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Application of Oppositional Krill Herd Algorithm for Solving the Economic Load dispatch Problem

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Abstract-— **The focal center of this paper is to resolve the problem of cost optimization in electricity market with application of oppositional based learning (OBL) method with computational method called Krill Herd Algorithm (KHA). The combination of both techniques leads to development of new algorithm called Oppositional Krill Herd Algorithm (OKHA) that enhances the characteristics of existing algorithm. The new algorithm is based on searching behavior of krill herd for food with oppositional based learning characteristics which helps to solve the economic load dispatch (ELD) problem with fast and accurate computations. In this paper, proposed technique is being applied on 10-unit system and outputs obtained by OKHA method are being compared with KHA. By evaluation of results, the proposed algorithm is competent to reach the optimal cost value of power system along with generation of improved convergence cost curves.**

Keywords - Economic Load Dispatch, Cost function, Oppositional Based learning, krill herd Optimization.

1. INTRODUCTION

The provision of generating units in electrical system of a region should be made in such a manner that it should satisfy the economical as well as physical factors. The main purpose of solving ELD (economic load dispatch) problem is to find the preeminent price for generating unit along with utmost utilization limit of natural resources with minimum losses. The solution of ELD problem involves the enhancements as well as complications which inspire for the development of new computational algorithms for hybrid structures [1]. These new techniques are inspired from the natural activities of plants, insects and animal's, etc. The main consideration in economic operation of power system is optimization of fuel cost factor along with balancing of load. Basically, there are many new developed algorithms that are used in optimization process such as Bat algorithm (BA), Ant Colony Optimization (ACO), Genetic algorithm (GA) but not many of them are being integrated with opposition-based learning technique [2-3].

The new proposed hybrid algorithm called oppositional krill herd algorithm (OKHA) deals in updating the position of local as well as global parameters that lead to determination of optimal solution of economic load dispatch in electricity market. There is configuration of oppositional based population matrix which helps in exploration and exploitation of candidates in searching space. Therefore, this meta-heuristic technique has capability to enhance the operational characteristics of the power system. In this paper, main focus is on obtaining the solution of ELD problem having 10 generating units of bus systems by using this OKHA technique which involves the various parameters like fuel cost function, power balance constraints and output cost curves.

2. PROBLEM FORMULATION

2.1 Objective Function

The main reflection in solving the ELD problem is to reduce the generating fuel cost of power system along with fair distribution of the load [4]. The objective equation for the economic load dispatch (ELD) problem can be given as

$$\text{MIN COST } F_T = \sum_{i}^{N_G} F_i(P_i) \tag{1}$$

Where $F_i(P_i)$ is the fuel cost of generating function and it is formulated as

$$F_i(P_i) = \sum_{i=1}^{N_G} \left\{ a_i P_i^2 + b_i P_i + c_i + \left| d_i \times \sin(e_i \times (P_i^{min} - P_i)) \right| \right\}$$
(2)

Where N_G is the number of power generating units, P_i is output power of generating unit, P_i^{min} is the minimum output power of generating unit and a_i, b_i , c. d_i and e_i are fuel cost coefficients

2.2 Constraint equations

i) Power unit constraints for upper and lower limits are given by equation as

$$P_i^{min} \leq P_i \leq P_i^{min} \quad (3)$$

Where P_i^{min} and P_i^{max} are lower and upper generation limit of unit i

ii) Power balancing equation

$$\sum_{i=1}^{N_G} P_i = P_L + P_D \quad (4)$$

Where P_L is transmission loss and P_D is power demand. The P_L can be calculated by using Kron's formula method and is given by

