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IMPROVED GREY WOLF OPTIMIZATION ALGORITHM FOR REDUCTION OF REAL POWER LOSS

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ABSTRACT

This paper projects Improved Grey Wolf Optimization (IGWO) algorithm for solving optimal reactive power problem. Projected IGWO algorithm hybridizes the wolf optimization (WO) algorithm with particle swarm optimization (PSO) algorithm. This algorithm is inspired by the hunting behavior and social leadership of grey wolves in nature. Due to the hybridization of both WO with PSO exploration ability of the proposed Grey wolf optimization algorithm has been enhanced. Efficiency of the projected Improved Grey Wolf Optimization (IGWO) algorithm is tested in practical 191 bus test system. Simulation results indicate the augmented performance of the projected Improved Grey Wolf Optimization (IGWO) algorithm in solving the reactive power problem. Real power losses are reduced and voltage profile index are well within the limits

Keywords: *Optimal Reactive Power, Transmission loss, grey wolf optimization, Particle Swarm Optimization.*

I. INTRODUCTION

Reactive power control is traditionally considered as an important factor in the design and operation of electrical power systems. Since the impedances of power system components are dominantly reactive, active power transmit requires phase angle difference between beginning and end of the line [1-7]. While, to transmit the reactive power, it is necessary that the amplitude of this voltages to be different. Not only most of the system components consume reactive power, but also most of electrical loads are reactive power consumer. Therefore, the consumed reactive power should be supplied from a location. If reactive power is not easily transferable, it must be produced where it is needed. A fundamental and important relationship is between reactive and active power transfer so that active power transfer requires to voltage and phase displacement. However, the amount of voltage to the same extent is important. They not only have a high enough level to be able to support loads but it should be low enough which is not to defeat equipment insulation. Therefore, voltages should be controlled at key points or support or restrictions should be applied upon them. This control can be widely by the generation or consumption of reactive power at key points. Today has at least two very important reasons. The first reason is due to the increasing pressure to operate the maximum possible from transmission systems. Second reason is that, a variety of controllable reactive. Compensators have been developed. In the year so far, in the growth trend of electrical power networks the synchronous condensers are used to support and improve the ability of power transfer. At the same time, in the distribution system, the parallel capacitors are used to improve the voltage profile and line loading reduction and the losses. A part of reactive power is consumed by series elements of network such as reactance of lines and transformer. Hence, one of the direct ways of increasing transmission power in the transmission system and reduction of voltage drop in distribution system, is compensation of a part of series inductive reactance by capacitors. Despite the development of direct current transmission technology in many of these projects, alternating-current transmission is preferred. Stability and control problems of voltage is related to reactive power control problems and many solutions have been proposed that begins from parallel reactors and capacitors and continues until series capacitors, synchronous condensers and new static compensators . Reactive power control is an essential tool in maintaining supply quality. Numerous types of evolutionary algorithms [8–15] are utilized to solve the problem. For last twenty years, various types of programming and probabilistic-based approach [16–20] have been used to solve the problem. This paper proposes Improved Grey wolf optimization (IGWO) algorithm to solve the reactive power problem. Both the Exploration & Exploitation in the search has been improved in order to reach the Global optimal solution. In the 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 improved version called as Improved Grey wolf optimization (IGWO). PSO will aid to form better preliminary population to WO. Efficiency of the proposed Improved Grey wolf optimization (IGWO) algorithm has been appraised in practical 191 bus test system. Projected approach minimizes real power loss considerably when compared with other standard reported algorithms and voltage profiles within the limits.

II. PROBLEM FORMULATION

Minimizing the Real power loss in the transmission network is the main objective of the problem & it described as follows:

The objective of the reactive power dispatch is to minimize the active power loss in the transmission network, which can be described as follows:

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

Where F- objective function, P_L – power loss, g_k-conductance of branch, V_i and V_j are voltages at buses i,j,Nbr- total number of transmission lines in power systems.

