

Hybrid GWO-PSO Algorithm for Solving Convex Economic Load Dispatch Problem

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Abstract-- Particle swarm optimization (PSO) is a swarm intellect based meta-heuristic technique which finds the optimum solution of problem by moving particles in search space. Grey Wolf Optimization (GWO) is a new meta-heuristic inspired by grey wolves. The leadership hierarchy and hunting mechanism of the grey wolves is mimicked in GWO. In this paper GWO has been hybridized with PSO algorithm to improve the performance of GWO. The objective of ELD problem is to minimize the total generation cost while fulfilling the different constraints, when the necessary load demand of a power system is being supplied. The proposed technique is implemented on three different test systems for solving the ELD with various load demands. To show the effectiveness of hybrid GWO-PSO to solve ELD problem results were compared with other existing techniques.

Index Terms- GWO, PSO, Economic Load Dispatch, Transmission Losses.

1. INTRODUCTION

The most important problem in the planning and operation of electric power generation system is the efficient scheduling of all generators in a system to meet up the necessary demand. The Economic Load Dispatch (ELD) problem is the major optimization problem in scheduling the generation of thermal generators in power system. In ELD problem, the final goal is to minimize the operation cost of the power generation system, while supplying the required power demanded. In addition to this, the various operational constraints of the system should also be satisfied. Traditional methods to solve ELD problem include the linear programming method, gradient method, lambda iteration method and Newton's method [1].

Dynamic programming is one of the techniques to solve ELD problem, but it suffers from problem of irritation of dimensionality or confined optimality [2]. Meta-heuristic techniques, such as genetic algorithms [3-5], differential evolution [6], tabu search [7], simulated annealing [8], particle swarm optimization (PSO) [9], biogeography-based optimization [10], intelligent water drop algorithm [11], harmony search [12], gravitational search algorithm [13], firefly algorithm [14], hybrid gravitational search [15], cuckoo search (CS) [16], modified harmony search [17], grey wolf optimization (GWO) [19], ant lion optimization [20] have been successfully applied to ELD problems. In this paper the ELD problem has been solved by using hybrid GWO-PSO algorithm.

2. PROBLEM FORMULATION

The objective function of the ELD problem is to minimize the total generation cost while satisfying the different constraints, when the necessary load demand of a power system is being supplied [19]. The objective function to be minimized is given by the following equation:

$$F(P_g) = \sum_{i=1}^n (a_i P_{gi}^2 + b_i P_{gi} + c_i) \quad \dots$$

(1)

The total fuel cost has to be minimized with the following constraints:

a) Power balance constraint

The total generation by all the generators must be equal to the total power demand and system's real power loss [19].

$$\sum_{i=1}^n P_{gi} - P_d - P_l \quad \dots$$

(2)

b) Generator limit constraint

The real power generation of each generator is to be controlled within its particular lower and upper operating limits [19].

$$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max} \quad i=1,2,\dots,ng$$

.....(3)

Where

a_i, b_i, c_i : fuel cost coefficient of i^{th} generator, Rs/MW² h, Rs/MW h, Rs/h [19]

$F(P_g)$: total fuel cost, Rs/h

n : number of generators

P_{gi}^{min} : Minimum generation limit of i^{th} generator, MW

P_{gi}^{max} : Maximum generation limit of i^{th} generator, MW

P_l : Transmission losses, MW

P_d : Power demand, MW

3. HYBRID GWO-PSO APPROACH

3.1 Particle swarm optimization

Particle swarm optimization, motivated by societal behavior of birds is a swarm-intelligence-based

optimization algorithm which offers a population-based searching method by taking particles and moving them around in the search space for receiving the best solution for the problem. In PSO, particles move in a multi-dimensional search space, each particle regulates its position according to its own experience and the experience of neighboring particles, utilizing best position encountered by itself and its neighbors [9]. PSO is metaheuristic optimization technique and provides a population-based search procedure for global optimization, having principal advantage of easy to perform and few parameters to adjust.

