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ARTIFICIAL BEE COLONY ALGORITHM TO SOLVE ECONOMIC DISPATCH PROBLEM

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Abstract:

This paper the problem of economic dispatch is solved by means of Artificial Bee Colony Algorithm (ABC). ABC is good at exploration the optimization problem involves economically scheduling the generating units with some constraints like meeting total load demand and losses within the power generation limits. The algorithm presented in this paper also considers the effect of Bmn coefficients. The performance of the algorithm is applied and tested on IEEE 6 units systems.

Key Terms: Artificial Bee Colony Algorithm (ABC), Economic Dispatch, Total Load Demand & Generation Limits.

1. Introduction:

Economic dispatch is an important optimizing problem in the electric power system operating. The aim of the problem is to determine the power outputs of all generating units from a system, for a given time interval, in order to have minimum fuel cost, and to meet the required constrains.

The simplest model for the ED problem is one in which the fuel cost of the generating units is defined by a quadratic function, and the constraints are limited to only two: the equality between the powers generated and demanded in the system, respectively the generating units operation between the minimum and maximum limits of power. The mathematical model has been improved by considering the transmission losses.

To solve the ED problem, several methods, classic or based on artificial intelligence, have been used over time. Among the classical methods the following can be mentioned: quadratic programming, non-linear programming. lambda iteration method, gradient method, linear programming, Lagrangian relaxation algorithm, quadratic programming and dynamic programming.

Linear programming methods are fast and reliable; however, they have the disadvantage of being associated with the piecewise linear cost approximation. Non-linear programming methods have the known problems of convergence and algorithmic complexity. Newton-based algorithms have difficulty in handling a large number of inequality constraints.

In order to make the numerical methods more convenient for solving the ED problems, heuristics stochastic search algorithms such as the genetic algorithms (GA). Tabu Search (TS)m, evolutionary programming (EP) , simulated annealing (SA), particle swam optimization (PSO), differential evolution algorithm (DE); harmony search and Bacterial Foraging (BF) have been successfully applied.

The Artificial bee colony (ABC) algorithm introduced in, is one approach that has been used to find an optimal solution in numerical optimization problems. This algorithm is inspired by the behavior of honey bees when seeking a quality food source.

2. Problem Formulation:

The objective of Economic Dispatch problem is to allocate the most optimum real power generation level for all the available generating units in the power station that satisfies the load demand at the same time meeting all the operating constraints. The main objective function of the thermal ED problem is the fuel cost function of the thermal units expressed as:

$$F_i = \sum_{i=1}^{N} a\, i P_{Gi}^2 + b_i P_{Gi} + c_i$$

Where a_i,b_i,c_i are the cost coefficient for i^{th} generator, N is the number of units, P_{Gi} is the real power output of the i^{th} generator.

Inequality Constraint:

If the power output of a generator for optimum scheduling of the system is less than a prespecified value Pmin, the unit is not synchronized with the bus bar because it is not possible to generate that low value of power from that unit. Hence the generator power cannot be outside the range stated by the inequality

$$P_{Gi,min} \leq P_{Gi} \leq P_{Gi,max}$$

Where PGi,min = lower real power generation limit of unit 'i'(MW), PGi,max = upper real power generation limit of unit 'i' (MW).

Generating Constraints:

The sum of all the generating units on line must equal the system load plus the transmission losses. The system power balance constraint is

$$\sum_{i=1}^{N} P_{Gi} - P_L - P_D = 0$$

Where P_{Gi} = the real power output of the i^{th} generator, P_L = total loss in the transmission network in terms of loss coefficients, P_D = load demand.

$$P_L = P^t B P + P^t B_0 + B_{00}$$

Where, Pt = the vector generator loading, B = loss coefficient matrix, B0 = loss coefficient vector, B00 = loss constant.

