left(\left(1 - \frac{t}{t_{max}}\right)^k \cdot \pi\right)$

h. Employ Adaptive cross-over operation by

$$P_c = \begin{cases} 0.750 & -\frac{1}{|f_{best} - f_{mean}|}, |f_{best} - f_{mean}| > \varepsilon_1 \\ 0.50 & \text{else} \end{cases}$$

$$P_m = \begin{cases} 0.0750 & -\frac{1}{|f_{best} - f_{mean}|}, |f_{best} - f_{mean}| > \varepsilon_1 \\ 0.050 & \text{else} \end{cases}$$

i. Employ Adaptive cross-over operation by

$$Q' = \lambda_1 \cdot Q_a + (1 - \lambda_1) \cdot Q_b;\ Q'' = Q_i \cdot (1 + \lambda_2)^m$$

j. Modernize the position existing wolf

k. When end criteria satisfied then stop

l. Output the best solution

4. Simulation Results

At first in standard IEEE 14 bus system [18] the validity of the proposed Timber Wolf optimization (TWO) algorithm has been tested, Table 1 shows the constraints of control variables Table 2 shows the limits of reactive power generators and comparison results are presented in Table 3.

Tab. 1. Constraints of control variables

System	Variables	Minimum (PU)	Maximum (PU)
IEEE 14 Bus	Generator Voltage	0.95	1.1
	Transformer Tap	0.9	1.1
	VAR Source	0	0.20

Tab. 2. Constrains of reactive power generators

System	Variables	Q Minimum (PU)	Q Maximum (PU)
IEEE 14 Bus	1	0	10
	2	–40	50
	3	0	40
	6	–6	24
	8	–6	24

Then the proposed Timber Wolf optimization (TWO) algorithm has been tested, in IEEE 30 Bus system. Table 4 shows the constraints of control variables, Table 5 shows the limits of reactive power generators and comparison results are presented in Table 6.

Tab. 3. Simulation results of IEEE –14 system

Control variables	Base case	MPSO [19]	PSO [19]	EP [19]	SARGA [19]	TWO
VG–1	1.060	1.100	1.100	NR*	NR*	1.019
VG–2	1.045	1.085	1.086	1.029	1.060	1.020
VG–3	1.010	1.055	1.056	1.016	1.036	1.018
VG–6	1.070	1.069	1.067	1.097	1.099	1.013
VG–8	1.090	1.074	1.060	1.053	1.078	1.027
Tap 8	0.978	1.018	1.019	1.04	0.95	0.919
Tap9	0.969	0.975	0.988	0.94	0.95	0.925
Tap10	0.932	1.024	1.008	1.03	0.96	0.908
QC–9	0.19	14.64	0.185	0.18	0.06	0.130
PG (MW)	272.39	271.32	271.32	NR*	NR*	271.73
QG(Mvar)	82.44	75.79	76.79	NR*	NR*	75.81
Reduction in PLoss (%)	0	9.2	9.1	1.5	2.5	23.60
Total PLoss (Mw)	13.550	12.293	12.315	13.346	13.216	10.351

NR* – Not reported.

Tab. 4. Constraints of control variables

System	Variables	Minimum (PU)	Maximum (PU)
IEEE 30 Bus	Generator Voltage	0.95	1.1
	Transformer Tap	0.9	1.1
	VAR Source	0	0.20

Tab. 5. Constrains of reactive power generators

System	Variables	Q Minimum (PU)	Q Maximum (PU)
IEEE 30 Bus	1	0	10
	2	–40	50
	5	–40	40
	8	–10	40
	11	–6	24
	13	–6	24

5. Conclusion

In this paper Timber Wolf optimization (TWO) algorithm successfully solved the optimal reactive

Tab. 6. Simulation results of IEEE –30 system

Control variables	Base case	MPSO [19]	PSO [19]	EP [19]	SARGA [19]	TWO
VG–1	1.060	1.101	1.100	NR*	NR*	1.022
VG–2	1.045	1.086	1.072	1.097	1.094	1.020
VG–5	1.010	1.047	1.038	1.049	1.053	1.013
VG–8	1.010	1.057	1.048	1.033	1.059	1.021
VG–12	1.082	1.048	1.058	1.092	1.099	1.014
VG-13	1.071	1.068	1.080	1.091	1.099	1.022
Tap11	0.978	0.983	0.987	1.01	0.99	0.921
Tap12	0.969	1.023	1.015	1.03	1.03	0.926
Tap15	0.932	1.020	1.020	1.07	0.98	0.922
Tap36	0.968	0.988	1.012	0.99	0.96	0.923
QC10	0.19	0.077	0.077	0.19	0.19	0.094
QC24	0.043	0.119	0.128	0.04	0.04	0.101
PG(MW)	300.9	299.54	299.54	NR*	NR*	297.71
QG(Mvar)	133.9	130.83	130.94	NR*	NR*	131.37
Reduction in PLoss (%)	0	8.4	7.4	6.6	8.3	17.99
Total PLoss (Mw)	17.55	16.07	16.25	16.38	16.09	14.392

power problem. Exploration procedure has been modeled by imitating the hunting actions of timber wolf by using searching, encircling, and attacking the prey. There are three fittest candidate solutions embedded as α, β and γ to lead the population toward capable regions of the exploration space in each iteration of Timber Wolf optimization. Adaptive crossover, mutation operation of genetic algorithm has been utilized to perk up the exploitation capability of the algorithm. Proposed Timber Wolf optimization (TWO) algorithm has been tested in standard IEEE 14, 30 bus test systems and simulation results show the projected algorithm reduced the real power loss effectively.

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