3.2 Grey Wolf Optimization

The GWO is firstly proposed by Mirjalili et al., [18]. The algorithm was inspired by the democratic behavior and the hunting mechanism of grey wolves in the wild. In a pack, the grey wolves follow very firm social leadership hierarchy. The leaders of the pack are a male and female, are called alpha (α). The second level of grey wolves, which are subordinate wolves that help the leaders, are called beta (β). Deltas (δ) are the third level of grey wolves which has to submit to alphas and betas, but dominate the omega. The lowest rank of the grey wolf is omega (ω), which have to surrender to all the other governing wolves. The GWO algorithm is provided in the mathematical models as follows [19]:

3.2.1 Social hierarchy

In the mathematical model of the social hierarchy of the grey wolves, alpha (α) is considered as the fittest solution. Accordingly, the second best solution is named beta (β) and third best solution is named delta (δ) respectively. The candidate solutions which are left over are taken as omega (ω). In the GWO, the optimization (hunting) is guided by alpha, beta, and delta. The omega wolves have to follow these wolves [19].

3.2.2 Encircling prey

The grey wolves encircle prey during the hunt. The encircling behavior can be mathematically modeled as follows [18]:

$$\vec{D} = |\vec{C} \cdot \vec{X}_p(t) - \vec{X}(t)| \quad \dots$$

$$\vec{X}(t+1) = \vec{X}_p(t) - \vec{A} \cdot \vec{D} \quad \dots$$

Where \vec{A} and \vec{C} are coefficient vectors, \vec{X}_p is the prey's position vector, \vec{X} denotes the grey wolf's position vector and 't' is the current iteration.

The calculation of vectors \vec{A} and \vec{C} is done as follows [18]:

$$\vec{A} = 2 \cdot \vec{a} \cdot \vec{r}_1 - \vec{a} \quad \dots$$

$$\vec{C} = 2 \cdot \vec{r}_2 \quad \dots$$

Where values of ' \vec{a} ' are linearly reduced from 2 to 0 during the course of iterations and r_1, r_2 are arbitrary vectors in gap [0, 1].

3.2.3 Hunting

The hunt is usually guided by the alpha, beta and delta, which have better knowledge about the potential location of prey. The other search agents must update their positions according to best search agent's position. The update of their agent position can be formulated as follows [18,19]:

$$\begin{cases} \vec{D}_\alpha = |\vec{C}_1 \cdot \vec{X}_\alpha - \vec{X}| \\ \vec{D}_\beta = |\vec{C}_2 \cdot \vec{X}_\beta - \vec{X}| \\ \vec{D}_\delta = |\vec{C}_3 \cdot \vec{X}_\delta - \vec{X}| \end{cases} \quad \dots$$

$$\begin{cases} \vec{X}_1 = \vec{X}_\alpha - \vec{A}_1 \cdot (\vec{D}_\alpha) \\ \vec{X}_2 = \vec{X}_\beta - \vec{A}_2 \cdot (\vec{D}_\beta) \\ \vec{X}_3 = \vec{X}_\delta - \vec{A}_3 \cdot (\vec{D}_\delta) \end{cases} \quad \dots$$

$$\vec{X}(t+1) = \frac{\vec{X}_1 + \vec{X}_2 + \vec{X}_3}{3} \quad \dots$$

3.2.4 Search for prey and attacking prey

The 'A' is an arbitrary value in the gap [-2a, 2a]. When $|A| < 1$, the wolves are forced to attack the prey. Attacking the prey is the exploitation ability and searching for prey is the exploration ability. The random values of 'A' are utilized to force the search agent to move away from the prey. When $|A| > 1$, the grey wolves are enforced to diverge from the prey [19].

3.3 Basic Steps Of Hybrid GWO-PSO Algorithm

- 1) Initialize the population and form the solution space.
- 2) Run GWO
- 3) Generate minimum values for all individuals
- 4) Pass these individuals to the PSO as starting points
- 5) Give the updated positions back to GWO.
- 6) Run till stopping criteria is met

The flowchart of proposed hybrid algorithm has been shown in Fig.1.

4. RESULTS & DISCUSSIONS

Hybrid GWO-PSO has been used to solve the ELD problems in different test cases for exploring its optimization potential, where the objective function was limited within power ranges of the generating units and transmission losses were also taken into account. The iterations performed for each test case are 500 and number of search agents (population) taken in both test cases is 30.