3. Artificial Bee Colony Algorithm (ABC):

The artificial bee colony (ABC) algorithm, proposed by Karaboga in 2005 for real parameter optimization is an optimized algorithm which simulates the forging behavior of a bee colony. The minimal model of swarm intelligent forage selection in a honey bee colony which the ABC algorithm simulates consists of three kinds of bees: employed bees, onlooker bees and scout bees. Half of the colony consists of employed bees, and the other half includes onlooker bees.

Employed bees are responsible for exploiting the nectar sources explored before and giving information to the waiting bees (onlooker bees) in the hive about the quality of the food sources sites which they are exploiting. Onlooker bees wait in the hive and decide on a food source to exploit based on the information shared by the employed bees. Scout either randomly searches the environment in order to find a new food source depending on an internal motivation or based on possible external clues. This emergent intelligent behavior in foraging bees can be summarized as follows:

1) At the initial phase of the foraging process, the bees start to explore the environment randomly in order to find a food source.

2) After finding a food source, the bee becomes an employed forager and starts to exploit the discovered source. The employed bee returns to the hive with the nectar and unloads the nectar. After unloading the nectar, she can go back to her discovered source site directly or she can share information about her source site by performing a dance on the area. If her source is exhausted, she becomes a scout and starts to randomly search for a new source.

3) Onlooker bees waiting in the hive watch the dances advertising the profitable sources and choose a sources site depending on the frequency of the dance proportional to the quality of the source.

In the ABC algorithm the position of food source represents a possible solution to the optimization problem, and the nectar amount of a food source corresponds to the profitability (fitness) of associated solution.

The number of employed bee is equal to the number of food sources existing around the hive (number of solutions in the population). The employed bee whose food source has been abandoned becomes a scout.

3. A. Parameter Initialization:

The parameters of the basic ABC algorithm are the number of food sources (SN) which is equal to the number of the employed bees or onlooker bees, The colony size is 2*SN = (NP), The number of trials after which a food source is assumed to be abandoned (*limit*), and a termination criterion (MCN). In the basic ABC algorithm, the number of employed bees or the onlookers is set equal to the number of food sources in the population. In other words for every food source, there is only one employed bee.

3. B. Producing Initial Food Sources:

If the search spaces considered being the environment of the hive that contains the food source sites, Initially food source is generated by control variable between their boundaries.

$$X_{ij} = X_j + rand(0,1)(X_j^{max} - X_j^{min})$$

Where i = 1…SN, j=1…D, SN is the number of food sources and D is the number of optimization parameters. In addition, counters which store the number of trials of solutions are reset to zero in this phase.

After initialization, the population of the food sources (solutions) is subjected to repeat cycles of the search process of the employed bees, the onlooker bees and the scout bees.

4. C. Sending Employed Bees to the Food Sources:

As mentioned earlier, each employed bee is associated with only one food source site. Hence the number of food source site is equal to the number of employed bees.

An employed bee produces a modification on the position of the food source (solution) in her memory depending upon local information (visual information) and finds neighboring food source, and then evaluates its quality. In ABC, finding a neighboring food source is defined by equation.

$$V_{ij} = X_{ij} + \varphi_{ij}(X_{ij} - X_{kj})$$

V_i is the neighboring food source for X_i and is determined by changing one parameter of X_i. Where j = random in the range [1,D] and k ϵ{1, 2…SN} is a randomly chosen index that has to be different from i. φ_{ij} is a uniformly distributed real random number in the range [-1, 1].

The difference between the parameters of the X_{ij} and X_{kj} decreases, the perturbation on the position X_{ij} decreases. Thus, as the search approaches to the optimal solution in the search space, the step length is adaptively reduced. If a parameter value produced by this operation exceeds its predetermined boundaries the parameter can be set to an acceptable value. If the value of the parameter exceed its boundary is set to its corresponding boundaries.

