Economic Load Dispatch Problem Using Butterfly Optimization Algorithm

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Abstract—The objective of the economic load dispatch (ELD) problem is to fulfill the requirement of the load by minimum cost using efficient algorithm. Optimization design strategy is better way to solve the problem with more efficiency. In this paper Butterfly optimization technique has been introduce to find efficient solution That emulates nourishment hunt and mating conduct of butteries. Butterflies uses their sense of smell to locate honeydew target or mating partner. The propose solution is contrasted with PSO and genetic algorithm to analyze performance.

Index Terms—Economic Load Dispatch, Butterfly optimization, Genetic algorithm, PSO

1. INTRODUCTION

The economic load dispatch problem concern to minimize the cost of the fuel and power loss for set of generators and also reduce the pollutant emission. The operational imperatives of the accessible resources and comparing transmission abilities different strategies introduced. The problem is divided into two parts Unit Commitment and load dispatch to proper generator. The commitment to satisfy the requirement of load varying with time per hour with minimum cost per unit. Also, ELD makes efficient combination among parallel processing generators to supply power as per the requirement.

Solving the real world problems is very complex task with the consideration of set of corresponding constrains and the multidimensionality of the problem. Bio inspired optimization algorithms provides better and efficient performance than traditional approaches. The butterfly optimization technique is used in this paper to solve the problem. The algorithm based on the search strategy used by the butterflies to locate food with their sense of smell.

The paper is consist of introduction to ELD problem followed by problem statement. Then Butterfly optimization algorithm is introduced and the solution to the ELD problem is described by BOA. The results of BOA is calculated basis on data in [1]. The performance of BOA is contrasted with PSO and genetic algorithm performance.

2. PROBLEM STATEMENT

Economic load dispatch Problem [2] focuses on minimization of fuel cost of a thermal plant satisfying the load demand

under given equality and inequality constraints. The cost function can be expressed as

$$A = \sum_{n}^{k=1} a_k + b_k P_k + c_k P_k^2 \qquad\qquad (1)$$

where n is the total number of the generators

P_k is the amount of the power generated by the kth generator A_k,B_k,C_k are the cost coefficient of the kth generator Equality and inequality constraint. The total power generated should be equal to the sum of the power loss and the power demand.

$$P_d + P_l = \sum_{k=1}^{n} P_g \tag{2}$$

Here, P_d is the power demand at the present moment, P_l is the power loss in transmission and P_g is the power by the generator. Every generator has minimum and maximum limit so the generated power should be in between the minimum and maximum power.

$$P_{min} < P < P_{max} \tag{3}$$

where, P_{min} is the minimum value of the real power, P_{max} is the maximum value of the real power and P indicates the generated real output power.

3. PSO ALGORITHM

The Particle Swarm Optimization algorithm(PSO) is discuss briefly in [3]. This algorithm optimizes the solution in an iterative manner based on the population of candidates. Solutions in the algorithm are consider as particles which searches the optimum particles within the problem space.

The local optimum solution (particle) is determined by the movement of the particles within the considerable population (swarm).The algorithm for ELD problem with genetic algorithm is given in [4] which summarized as:

Unit Commitment problem: This paper [4] solved the Unit Commitment problem with help of genetic algorithm. Here, the population is randomly generated with the consideration of bound of each unit requirement with dimension, velocities and searching points. Initialize Genetic Algorithm parameters such as population size, selection type, crossover rate, mutation rate and total number of generations. Each chromosome is validated over unit requirement and load constraints. The individuals which are dominated by minimum total generation cost individuals are eliminated. The eliminating individuals are considered as best and passed to the next generation. In each generation, genetic operation is executed on the chromosomes population. The solution is obtained in the last generation after repeating such process till maximum number of generation reached.

Low cost calculation: The PSO parameters such as Population size, Maximum inertia weight, Minimum inertia weight, Initial velocity, Initial position, Cognitive factor (c1), Social factor (c2), error gradient and maximum number of iterations are initialized. For each generator the fitness cost is calculated as per the equation in [4]. In each individuals calculation, the best local solution is considered as best which is then compared with the global optimum solution (which was before previous iteration) and updated if best is better than best. This process run until the maximum number of generation is achieved. After the halt of algorithm the individual which produces the best most recently is the solution of generating unit.

The PSO has variants such as classical PSO,PSO with chaotic inertia weight (PSO-CIW), PSO with chaotic acceleration coefficients (PSO-CIW) and Time varying PSO (PSO- TVAC) which are compared with traditional solver [5]. PSO shows better performance over other methods [6],[7].