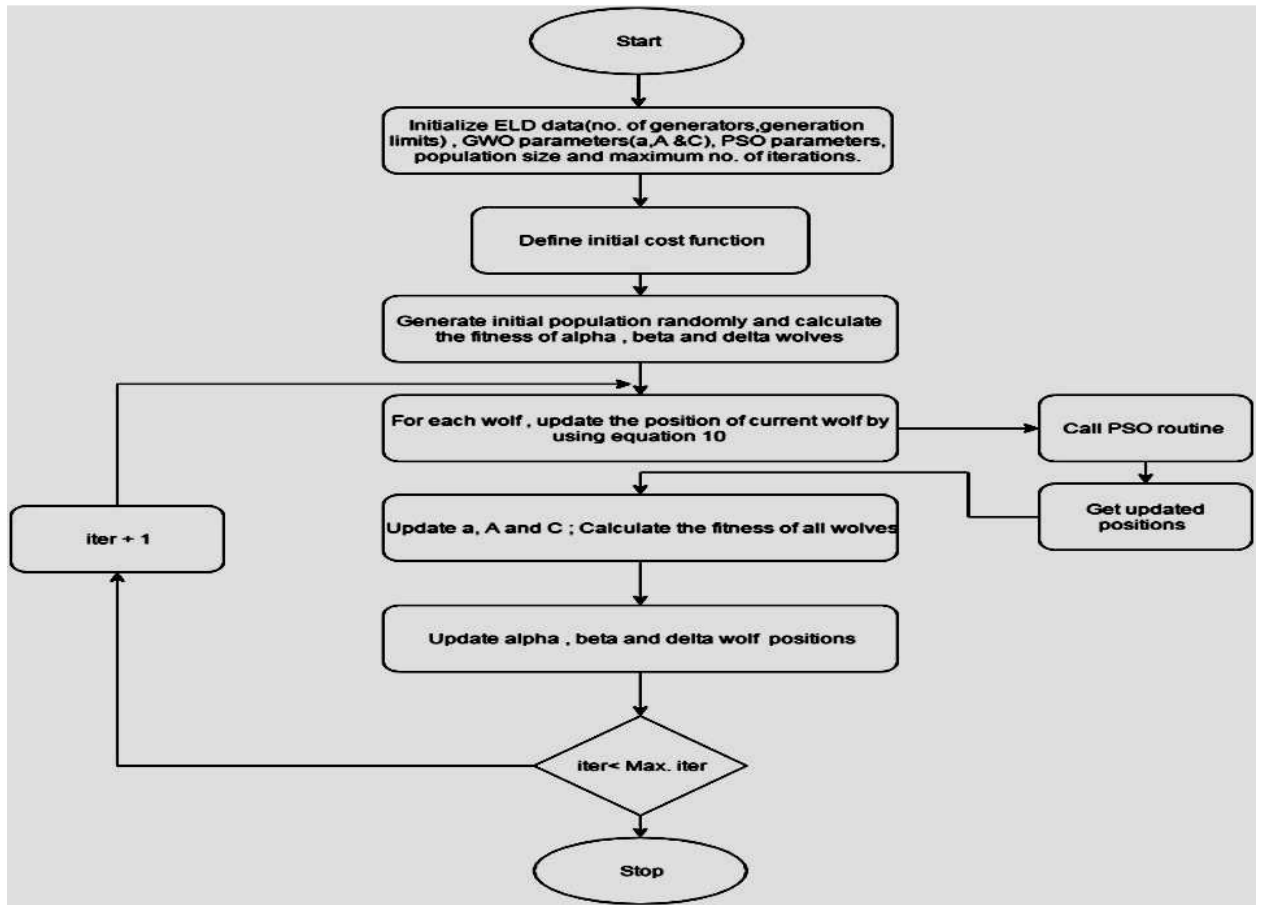


Fig.1. Flowchart for hybrid GWO-PSO algorithm

4.1 Test system I: Three generating units

The input data for three generators and loss coefficient matrix B_{mn} is derived from reference [16]. The economic

load dispatch for 3 generators is solved with GWO-PSO and results are compared with other techniques.

