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Power loss reduction by arctic wolf optimization algorithm

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Article Info	ABSTRACT
Article history: Received Jul 19, 2019 Revised Nov 12, 2019 Accepted Nov 27, 2019 *Keywords:* Arctic wolf optimization Optimal reactive power Transmission loss	This paper proposes Arctic Wolf optimization (AWO) algorithm to solve the optimal reactive power problem. Deeds of the Arctic wolf have been imitated to formulate the proposed algorithm. Arctic wolf also identified as the white wolf or polar wolf is a breed of gray wolf inhabitant from Melville Island to Ellesmere Island. It is average size, very smaller when compared to north western wolf, it possess whiter coloration, narrower braincase and big carnassials. Particle swarm optimization, Genetic algorithm has been used to improve the Exploration & Exploitation ability of the algorithm by utilizes flag vector & position, velocity update properties. Proposed Arctic Wolf optimization (AWO) algorithm has been tested in standard IEEE 30 bus test system and simulation results show the projected algorithms reduced the real power loss considerably. *Copyright © 2019 Institute of Advanced Engineering and Science.* *All rights reserved.*

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1. INTRODUCTION

Reactive power problem plays an important role in secure and economic operations of power system. 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 Arctic Wolf optimization (AWO) algorithm to solve the optimal reactive power problem. Arctic wolf also identified as the white wolf or polar wolf is a breed of gray wolf inhabitant from Melville Island to Ellesmere Island. It is average size, very smaller when compared to north western wolf, it possess whiter coloration, narrower braincase and big carnassials. Arctic wolf is fairly unafraid of people, and can be entice to approach people in several areas. Very particularly they do not fear humans & approach cautiously, curiously and closely. During wintertime when there is absolute darkness Arctic wolf will make the movement at temperature was as low as -53 °C (-63 °F) and mainly they prey mainly on the muskoxen. Muskoxen are certainly their most important prey because Arctic wolf presence and reproduction seem to be superior when muskoxen are more available than normal availability. Particle swarm optimization, Genetic algorithm has been used to improve the Exploration & Exploitation ability of the algorithm by utilizes flag vector & position, velocity update properties. Proposed Arctic Wolf optimization (AWO) algorithm has been tested in standard IEEE 57 bus test system and simulation results show the projected algorithm reduced the real power loss considerably.

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:

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

constraint (Equality)

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

constraints (Inequality)

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

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

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

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

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

3. ARCTIC WOLF OPTIMIZATION

Arctic Wolf optimization (AWO) mimics the deeds of Arctic Wolf in nature. The deeds of the arctic wolf have been imitated to formulate the algorithm. During wintertime when there is absolute darkness Arctic wolf will make the movement at temperature was as low as -53 °C (-63 °F) and mainly they prey mainly on the muskoxen. Muskoxen are certainly their most important prey because Arctic wolf presence and reproduction seem to be superior when muskoxen are more available than normal availability. Hunting procedure of the arctic wolf is designed to formulate the algorithm. There are three fittest candidate solutions (Arctic Wolf) embedded as α,β and γ to lead the population toward capable regions of the exploration space in each iteration of Arctic Wolf optimization. φ is named for the rest of Arctic Wolf and it will assist α,β and γ to encircle, hunt, and attack prey; to find improved solutions. In order to technically imitate the encircling deeds of Arctic wolves, the following equations are projected:

$$\vec{H} = |\vec{I}.\vec{J_P}(t) - \vec{J}(t)|, \tag{10}$$

$$\vec{J}(t+1) = \vec{J_P}(t) - \vec{J}.\vec{H} \tag{11}$$

in order to scientifically imitate the hunting deeds of Arctic wolf, the following equations are projected,

$$\begin{aligned}\vec{H_\alpha} &= |\vec{I_1}.\vec{J_\alpha} - \vec{J}| \\ \vec{H_\beta} &= |\vec{I_2}.\vec{J_\beta} - \vec{J}| \\ \vec{H_\gamma} &= |\vec{I_3}.\vec{J_\gamma} - \vec{J}|\end{aligned} \tag{12}$$

$$\begin{aligned}\vec{J_1} &= \vec{J_\alpha} - \vec{G_1}.\vec{H_\alpha} \\ \vec{J_2} &= \vec{J_\beta} - \vec{J_2}.\vec{H_\beta} \\ \vec{J_3} &= \vec{J_\gamma} - \vec{G_3}.\vec{H_\gamma}\end{aligned} \tag{13}$$

$$\vec{J}(t+1) = \frac{\vec{J_1} + \vec{J_2} + \vec{J_3}}{3} \tag{14}$$

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

$$flag_{i,j} = \begin{cases} 1 & J_{i,j} > 0.475 \\ 0 & otherwise \end{cases} \tag{15}$$

where i, indicates the jth position of the ith Arctic wolf, $flag_{i,j}$ is features of the Arctic wolf. The interactions of the Arctic wolf among them is increased by,

$$\omega_i^d = j_i^d + \varphi_{id}(j_\alpha^d - z_i^d) + \varphi_{id}(j_j^d - j_k^d) \tag{16}$$