$$P_L = P^T B P + P^T B_0 + B \quad (5)$$

iii) Ramp rate limit constraints

$$P_{it} - P_{it-1} \leq UR_i \quad (6)$$

$$P_{it-1} - P_{it} \leq DR_i \quad (7)$$

Where, D_{ri} = Damp Power Function, U_{ri} = Ramp Power Function

3. OPPOSITIONAL BASED KRILL HERD ALGORITHM (OKHA)

3.1 KRILL HERD ALGORITHM (KHA)

The krill herd is a biological algorithm which was introduced by Gandomi and Alavi in 2012 has principle of swarm intelligence and herding behavior of krill species found in Antarctica. The new model of algorithm is based on the finding of food by krill with covering the smallest distance. This biological phenomenon helps to design the model of multi-objective problem along with finding of solution by artificial algorithm in power system. It basically involves the two steps of evolution. First one is to increase the density of the krill and second is the reaching of target called food. The position of every individual krill is dependent on time factor and governed by three main factors and they are (i) induction of movement by other krill individuals, (ii) diffusion of random variable and (iii) foraging activity. There are many advantages of using Krill Herd algorithm like: Elevated degree of convergence, taking less time of iteration cycles, best efficiency in time of CPU. In the diagram, there are numbers of krill's present inside as well outside of circle but the main lie inside the cycle that give the sensing advantage [5-6].

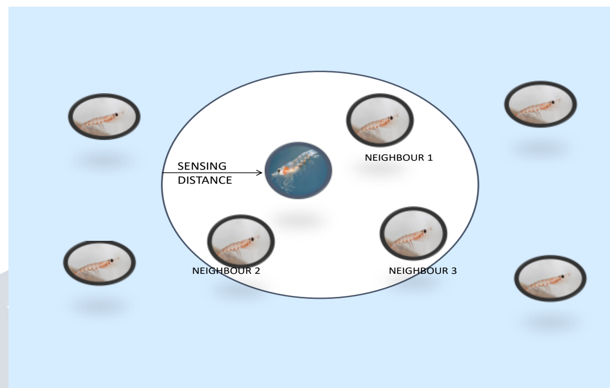

Fig.1 Basic Process of Krill Herd Optimization (KHO)

The krill herd process undergoes through various stages and includes process which is mentioned below as:

a) Movement influence by other krill individuals: In this step, movement of krill is being affected by other individual's krill. The movement of target swarm density is being adjusted according to conditions of local as well as repulsive swarm density [7]. Mathematically, the velocity of i^{th} krill is defined by

$$v_i^k = \alpha_i v_i^{max} + \omega_n v_i^{k-1}$$

$$\alpha_i = \alpha_i^{new} + \alpha_i^{target}$$

where

(8)

Where v_i^{max} is maximum induced speed, v_i^k, v_i^{k-1} are induced motion of i^{th} krill at k=h and (k-1) movement, ω_n is the inertia weight of motion in range (0, 1), α_i^{new} , α_i^{target} are local and target effect.

b) Foraging action:The foraging velocity of krill herd is based on two main factors. The first factor is its own Food location and second one is previous location of the food [8]. Mathematically, it is given by

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$$v_{fi}^{k} = 0.02\partial_i + \omega_x v_{fi}^{k-1}$$

$$\partial_i = 2\left(1 - \frac{i}{i_{\max}}\right) f_i \frac{\sum_{j=1}^{s} \frac{z_i}{f_i}}{\sum_{j=1}^{N_s} \frac{1}{f_i}} + f_i^{best} x_i^{best} \tag{9}$$

Where ∂_i is the sensing distance, ω_x is the inertia weight of foraging motion, v_{fi}^{k}, v_{fi}^{k-1} is the foraging motion of i^{th} krill at $(k-1)^{th}$ movement.

c) Random diffusion:This process is random based diffusion process in which speed of the krill and directional factor [9] is given by

$$v_{d_i}^{k} = \lambda v_d^{\max} \tag{10}$$

Where $v_d^{\max}$ is maximum diffusion motion, λ is directional vector uniformly distributed between (-1, 1).

d) Position Update: In this step, the position of krill individual in range of time interval t to Δt is given by

$$z_i(t+\Delta t) = z_i(t) + \Delta t\left(v_i^k + v_{f_i}^k + v_{d_i}^k\right)$$

$$\Delta t = c_t \sum_{i=1}^{N} U_i - L_i \tag{11}$$

Where z_i is the updated position, N is the total number of controlling variables, U_i is upper limit of i^{th} control variable, L_i is the lower limit of control variable and c_t is position constant factor.