4. GENETIC ALGORITHM

Genetic Algorithm involves global optimization using the evolutionary techniques,such as inheritance, mutation,selection,and crossover. Genetic algorithm uses Darwin's theory where the fittest will survive , and the next generation will inherit the features of the fittest of the previous generation. The selection of the fittest is determined by the fitness function, Population is randomly generated for a generation and fitness is calculated. Generation of the population is stopped when the maximum population count is reached or satisfactory fitness is achieved. Each individual represent characteristics corresponds to chromosomes in genes. Production of new generation is carried for some fixed number of steps. Individuals in the final generation often have different character and features from their ancestors and have the best solution to the problems[3].

5. BUTTERFLY OPTIMIZATION

Butterflies are insect with coloured wings which uses their sense to perform life activities and for survival. Butteries utilize their feeling of smell, locate, taste, contact and hearing and nourishment and mating accomplice. Butterflies can use these senses to additionally supportive in relocating starting with one place then onto the next. These senses are helpful to keep themselves safe from predator and to lay eggs at safe place [8]. under research study it is found that butterflies possess very exact tendency to locate fragrance source. The butterfly optimization search is correlated from the strategy used by butterflies to communicate with other butterflies. They generate fragrance with different intensities. The other butterflies smells the fragrance to reach at the source generator which is correlated to global search. The proper variation in the intensities results in fitness function. The optimum search is finalized with the fitness function [9].

a. Calculation of fragrance

The basic concept depends on the parameters or methodology conducted by butterflies. Methodology generalize to smell, temperature, sound, light etc. In BOA technique fragrance is the main parameter. The fragrance calculation given below is same as given in [9]. The fragrance can be given as physical intensity function of stimulus as:

$$f = cl^a \tag{4}$$

Where f is the intensity of fragrance in the region, c is the differential factor between smell parameters and other factor, I is the intensity of emitting the fragrance by the butterfly and a is the parameter for regular expression, linear compression and linear expansion.

b. Forging of butterflies

All the butterflies undergoes some mechanism which helps them in searching. Searching can be for food, safe place or to find other butterfly for communication. These mechanisms are followed by common characteristics. They generate some fragrance to notify others about their presence in nearby places. All butterflies used to catch up with the intensities of fragrance. They undergo random search or search according to the fragrance emitted by others. These characteristic helps butterflies to attract each other.

The BOA process in following steps:

Step1: Initialization

In this step, all the parameters that will proceed in BOA are assigned with the respective values. The calculation continues to make an underlying populace of butteries for streamlining. The butterflies with respect to fragrance parameters and fitness values assigned with the arbitrary places. This results into a solution space.

Step2: Searching

The algorithm with the iteration varies current position of the butterflies mentioned in the solution space to new position and evaluate their fitness values. All the butterflies evaluated on all combinations of the positions within solution space which generates fragrance at different position with the help of Equation (4).Then the algorithm undergoes through global search phase and local search phase. The Eq. (5) determines the calculations regarding to the solution space considering each position change in vector by each butterfly. The Eq. (5) is for global search phase per butterfly.

$$x_i^{t+1} = x_i^t + (r^2 \times g - x_i^t) \times f_i \tag{4}$$

where x_i^t is the solution vector in the tth iteration for the ith butterfly. Here, r is arbitrary generated value form range [0,1]. The local optimal solution within the same iteration is given by g^*. If the butterflies sense the fragrance, then they will follow the global search. Parameter f_i is fragrance value for i^{th} butterfly. The Eq. (6) is for local random search by each butterfly in corresponding iteration.

$$x_i^{t+1} = x_i^t + (r^2 \times x_j^t - x_k^t) \times f_i \tag{5}$$

where x_j^t and x_k^t are j^{th} and k^{th} butteries from the solution space. Above equation is formulated when x_j^t and x_k^t present in the same swarm. Here, r is an arbitrary value in [0,1]. If the butterflies failed to sense the fragrance, they will follow local random search.

Here, the physical parameters like rain, heavy wind, light distraction etc. can interrupt search strategies. Sudden switch from global to local search can be occur. In algorithm, p is considered as switching probability between two searches. The stopping criteria for the algorithm is limited to maximum CPU running time, maximum iteration number, the maximum number of iterations with no improvement etc. The algorithm results optimum solution values as algorithm terminates with best fitness.

c. The pseudo code

The pseudo code for the butterfly optimization algorithm is given below. This algorithm is symmetric to [9]. The given strategy can be utilized upon to solve the ELD problem.

Algorithm 1 Butterfly optimization algorithm

 Input: $X_i \dots X_n$
 Output: Minimum Cost function
 Stimulus Intensity I_i at X_i is determined by $f(x_i)$
  c: sensor modality
  a: power exponent
  p: switch probability
1   while condition satisfy do
2   for each butterfly *bf* in population do
3   Calculate fragrance for bf using Eq. (1)
4   ends for
5   Find the best *bf*
6   for each butterfly *bf* in population do
7   Generate a random number *r* from [0, 1]
8   if $r < p$ then
9   Move towards best butterfly/solution using Eq. (2)
10   else
11   Move randomly using Eq. (3)
12   end if
13   end for
14   Update the value of a
15   end while
16   Display the optimum result.