If $X_i > X_i^{max}$ then $X_i = X_i^{max}$,if$X_i < X_i^{min}$ then $X_i = X_i^{min}$. After producing the V_i with the boundaries then find the fuel cost function for V_i.

$$fitness(i) = \begin{cases} 1 + abs(f(i)), & x < 0 \\ 1/(1 + f(i)), & x \geq 0 \end{cases}$$

Where f(i) is the cost value of Vi. For maximization problems, the cost function can be directly used as a fitness function. A greedy selection is applied between X_i and V_i, the better one is selected depending on fitness values representing the nectar amount of the food sources at X_i and V_i. If the source at V_i is superior to that of x_i in terms of fitness values, the employed bees memorize the new position and forget the old one. Otherwise the previous position is kept in memory. If X_i cannot be improved its counter holding the number of trials is incremented by one, otherwise the counter is reset to zero.

3. D. Calculating Probability Values Involved in Probabilistic Selection:

After all employed bees complete their searches, they share their information related to the nectar amount and the positions of their sources within the onlooker bees on the dance area. This is the multiple interaction features of the artificial bees of ABC. Onlooker bees evaluate the nectar information taken from all employed bees and choose a food source site with a probability related to its nectar amount. Here in ABC, roulette wheel selection scheme in which each slice proportional to size to the fitness value is employed in Equation.

$$P_i = \frac{fitness(i)}{\sum_{i=1}^{N} fitness(i)}$$

3. E. Food Source Site Selection by Onlookers Based on the Information Provided by Employed Bees:

In the basic ABC algorithm, a random real number within the range [0, 1] is generated for each source. If the probability value (Pi in Equation of finding neighbor solution) associated with that source is greater than this random number then the onlooker bee produces a modification on the position of this food source site by using Equation as in the case of the employed bee. After the source is evaluated, greedy selection is applied and the onlooker bee either memorizes the new position by forgetting the old one or keeps the old one. If solution Xi cannot be improved, its counter holding trial is increased by one; otherwise, the counter is reset to zero. This process is repeated until all onlookers are distributed onto food source sites.

3. F. Abandonment Criteria: Limit and Scout Production:

In a cycle, after all employed bees and onlooker bees complete their searches the algorithm checks to see if there is any exhausted source to be abandoned. In order to decide if a source is to be abandoned, the counters which have been updated during search are used. If the value of the counter is greater than the control parameter of the ABC algorithm, known as the "*limit*", then the source associated with this counter is assumed to be exhausted and is abandoned.

The food source abandoned by its bee is replaced with a new food source is discovered by the scout, which represents the negative feedback mechanism and fluctuation property in the self-organization of ABC. This is simulated by producing a site position randomly and replacing it with the abandoned one. Assume that the abandoned source is Xi, and then the scout randomly discovered a new food source to be replaced with Xi. This operation can be defined as Equation.

In the basic ABC, it is assumed that only one source can be exhausted in each cycle, and only one employed bee can be a scout. If more than one counter exceeds the "*limit*" values, one of the maximum ones might be chosen programmatically.

4. The ABC Algorithm for the ED Problem:

ABC algorithm to find a solution for the ED problem is given below:

Step-1: Initialization of the control parameters. The parameters of the basic ABC algorithm are the colony size (NP), the number of food sources (SN=NP/2), the limit for scout, L = SN*D, D is the dimension of the problem and a Maximum Cycle Number (MCN).

Step-2: Producing initial food source sites. The initialize the power loadings Xi=[P1, P2,...PD]T, i=1,2,....NP such that each element in the vector is determined by $X_{ij} = X_j + rand(0,1)\left(X_j^{max} - X_j^{min}\right)$ where j=1, 2...D with one generator as a dependent generator and evaluate the fitness value using Equation. then select SN the best food source on the basis of highest fitness value as initial food sources and set the cycle=1, the trail number of each solution X_i, *trial*$_i$, is equal to zero.

$$Fitness(F) = \frac{1}{\sum_{i=1}^{NP}(1 + F_{ti}(P_i))}$$

Fti is fuel cost of each food source.

