ANT COLONY OPTIMIZATION: A NEW APPROACH FOR ECONOMIC LOAD DISPATCH

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ABSTRACT

Economic load dispatch is the short-term determination of optimal generation scheduling of available generators in an interconnected power system to meet the system load, at lowest possible cost, while satisfying various equality and inequality constraints. This paper presents an efficient optimization method to solve economic load dispatch problem using Ant colony optimization (ACO), which is a probabilistic technique for solving computational problems. Ant colony optimization technique is inspired from the observation of real ant colonies based on its trail information and foraging behavior. The proposed technique is tested and analyzed on 3 generator unit system and results are compared with Genetic Algorithm (GA). The comparison shows that the proposed technique has merits in obtaining optimal solution.

Key Words: Economic load dispatch, Ant colony optimization, Genetic algorithm.

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1. INTRODUCTION

In present days the main task for the electrical power utility is to ensure that the electrical energy requirement from the customer is served while minimizing the cost of power generation. Hence, for economic operation of the system, the total demand must be optimally shared among all the generating units with an objective to minimize the total generation cost. Economic load dispatch (ELD) is a procedure to schedule the optimal combination of generation of all generating units in power system so that the total generation cost of system is minimized, while satisfying the load demand and system equality and inequality constraints. Economic load dispatch determines the best way to minimize the current generator operating costs. The essential operation constraints are the power balance constraint, i.e the total generated power must be equal to the load demands plus the transmission losses on the electrical network, and the power limit constraints of the generating units. ELD is one of the fundamental optimization problems in power system operation and planning [4]. It is therefore of great importance to solve this problem as quickly and accurately as possible. Conventional techniques such as lambda iteration method, Gradient-based method, linear programming etc. offer good results, but when the search space is nonlinear and has discontinuities, these techniques become difficult to solve with a slow convergence ratio and not always seeking to the global optimal solution because they usually get stuck at local optimum. Recently, modem heuristic optimization techniques have been applied to solve ED problem due to their abilities of finding an almost global optimal solution. Genetic algorithm (GA) is stochastic optimization technique, which is based on the principle of natural selection and genetics.

The search for a global optimum to an optimization problem is conducted by moving from an old population of individuals to a new population using genetics operators. GA searches multiple solutions simultaneously in contrast to conventional optimal algorithms [6]. More recently a new optimization approach known as Ant Colony Optimization (ACO) is used for many optimization applications. The first ACO was introduced by Dorigo [11]. The ACO algorithm is inspired by the behaviors of real ant colonies.

The goal of this paper is to develop the ACO algorithm for solving economic load dispatch problem to minimize the generation cost. The proposed algorithm is applied on 3 and 6 generating unit system to find optimal allocation of generation on each generating unit and results are compared with conventional methods and GA.

2. ELD PROBLEM FORMULATION

The Conventional economic load dispatch (ELD) problem of power generation involves allocation of power generation to different generating units to minimize the operating cost subject to diverse equality and inequality constraints of the power system. The solution of ELD gives optimal generation of generating units that satisfy the system power balance equation and generation limit constraints. The Economic load dispatch problem can be formulated mathematically as follows:

2.1 Objective Function

Minimize f= $\sum^{Ng} F_i(P_i)$ (1)

Where f is summation of cost function of each generator in power system, g is the number of generating units, (Fi Pi) is the cost function and Pi the power output of unit i. Fi(Pi) is the generator cost curves usually modeled with smooth quadratic functions given by:

$Fi(Pi)=aiPi^2 + biPi+ci$ (2)

where ai, bi and ci are the cost coefficients of unit i.

2.2 Constraints Equation

1) Inequality Constraints: These are units operational constraints, each generating unis have lower (Pi min) and upper (Pi max) generation limits, which are directly related to the design of the machine. Theses bounds can be defined as a pair of inequality constraints, as follows:

   $Pimin \leq Pi \leq Pimax$; i= 1,2,3…..Ng (3)

2) Equality Constraints: This is power balance constraint: According to it ,the total power generated must be equal to total demand plus losses in the system.

$\sum_{i}^{Ng} Pi = PL + PD$ (4)

The transmission loss can be calculated by the B coefficient method or power flow analysis.