Table 1: GWO-PSO results for 3-unit system

Sr.no.	Power demand (MW)	P1(MW)	P2(MW)	P3(MW)	PLoss (MW)	Fuel Cost (Rs/hr)
1	350	70.301	156.267	129.208	5.776	18564.483
2	450	93.937	193.813	171.861	9.612	23112.3634
3	500	105.879	212.727	193.306	11.914	25465.46914

Table 2: Comparison results of GWO-PSO for 3-Unit system

Power demand (MW)	Fuel Cost (Rs/hr)			
	Lambda Iteration Method [16]	Cuckoo Search Algorithm [16]	GWO	GWO-PSO
500	25495.2	25465.5	25465.473	25465.469

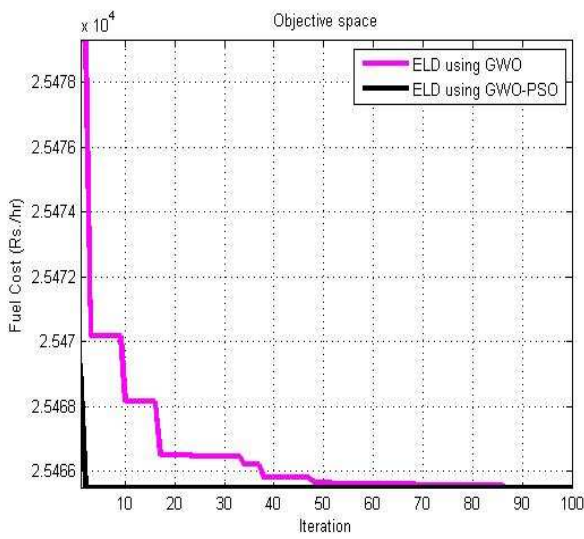


Fig 2: Convergence characteristics of test system I with 500MW demand

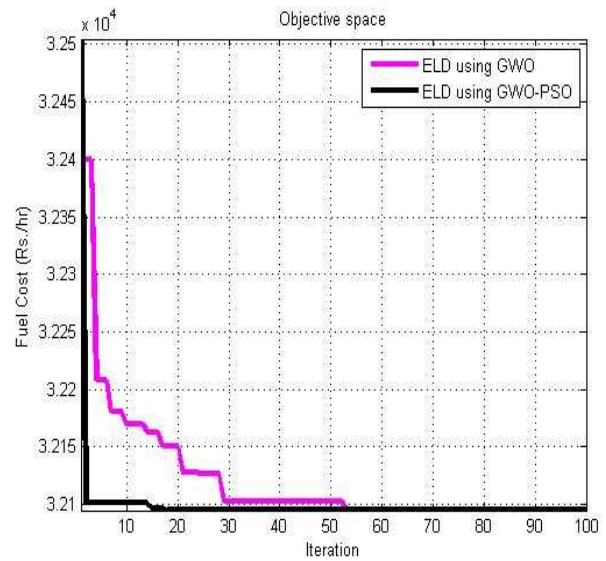


Fig 3: Convergence characteristics of test system II with 600 MW demand

5.2 Test system II: Six generating units

The input data for six generators and loss coefficient matrix B_{mn} is derived from reference [16]. The economic load dispatch for 6 generators is solved with GWO-PSO

and results are compared with conventional quadratic programming, lambda iteration, particle swarm optimization, cuckoo search and GWO.

Table 3: GWO-PSO results for 6-unit system

Sr.no.	Power demand (MW)	P1 (MW)	P2 (MW)	P3 (MW)	P4 (MW)	P5 (MW)	P6 (MW)	P Loss (MW)	Fuel Cost (Rs/hr)
1	600	23.921	10.00	95.582	100.751	202.647	181.352	14.2164	32094.58
2	700	28.269	10.00	119.386	119.025	230.783	212.950	19.4150	36912.16
3	800	32.599	14.483	141.544	136.041	257.658	242.003	25.3306	41896.62

Table 4: Comparison results of GWO-PSO for 6-Unit system

Power demand (MW)	Fuel Cost (Rs/hr)					
	Lambda Iteration Method[16]	QP[9]	PSO[9]	CS[16]	GWO	GWO-PSO
700	36946.4	36914.01	36912.16	36912.2	36912.472	36912.167

6 CONCLUSION

In this paper economic load dispatch problem has been solved by using hybrid GWO-PSO algorithm. The results of hybrid GWO are compared for three and six generating unit systems with other techniques. The algorithm is programmed in MATLAB (R2009b) software package. The results show effectiveness of hybrid GWO algorithm for solving the economic load dispatch problem. The advantage of hybrid GWO-PSO algorithm is its simplicity and faster convergence for finding solutions to global optimization problems.

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