3.2 OPPOSTION BASED LEARNING

Opposition based learning (OBL) technique was developed by Tizhoosh which is used to increase the speed of convergence characteristics of different optimizations. It evaluates both parameters of current and reverse population. Opposition parameter helps to get better the solution rather than random generation [10]. The flow chart in Figure 2 shows the whole process of application of opposition krill herd algorithm to ELD problems. The two important considerations of OBL technique are

i) Opposite number :It opposes the solution by generating the mirror image in searching space and given by

$$x^o = a + b - x \tag{12}$$

Where x^o is opposite based number, x is real number lie in the range of [a, b]

ii) Opposite point:The opposite point in sample search space'd' is given by

$$P_i^o = a_i + b_i - P_i;\ P_i \in [a,b]$$

(13)

Where P_i^o is opposite point and range of opposite point is i =1, 2…….….d

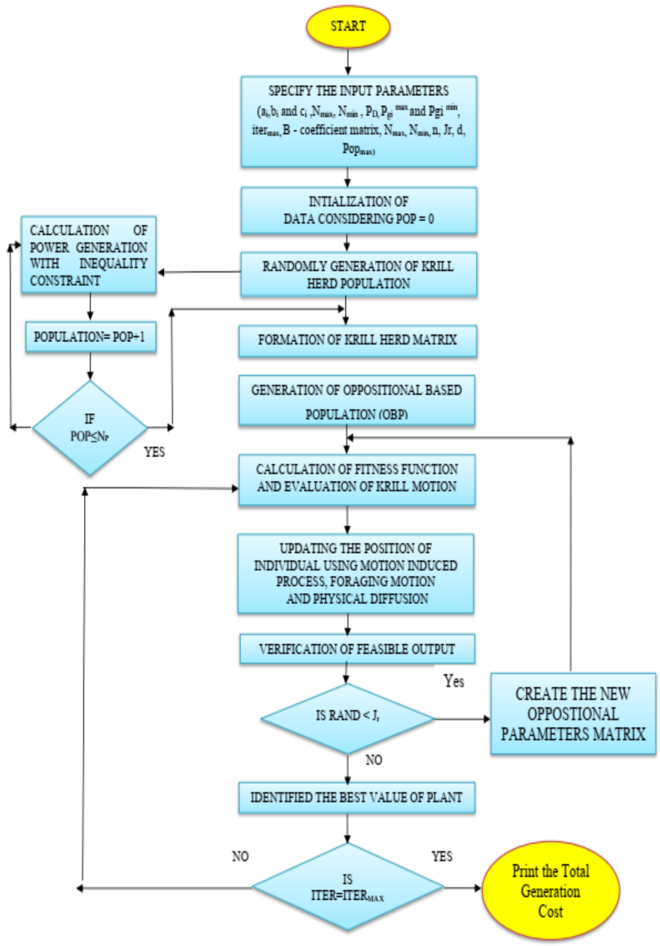

Figure 2: Flowchart of Oppositional Krill Herd Algorithm (OKHA)

4. SIMULATION RESULTS

In order to validate the competence of Oppositional Krill Herd Algorithm (OKHA) technique, 10 generator test system for power demand of 2520 MW is being considered for computational simulation. The generating parameters of the designed algorithm are run in MATLAB software. The standard result of fuel cost function of both comparative models known as Krill Herd Algorithm (KHA) and Oppositional Krill Herd Algorithm (OKHA) is given in the Table1. From the table, it has been observed that Oppositional Krill Herd Algorithm (OKHA) has better convergence rate and finest value for generating functions as compared to conventional Krill Herd Algorithm (KHA) technique. Figure 3 displays the curve between the total generation cost and number of iterations for both KHA and OKHA techniques.

Table 1: Comparison of 10 generator system using OKHA and KHA

Unit Number	OKHA	KHA
1	203.67	205.65
2	196.36	197.32
3	321.25	319.23
4	212.45	214.76
5	248.54	247.67
6	212.96	211.67
7	265.23	263.56
8	217.32	218.35
9	402.35	401.54
10	239.87	241.45
Total cost ($/hr.)	595.65	596.43

Figure 3: Total Generation Cost vs. Number of Iterations for 10 generator system

5. CONCULSION

In this paper, Oppositional Krill Herd Algorithm (OKHA) has been successfully implemented to 10 generator system having power demand of 2520 MW for solving the problem of economic load dispatch (ELD) in power market. The simulation result of OKHA technique is being compared with basic KHA technique and it has been observed that oppositional krill herd algorithm delivers superior results along with enhanced convergence rate cost curves. Therefore, it may be concluded that proposed algorithm (OKHA) is a powerful tool for solving of economic optimization problems in power systems.

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