PL=PTB.P+PTBO+BOO (5)

Where PT is an associated matrix of P, .B is an Ng X Ng coefficient matrix. , Bo is an Ng dimensional column vector. Boo is a coefficient.

2.3 Solution Coding

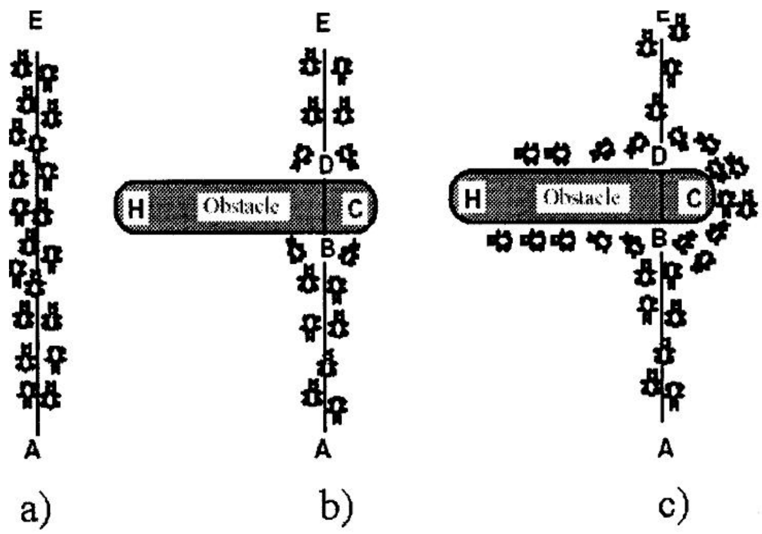
Let Pi = (p1,p2, ...pNg) be a vector denoting the ith individual of ant colony, where Ng is the number of units and Pi is the generated output of unit i. At initialization phrase, Pi is selected randomly from the selected region R.

2.4 Objective Function and Feasible Region

In order to minimize the objective function of ELD the constraints must be obeyed. Penalty function was used to transform those constraints which have difficulties to deal with in the feasible region including power balance, etc. The feasible region R is determined by the unit operation constraints.

3. ANT COLONY OPTIMIZATION (ACO)

The ACO algorithm is inspired by the collective behavior of real ant colonies. The idea is based on the observation of pheromone of ants' colonies to find the shortest path between the nest and the food source. The real ants lay down a chemical substance trail, called pheromone on the ground when they move in their way to food source. The pheromone quantity depends on the length of the path and the quality of the discovered food source [12]. This pheromone can be observed by other ants and they choose the path with the intensity of the pheromone. The pheromone trail evaporates over time if no pheromone is laid down. The pheromone trail on the path having better food source closest to the nest will be more frequented and will therefore grow faster. In this way, the best solution has more intensive pheromone and has higher probability to be chosen. The following example shows finding the new shortest path once the old one is no longer feasible due to the new obstacle. In fig.1a, Ants are moving on a straight line to find food from their nest. In fig. 1b. an obstacle appears and the path was cut off. So, they cannot continue to go. Therefore they have to choose to turn right or left. Half the ants choose to turn right and another half choose to turn left as in Fig. 1 c, Ants choosing the shorter path more rapidly reconstitute the interrupted pheromone trail compared with longer path. Thus, the shorter path will collect larger amount of pheromone per unit time and therefore more number of ants choose the shorter path. The result is that, finally all ants will follow the shortest path as in figure 1.



The algorithm for Economic Dispatch Problems using ACO has been described in the flow chart Fig. 2. The overall steps of ACO involve initialization, state transition rule, local updating rule, fitness evaluation and global updating rule [9]. The following steps below explian the ACO algorithm in details.

Step 1: Initialization

In the initialization process, the following parameters are specified with a limiting range by trail and error in order to obtain better result for the ACO implementation.

n: no. of nodes

m: no. of ants

t max: maximum iteration

dmax: maximum distance for every ants tour

β : parameter, which determines the relative importance of pheromone versus distance (β > 0)

ρ : heuristically defined coefficient (0 < ρ < 1)

α : pheromone decay parameter (0 < α < 1)

q0 : parameter of the algorithm (0 < q0 < 1)

τo : initial pheromone level

dmax can be calculated by using this formula:

$$d_{max} = \left[\sum_{i=1}^{n-1} d_i \right] \quad (6)$$

d= │c- max (u)│

where:

r : current node

u : unvisited node

di : distance between two nodes

Step 2: Generate First Node Randomly

A random number ranging from 1 to n will be generated by selecting the first node based on the uniform distribution ,then ant tour will begin.