Improvement of Voltage profile
The objective function has been written as follows, to minimize the voltage deviation in PQ buses

$$F = PL + \omega_v \times VD \qquad (2)$$

Where ωv: voltage deviation is a weighting factor.

Voltage deviation given by VD is the and mathematically written by:

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \qquad (3)$$

Equality Constraint
The equality constraint is represented by the power balance equation, in which total power generation (P_G) must equal to the total power demand (P_D) and the power losses (P_L):

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

Inequality Constraints
The inequality constraints and the limits are created to ensure system security and written mathematically as follows,

$$P_{gslack}^{min} \le P_{gslack} \le P_{gslack}^{max} \qquad (5)$$

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

Bus voltage magnitudes upper and lower bounds

$$V_i^{min} \le V_i \le V_i^{max}, i \in N \qquad (7)$$

Transformers tap ratios upper and lower bounds

$$T_i^{min} \le T_i \le T_i^{max}, i \in N_T \qquad (8)$$

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Compensators reactive powers upper and lower bounds

$$Q_c^{min} \leq Q_c \leq Q_C^{max}\ , i \in N_C \qquad (9)$$

Where total number of buses indicated by N, the total number of Transformers indicated by NT, total number of shunt reactive compensators indicated by Nc.

III. GREY WOLF OPTIMIZATION

Grey wolf optimization mimics the communal management and hunt deeds of Grey 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 Grey wolf optimization. φ is named for the rest of Grey wolves and it will assist α,β and γ to encircle, hunt, and attack prey, that is, to find Improved solutions. In order to scientifically replicate the encompassing behavior of Grey wolves, the following equations are proposed:

$$\vec{G} = \left|\vec{F}.\overrightarrow{X_P}(t) - \vec{X}(t)\right|,$$
$$\vec{X}(t+1) = \overrightarrow{X_P}(t) - \vec{H}.\vec{G} \qquad (10)$$

Where t indicates the current iteration, $\vec{H} = 2\vec{b}.\vec{r_1} - \vec{b}$, $\vec{F} = 2.\vec{r_2}$, $\widehat{X_P}$ the position vector of the prey, $\vec{X}$ is the position vector of a Grey 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].
In order to mathematically simulate the hunting behavior of Grey wolves, the following equations are proposed,

$$\overrightarrow{G_\alpha} = \left|\overrightarrow{F_1},\overrightarrow{X_\alpha} - \vec{X}\right|$$
$$\overrightarrow{G_\beta} = \left|\overrightarrow{F_2},\overrightarrow{X_\beta} - \vec{X}\right| \qquad (11)$$
$$\overrightarrow{G_\gamma} = \left|\overrightarrow{F_3},\overrightarrow{X_\gamma} - \vec{X}\right|$$
$$\overrightarrow{X_1} = \overrightarrow{X_\alpha} - \overrightarrow{H_1}\ .\overrightarrow{G_\alpha}$$
$$\overrightarrow{X_2} = \overrightarrow{X_\beta} - \overrightarrow{H_2}\ .\overrightarrow{G_\beta} \qquad (12)$$
$$\overrightarrow{X_3} = \overrightarrow{X_\gamma} - \overrightarrow{H_3}\ .\overrightarrow{G_\gamma}$$
$$\vec{X}(t+1) = \frac{\overrightarrow{X_1}+\overrightarrow{X_2}+\overrightarrow{X_3}}{3} \qquad (13)$$

In this work, a new Improved Grey wolf optimization (IGWO) algorithm is proposed for solving reactive power problem & the position of a Grey wolf was updated by equation (13) & the following equation is used to discrete the position.

$$flag_{i,j} = \begin{cases} 1 & X_{i,j} > 0.50 \\ 0 & otherwise \end{cases} \qquad (14)$$

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

IV. PARTICLE SWARM OPTIMIZATION (PSO)

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

$$v_{t+1}^i = \omega_t.v_t^i + cg_1.Rm_1.\left(m_t^i - y_t^i\right) + cg_2.Rm_2.\left(m_t^g - y_t^i\right) \qquad (15)$$
$$y_{t+1}^i = y_t^i + v_{t+1}^i \qquad (16)$$

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

$$\omega_t = (\omega_{max} - \omega_{min}).\frac{(t_{max} - t)}{t_{max}} + \omega_{min} \qquad (17)$$

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.