The confined density of the Arctic wolf is denoted by,

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

Arctic wolf is less than "dc" when the the Arctic wolf's distance from the j_i, the greater than the confined density of the Arctic wolf. d_{ij} symbolize the Euclidean distance between the j_i, j_j of Arctic wolf, φ_{id} is a arbitrary number in [0, 1], φ_{id} is a arbitrary number in [-1,1]

"2 m" Arctic Wolf with the leading confined thickness is chosen & well-organized by density [17] from big to little in set "R". Afterwards, "2 m" Arctic Wolf's, are selected to adjust to the most awful Arctic Wolf's and it has been placed in set "Y" with reference to the fitness values from very small to large. "X" and "Y" intersection of sets is symbolized by "E":

$$E = X \cap Y \tag{18}$$

$$E = \{e; e_i \in S, e_i \in X, i = 1,2,..,i\} \tag{19}$$

Two major abolition methods are implemented. Let "V" be the store to stockpile the abolished individuals,

$$V = \begin{cases} V_1, random > e^{\left(\frac{t}{t_{maximum}}\right)^2} \\ S[1; E], other \end{cases} \tag{20}$$

Arbitrary numbers are engendered by the random function in the interval [0, 1]. The probability of the establishment of $random > e^{\left(\frac{t}{t_{maximum}}\right)^2}$ in the primary stage is big. With the increase in iteration steps, the probability will be reducing to lesser. The algorithm to be inclined to explore globally, and afterwards, the algorithm is apt to explore local mode.

Positions and velocities are modernized to improve the performance of the exploration & exploitation in the projected algorithm.

$$v_{t+1}^i = \omega_t . v_t^i + cg_1. Rm_1 . (m_t^i - y_t^i) + cg_2. Rm_2 . (m_t^g - y_t^i) \tag{21}$$

$$y_{t+1}^i = y_t^i + v_{t+1}^i \tag{22}$$

The present 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:

$$\omega_t = (\omega_{max} - \omega_{min}).\frac{(t_{max} - t)}{t_{max}} + \omega_{min} \tag{23}$$

Maximum and minimum of ω_t is represented by ω_{max} and ω_{min} ; maximum number of iterations is given by t_{max}.

Genetic algorithm (GA) as an adaptive optimization exploration method is based on natural selection and genetics. In GA, a population is composed of a set of candidate solutions called chromosomes and it includes numerous genes with binary values 0 and 1.The major steps are of GA are. (i) Initialization; Chromosomes are arbitrarily generated. (ii) Selection; to choose parent chromosomes a roulette choosing method is used. (iii) Crossover; to generate offspring chromosome a single point crossover method is used. (iv) Mutation; unvarying mutation is implemented (v) Decode; Decode the mutated chromosomes as the preliminary positions of population.

Fitness function will be calculated by,

$$Fitness = \alpha T + \beta \frac{M-G}{M} \tag{24}$$

Where T define the accurateness, G is the length of chosen element division, M is the sum of all features, and α and β are the weight of classification and picking quality, $\alpha \in [0,1]$ and $\beta = 1 - \alpha$

Initialization of the parameters
  i = 1: population size; j = 1: n
  When (i, j) > 0.475; (i) = 1; Else (j) = 0;
  End if
  End for
  Calculation of the fitness functions by; $Fitness = \alpha T + \beta \frac{M-G}{M}$
  Primary, secondary, third maximum fitness of the Arctic wolf is designated as "α", "β", "γ"
  While k < maximum number of iteration
  For i = 1: population size
  Modernize the existing position of Arctic wolf by $\vec{J}(t + 1) = \frac{\vec{J_1} + \vec{J_2} + \vec{J_3}}{3}$
  Existing wolf Arctic location has been revised periodically
  End for
  For i = 1: population size; For i=1:n
  If (i, j) > 0.475; (j) = 1; Else; (j) = 0;
  End if
  End for
  At irregular intervals renew the parameter values
  Fitness function will be calculated by; $Fitness = \alpha T + \beta \frac{M-G}{M}$
  The assessment of Arctic Wolf "α","β" and "γ" has to be revised
  t=t+1;
  End while
  Return the best solution" α "
  End

4. SIMULATION STUDY

Proposed Arctic Wolf optimization (AWO) algorithm has been tested, in IEEE 57 Bus system [18]. 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. Figure 1 gives the Comparison of real power loss and Figure 2 gives the Reduction of real power loss (%) with reference to base case value.