Step 3: State Transition Rule

In this state transition rule, the ant k positioned at current node (c) will choose to next node (s) by following rule:

$$I = \begin{cases} \text{argmaxu€l k (c) } \{[t\ (c,u)].\ [n\ (c,u)\beta], \\ \text{If } q \le qo \text{ (exploitation)} \\ (L, \text{otherwise (biased exploration)} \end{cases} \quad (8)$$

Where:

τ: pheromone

Jk(c): set of nodes that remain to be visited by ant k positioned on node (to make the solution feasible).

η: 1/d, is the inverse of the distance d (r,s).

Step 4: Local Pheromone updated rule

While constructing a solution for the problem, the ants visit edges and change their pheromone level by applying the local pheromone updated rule of equation

$$\tau(c,l) \longleftarrow (1 - \rho)\ \tau(c,l) + \rho.\Delta\ \tau(c,l) \quad (9)$$

Where:

ρ heuristically defined coefficient (0< ρ<1)

Δ τ (c,l) = τ o (initial pheromone trail)

Step 5: Fitness Evaluation

Here after calculating objective function by subjecting to constraints, the fitness evaluation is done when all the ants have completed their tours. The control variable (X) in this evaluation is computed using the following equation:

D χ xmax

$X = \overline{\quad d} \max$ (10)

Where:

d: distance for every ants tour

xmax: maximum x

dmax: maximum distance for every ants tour

Step 6: Global pheromone update rule

In this step, pheromone is applied to edges belonging to the best ant tour which determine the best fitness among all ants. The pheromone level is updated after all ants completed their tours by applying the global pheromone updated rule in equation:

$$\tau(r,s) \longleftarrow (1-\alpha)\, \tau(r,s) + \alpha.\Delta\, \tau(r,s) \quad (11)$$

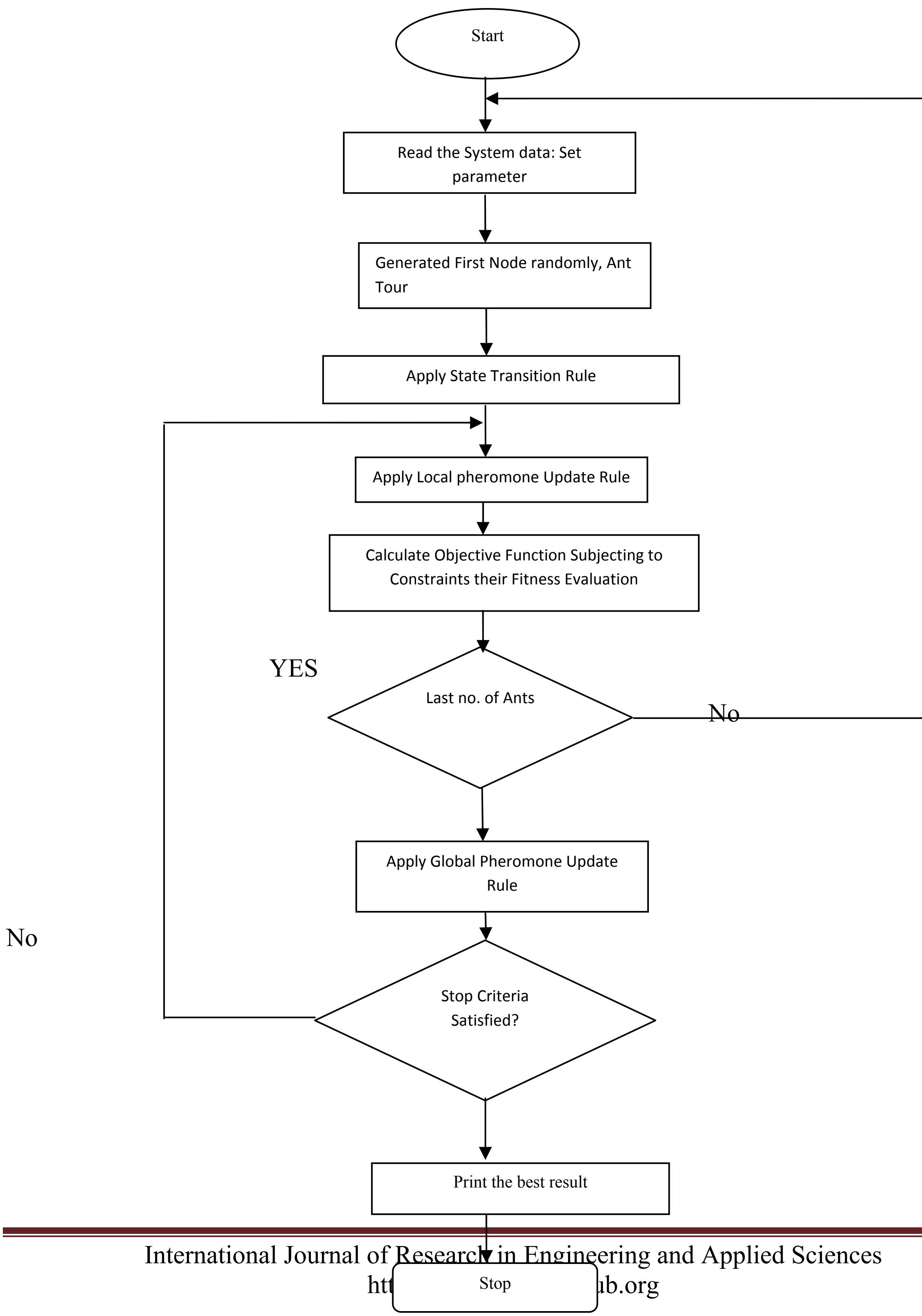
$$\Delta\, \tau\,(c.l) = \begin{cases} (Gib)\ \text{-}1, \text{ if } (c,l) \text{ € global best tour} \\ O, \text{ otherwise} \end{cases}$$