V. IMPROVED GREY WOLF OPTIMIZATION (IGWO) ALGORITHM FOR SOLVING REACTIVE POWER PROBLEM

In the simulation Grey 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 Grey wolves has been stimulated.
i = 1: population size
j = 1: n
When (i, j) > 0.462
(i) = 1;
 Else
(j) = 0;
End if
End for
Work out the maximum fitness of Grey wolves as follows,
Primary maximum fitness of the Grey wolf is designated as "$\alpha$"
Second maximum fitness of the Grey wolf is designated as "$\beta$"
Third maximum fitness of the Grey wolf is designated as "$\gamma$"
While k < maximum iteration
For i = 1: population size
Exact Location of the existing Grey 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
Sporadically revise the values of b, $\vec{H}$ and $\vec{F}$;
At this stage Fitness of Grey wolves has been calculated
The assessment of Grey wolves "$\alpha$","$\beta$" and " $\gamma$" has to be revised
k=k+1;
End while
Re-examine the value of" $\alpha$ "as the optimal characteristic division;
End
```

VI. SIMULATION RESULTS

Improved Grey wolf optimization (IGWO) algorithm has been tested in practical 191 test system and the following results have been obtained. In Practical 191 test bus system – Total number of Generators = 20, Total number of lines = 200, Total number of buses = 191, Total number of transmission lines = 55. Table 1 shows the optimal control values of practical 191 test system obtained by IGWO method. And table 2 shows the results about the value of the real power loss by obtained by Improved Grey wolf optimization (IGWO) algorithm.

Table 1. Optimal Control values

VG 1	1.100		VG 11	0.900
VG 2	0.740		VG 12	1.010
VG 3	1.010		VG 13	1.000
VG 4	1.010		VG 14	0.900
VG 5	1.100		VG 15	1.010
VG 6	1.100		VG 16	1.000
VG 7	1.100		VG 17	0.900
VG 8	1.010		VG 18	1.010
VG 9	1.100		VG 19	1.100
VG 10	1.010		VG 20	1.100

T1	1.010		T21	0.900		T41	0.900
T2	1.010		T22	0.900		T42	0.900
T3	1.010		T23	0.900		T43	0.900
T4	1.100		T24	0.900		T44	0.900
T5	1.010		T25	0.900		T45	0.910
T6	1.010		T26	1.010		T46	0.900
T7	1.010		T27	0.900		T47	0.910
T8	1.010		T28	0.900		T48	1.010
T9	1.010		T29	1.010		T49	0.900
T10	1.010		T30	0.900		T50	0.900
T11	0.900		T31	0.900		T51	0.900
T12	1.000		T32	0.900		T52	0.900
T13	1.010		T33	1.000		T53	1.010
T14	1.010		T34	0.900		T54	0.900
T15	1.010		T35	0.900		T55	0.900
T19	1.000		T39	0.900			
T20	1.010		T40	0.900			

Table 2. Optimum real power loss values obtained for practical 191 utility (Indian) system by IGWO method.

Real power Loss (MW)	IGWO
Min	149.002
Max	146.018
Average	148.002

VII. CONCLUSION

Optimal Reactive power problem has been successfully solved by Improved Grey wolf optimization (IGWO) algorithm. Both the Exploration & Exploitation in the search has been improved in order to reach the Global optimal solution. And the validity of the proposed IGWO algorithm has been verified by testing it in practical 191 bus test system. Real power loss has been reduced and voltage profile index are within the specified limits.

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