Table 1. Constraints of control variables

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

Table 2. Constrains of reactive power generators

System	Variables	Q Minimum (PU)	Q Maximum (PU)
IEEE 57 Bus	1	-140	200
	2	-17	50
	3	-10	60
	6	-8	25
	8	-140	200
	9	-3	9
	12	-150	155

Table 3. Simulation results of IEEE-57 system

| Control variables	Base case	MPSO [19]	PSO [19]	CGA [19]	AGA [19]	AWO
VG 1	1.040	1.093	1.083	0.968	1.027	1.008
VG 2	1.010	1.086	1.071	1.049	1.011	1.012
VG 3	0.985	1.056	1.055	1.056	1.033	1.004
VG 6	0.980	1.038	1.036	0.987	1.001	1.029
VG 8	1.005	1.066	1.059	1.022	1.051	1.048
VG 9	0.980	1.054	1.048	0.991	1.051	1.039
VG 12	1.015	1.054	1.046	1.004	1.057	1.026
Tap 19	0.970	0.975	0.987	0.920	1.030	0.911
Tap 20	0.978	0.982	0.983	0.920	1.020	0.909
Tap 31	1.043	0.975	0.981	0.970	1.060	0.906
Tap 35	1.000	1.025	1.003	NR*	NR*	1.007
Tap 36	1.000	1.002	0.985	NR*	NR*	1.021
Tap 37	1.043	1.007	1.009	0.900	0.990	1.032
Tap 41	0.967	0.994	1.007	0.910	1.100	0.947
Tap 46	0.975	1.013	1.018	1.100	0.980	1.028
Tap 54	0.955	0.988	0.986	0.940	1.010	0.939
Tap 58	0.955	0.979	0.992	0.950	1.080	0.928
Tap 59	0.900	0.983	0.990	1.030	0.940	0.938
Tap 65	0.930	1.015	0.997	1.090	0.950	1.026
Tap 66	0.895	0.975	0.984	0.900	1.050	0.939
Tap 71	0.958	1.020	0.990	0.900	0.950	1.042
Tap 73	0.958	1.001	0.988	1.000	1.010	1.012
Tap 76	0.980	0.979	0.980	0.960	0.940	0.906
Tap 80	0.940	1.002	1.017	1.000	1.000	1.030
QC 18	0.1	0.179	0.131	0.084	0.016	0.140
QC 25	0.059	0.176	0.144	0.008	0.015	0.131
QC 53	0.063	0.141	0.162	0.053	0.038	0.120
PG (MW)	1278.6	1274.4	1274.8	1276	1275	1272.67
QG (Mvar)	321.08	272.27	276.58	309.1	304.4	272.38
Reduction in PLoss (%)	0	15.4	14.1	9.2	11.6	27.43
Total PLoss (Mw)	27.8	23.51	23.86	25.24	24.56	20.172

NR* - Not reported.
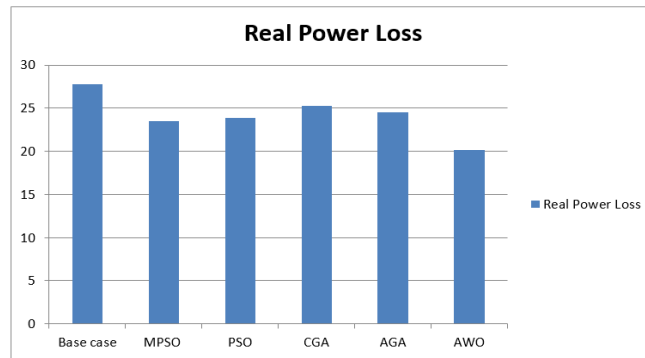
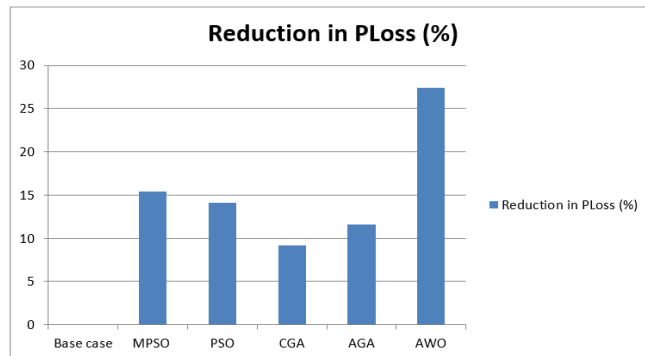Figure 1. Comparison of real power loss

Figure 2. Reduction of real power loss (%) with reference to base case value

5.   CONCLUSION

In this paper Arctic Wolf optimization (AWO) algorithm successfully solved the optimal reactive power problem. (Arctic Wolf) embedded as α,β and γ to lead the population toward capable regions of the exploration space in each iteration of Arctic Wolf optimization. φ is named for the rest of Arctic Wolf and it will assist α,β and γ to encircle, hunt, and attack prey. .Proposed Arctic Wolf optimization (AWO) algorithm has been tested in standard IEEE 57 bus test system and simulation results show the projected algorithms reduced the real power loss efficiently.

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