α: pheromone decay parameter ($0 < \alpha < 1$)

Gib: length of the globally best tour from the beginning of the tour.

Step 7: End Condition

The condition for algorithm to stop the iteration in this step is when a maximum number of iterations have been performed otherwise, repeat from step 3. Every ant tour that was visited by ants should be evaluated. If a better path is found in the evaluation, it will be kept as the next reference. The best path selected between all iterations gives the optimal solution to Economic Load Dispatch problem.


Start
Read the System data: Set parameter
Generated First Node randomly, Ant Tour
Apply State Transition Rule
Apply Local pheromone Update Rule
Calculate Objective Function Subjecting to Constraints their Fitness Evaluation
YES
Last no. of Ants
No
Apply Global Pheromone Update Rule
No
Stop Criteria Satisfied?
Print the best result
Stop

4. SIMULATION RESULT FOR ACO

A computer program implementing the proposed algorithm was first prepared and run for a 3 generator system. A comparison with Lambda method and Genetic Algorithm (GA) is provided in table 1. ACO parameters are set to the following values at initializing process.

N=10, m=5, tmax =10, dmax =49, β = 2, α= 0.1, qo=0.6,

r = 0.6 and □o= 1.

The fuel cost characteristics of 3 generators system ($/hr)

F (P1) =200+7.0P1+0.008P21 10 < P1<85

F (P2) =180+6.3P2+0.009P21 10 < P2<80

F (P3) =140+6.8P3+0.007P31 10 < P3<70

B = [.021 .0093 .0028; .0093 .0228 .0017; .0028 .0017 .0179];

B0 = [.0003 .0031 .0015];

B00 = [.00030523];

Load demand = 150 MW

Table 1: Result of ELD

Case Study	P1 (MW)	P2 (MW)	P3(MW)	Cost ($/h)	Time (Sec)
Lambda iteration	33.471	64.097	55.101	1599.98	-
GA	34.4895	64.0299	54.1534	1600.001	32.710
ACO	33.446	64.268	54.956	1599.9848	27.231

5. CONCLUSION

In this paper, we have studied the Economic Load Dispatch problem (ELD) and a recent approach. Ant colony Optimization (ACO) has been proposed to solve it. We have also compared the performance of the proposed algorithm on a set of the ELD problem instances with the GA approach and Lambda iteration approach. Computational results have indicated that the algorithm yields solution values that are superior to those of GA and Lambda iteration approach, and the proposed algorithm have good computational efficiency.

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