Step-3: Sending employed bees to the food sources [SN] and assigning the nectar amount

In this step each employed bee produces a new solution Vi by using Equation $V_{ij} = X_{ij} + \varphi_{ij}\left(X_{ij} - X_{kj}\right)$ and computes the fitness value of the new solution using Equation

$fitness(i) = \begin{cases} 1 + abs(f(i)), & x < 0 \\ 1/(1 + f(i)), & x \geq 0 \end{cases}$ satisfying with all constraints. If the fitness of the new one is higher than that of the previous one, the employed bee memorizes the new position and forgets the old one; otherwise the employed bee keeps the old solution.

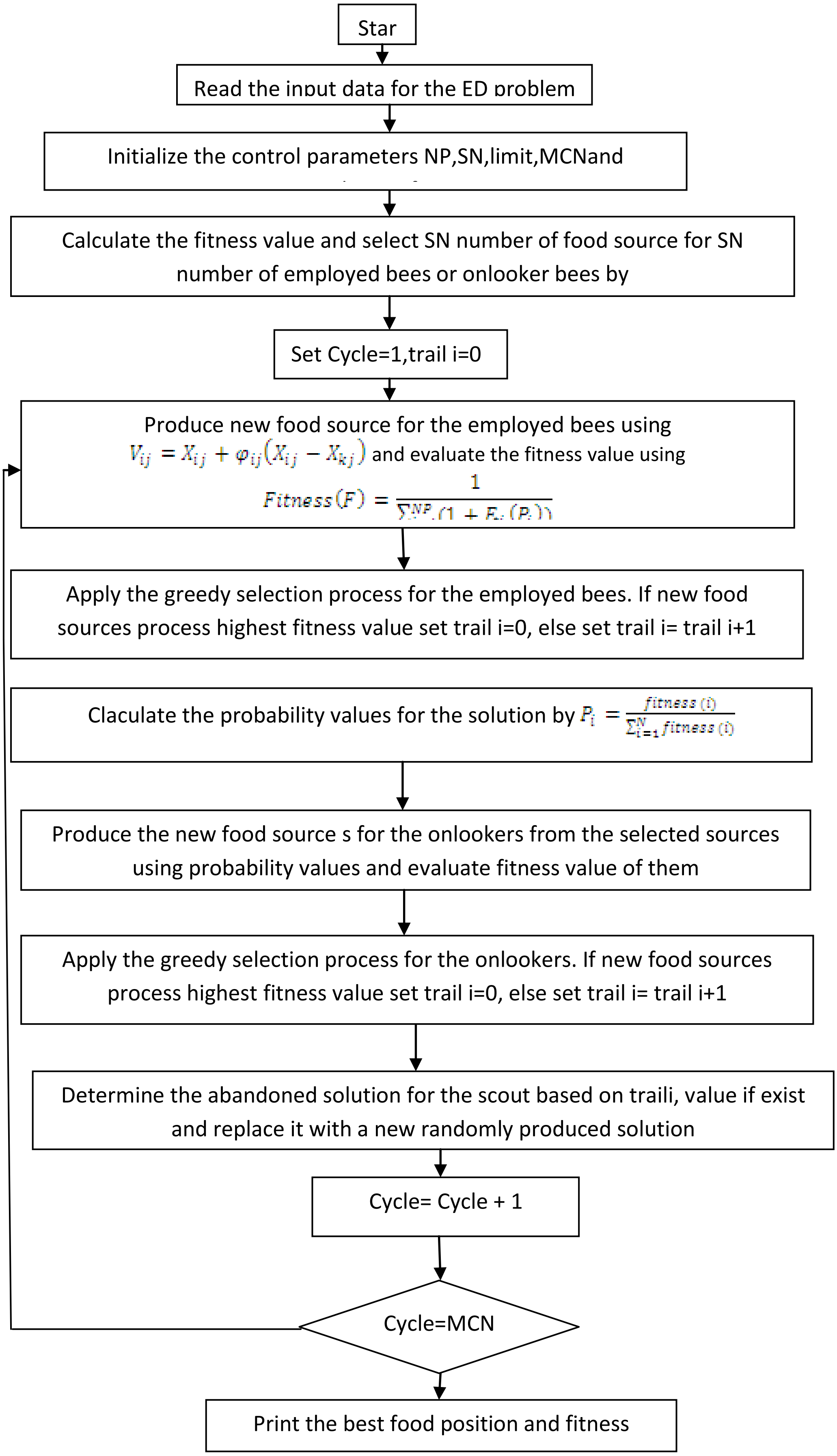
Step-4: Sending the onlooker bees to the food sources depending on their amount of nectar. This step required to calculate the probability value Pi of the solution Xi by means of their fitness value using Eq. $X_{ij} = X_j + rand(0,1)(X_j^{max} - X_j^{min})$ An onlooker bee selects a solution to update its solution depending on the probabilities and determines a neighbour solution around the chosen one. In the selection procedure for the first onlooker, a random number is generated between [0, 1] and if this number is less than P1, the solution is updated using Equation. Otherwise, the random number is compared with P2 and if less than that, the second solution is chosen. Otherwise, third probability of third solution is checked. This process is repeated until all onlookers have been distributed to solutions. The distributed onlooker bee updated its own solution just as the employed bees do.