6. RESULTS

BOA is used to solve ELD problem for optimizing the cost, here Range of the power of the generators , Transmission loss are taken into consideration. Here BOA uses 500 iterations and 30 search agents. The test case is for six generating units. Generating data and B_{mn} are from[3].The results of PSO are from[4][5].

Unit	a_i	b_i	c_i	P_{min}	P_{max}
1	0.007	7	240	100	500
2	0.0095	10	200	50	200
3	0.009	8.5	220	80	300

4	0.009	11	200	50	150
5	0.008	10.5	220	50	200
6	0.0075	12	120	50	120

TABLE 1.GENERATING UNIT DATA 1

$$B_{mn} = \begin{bmatrix} 0.000014 & 0.000015 & 0.000015 & 0.000019 & 0.000026 & 0.000022 \\ 0.000017 & 0.000013 & 0.000013 & 0.000016 & 0.000015 & 0.000020 \\ 0.000015 & 0.000065 & 0.000065 & 0.000017 & 0.000024 & 0.000019 \\ 0.000019 & 0.000017 & 0.000017 & 0.000072 & 0.000030 & 0.000025 \\ 0.000026 & 0.000024 & 0.000024 & 0.000030 & 0.000069 & 0.000032 \\ 0.000022 & 0.000019 & 0.000019 & 0.000025 & 0.000032 & 0.000085 \end{bmatrix}$$

POWER DEMAND (MW)	TECHNIQUE	POWER GENERATED BY EACH GENERATORS (MW)					
		G1	G2	G3	G4	G5	G6
500	BOA	225.54	50.00	80.00	50.000	50.000	50.000
	GA	213.62	55.66	80.35	50.232	55.036	50.743
	PSO	221.19	50.00	84.391	50.000	50.000	50.000
600	BOA	283.280	50.617	121.69	50.018	50.987	51.282
	GA	263.40	62.15	106.7	50.475	60.187	65.180
	PSO	280.597	50.00	127.31	50.00	50.00	50.00
700	BOA	321.93	78.186	151.0	53.413	55.983	50.134
	GA	301.07	56.443	159.8	51.996	67.442	74.494
	PSO	323.51	76.823	158.34	50.00	52.045	50.00

TABLE 2. GENERATED RESULTS

| POWER DEMAND (MW)	FUEL COST ($)			POWER LOSS (Mw)			COMPUTATION TIME (SECONDS)		
	BOA	GA	PSO	BOA	GA	PSO	BOA	GA	PSO
500	6132.56	6147.62	6132.26	5.5507	5.6540	5.5844	3.943866	11.681995	97.963707
550	6665.69	6855.03	6656.86	6.5561	7.5395	6.6876	3.810869	3.968480	83.652359
600	7206.93	7250.50	7203.43	7.8839	8.1211	7.9166	3.815957	6.279187	75.638182
650	7771.03	7869.64	7769.64	9.24782	9.9331	9.2546	3.804488	3.759764	53.560856
700	8355.25	8402.35	8352.61	10.7399	11.3487	10.7361	3.803770	8.823746	94.323699
750	8951.61	9088.52	8949.21	12.4345	13.13978	12.47068	4.434083	2.859592	84.331310

TABLE 3. COMPARISON OF BOA
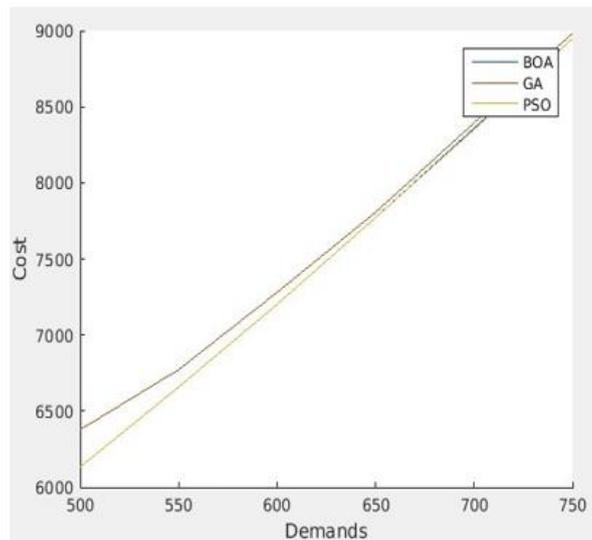
FIG 1. COMPARISON GRAPH

7. CONCLUSION

In this paper problem of economic load dispatch is solved using butterfly optimization algorithm. The algorithm is programmed using MATLAB(r2015a). The results are for 6 six generating units which are compared with other techniques. The BOA approach is efficient over GA in optimizing the fuel cost and in run time over PSO which gives advantage of using BOA in practical application.

8. REFERENCES

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