Step-5: Send the scouts to the search area to discover new food sources. If the solution Xi is not improved through step 3 and 4, the *trail*$_i$ value of solution Xi will be increased by 1. If the *trail*$_i$ of the solution is more than the predetermined *"limit"* the solution Xi is considered to be an abandoned solution, meanwhile the employed bee will be changed into a scout. The scout randomly produces the new solution and then compares the fitness of new solution with that its old one. If the new solution is better than the old solution, it is replaced with the old one and set its own *trail*$_i$ into zero. This scout will be changed into employed bee. Otherwise, the old one is retained in the memory.

Step-6: Record the best solution, In this step, the best solution so far is recorded and increase the cycle by 1.

Step-7: Check the termination criterion, If the cycle is equal to the maximum cycle number (MCN) then the algorithm is finished; otherwise go to step-3.

5. The Complete Flowchart for ABC Algorithm:



unit	Fuel cost coefficient a_i	b_i	c_i	P_{Gmin} (MW)	P_{Gmax} (MW)
G1	0.15247	38.53973	756.79886	10	125
G2	0.10587	46.15916	451.32513	20	150
G3	0.02803	40.39655	1049.99770	35	225
G4	0.03546	38.30552	1243.53110	35	210
G5	0.02111	36.32782	1658.55960	130	325
G6	0.01799	38.27041	1356.65920	125	325

Generator Data IEEE 30 Bus System with 6 Generating units

$$B_{mn} = \begin{matrix} 1.40 & 0.17 & 0.15 & 0.19 & 0.26 & 0.22 \\ 0.17 & 0.60 & 0.13 & 0.16 & 0.15 & 0.20 \\ 0.15 & 0.13 & 0.65 & 0.17 & 0.24 & 0.19 \\ 0.19 & 0.16 & 0.17 & 0.71 & 0.30 & 0.25 \\ 0.26 & 0.15 & 0.24 & 0.30 & 0.69 & 0.32 \\ 0.22 & 0.20 & 0.19 & 0.25 & 0.32 & 0.85 \end{matrix}$$

Bmn coefficient of the system

6. Results:

Simulation parameters

1) Colony size (employed bees + onlooker bees) = 20
2) Foodsources = 10
3) Limit=100
4) Max iterations=200

PD, MW	Performance	Conventional Method [10]	GA[10]	Proposed ABC	Computational time for ABC
500	Fuel cost, Rs/hr	27638.300	27695	**27613**	**4.111050**
	PL, MW	262.454	263.37	**263.012**	
	Total cost, Rs/hr	39159.500	39257.5	**39156.9**	

7. Conclusion:

Economic Load dispatch problem being attempted using ABC algorithm for various generator test system evaluates the per-formance of the proposed approach. Among all Evolutionary Algorithms, ABC is the best method to reach the near Global optimal solution but at the cost of high computational time.. However good choice of the number of iterations, population size, Employed and unemployed bees results in fast computa-tion. ABC can be modified using operators of fast compua-tional alogrithms to get a hybrid fast computational ABC.

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