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A Comparative Study between Non-Iterative Zero Tolerance Method with Evolutionary Algorithm Method for Economic Load Dispatch

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***Abstract*—This paper outlines the Optimal Scheduling of Generators Real Power Output and presents a Comparative study between a novel method and Evolutionary Algorithm Methods for studying the optimum load scheduling problem.**

The First Part of the paper describes a novel and time saving method and to obtain the optimum power dispatch This optimization procedure is free from iteration. The results are compared with the results found from Genetic Algorithm Techniques, where initially the portion of the transmission Losses has been neglected

The Second Part of the paper describes a Comparative Study between the result found from Genetic Algorithm method and Ant Colony Optimization Technique. In this portion transmission losses are incorporated.

***Index Terms*—iterative technique, optimization, economic load dispatch, Evolutionary Algorithm, Ant Colony Optimisation.**

I. INTRODUCTION

Economic Dispatch (ED) problem is one of the fundamental issues in power system operation. In essence, it is an optimization problem and its main objective is to reduce the total generation cost of units, while satisfying Constraints. [1] A bibliographical survey on ELD methods reveals that various numerical optimization techniques have been employed to approach the ELD problem. ELD is solved traditionally using programming based on optimization techniques such as lambda iteration, gradient method, dynamic programming (DP) and so on [1,3-6]. Recently modern heuristic methods (such as simulated annealing, genetic algorithms, evolutionary algorithms, adaptive tabu search, particle swarm optimization, etc [2]) are used to solve Economic Load dispatch problem. [7-8]. The main drawback of these used methods is that the accuracy of the result depends upon tolerance value and number of iterations, when the difference between actual and calculated value is less than tolerance, the program executes or terminates with the optimum result.

Bakirtzis et al. [9] have proposed a simple genetic algorithm solution to optimize the economic load dispatch problem. Here also the accuracy of the result depends upon the tolerance value.

The first part of this paper introduces a novel technique to solve economic Load dispatch problem. The advantage of this technique is that it is non iterative and requires no tolerance value, we can get the exact solution. The results compared with the results found by using Genetic Algorithm.

In the Evolutionary Algorithms one of the techniques is Ant Colony Optimization Method introduced by Marco Dorigo [2, 3, and 4]. This Algorithm has been developed by the observation of the foraging behavior of real ant colonies, is a metaheuristic which uses the concept of stigmergy (indirect communication mediated by pheromone rates).The results found from ACO technique is compared with the results found from Genetic Algorithm.

II. ELD PROBLEM FORMULATION

A. Nomenclature and Acronyms

N	Number of units of a system
F(Pi)	Fuel cost of *i*th unit
P_{Oi}	Optimum Output for ith unit.
P_d	Power Demand
P_L	Transmission Loss
Pmax	Maximum output limit of *i*th unit
Pmin	Minimum output limit of *i*th unit
α_i , $ß_i$ & γ_i	Fuel Cost Coefficient for ith unit

The Optimal Power Flow problem can be written as

F(x) is minimum

subject to h(x)=0

and $<g_{min}(x)g(x)<g_{max}(x)$

minimization of the objective function while satisfying both equality and inequality constraints.

B. Objective Function

The most commonly used objective function for the entire power system can be written as the sum of the quadratic fuel cost model of each generator.

$$F_1 (P_1) = \sum_{i=1}^{N} \alpha_i + ß_i * P_{gi} + \gamma_i * P_{gi}^2$$

P_{gi} is the generated active power of i th generator .

C. Equality Constraints

For optimal power output the power demand and system loss must be met by the generated active power.

$$P_d + P_L = \sum_{i=1}^{N} P_{gi}$$

D. Inequality Constraints

It is the upper and Lower bound on the active power generation.

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

C. Economic Dispatch using Genetic Algorithm

Genetic algorithms are search algorithms based on the process of biological evolution. In genetic algorithms, the mechanics of natural selection and genetics are emulated artificially. The search for a optimum to an optimization problem is conducted by moving from an old population of individuals to a new population using genetics-like operators. Each individual represents a candidate to the optimization solution. An individual is modeled as a fixed length string of symbols, usually taken from the binary alphabet. An evaluation function, called fitness function, assigns a fitness value to each individual within the population. This fitness value is measure for the quality of an individual. The basic optimization procedure involves nothing more than processing highly fit individuals in order to produce better individuals as the search progresses. In the economic dispatch problem, the unit power output is used as the main decision variable, and each unit's loading range is represented by a real number. The representation takes care of the unit minimum and maximum loading limits since the real representation is made to cover only the values between the limits.

The main objective of the economic dispatch is to minimize fuel costs while satisfying constraints such as the power balance equation. The most fit individuals will have the lowest cost of the objective function of the economic dispatch problem. The fitness function is used to transform the cost function value into a measure of relative fitness. For the economic dispatch problem, In order to produce two offspring, an arithmetic crossover operator is used. After crossover is completed, mutation is performed. In the mutation step, a random real value makes a random change in the *m*-th element of the chromosome. After mutation, all Flow Chart of the proposed method is shown below:

Where F(x) the objective function , h(x) is Equlity constraints and g(x) is inequality constraints and x is the control variable. The essence of the optimal power flow problem is the

constraints are checked whether violated or not. If the solution has at least one constraint violated, a new random real value is used for finding a new value of the *m*-th element of the chromosome. Then, the best solution so far obtained in the search is retained and used in the

generation. The genetic algorithm process repeats until the specified maximum number of generations is reached.

D. Economic Dispatch using Non iterative Zero tolerance method

Initially the technique is applied for Two generating system, later the technique will be applied so that it can be applied for n number of generating system.

We have considered Two generating units sharing load, the fuel cost function of two units can be written as

$$F_1(P_1) = \alpha_1 + ß_1 * P_1 + \gamma_1 * P_1^2$$
$$F_2(P_2) = \alpha_2 + ß_2 * P_2 + \gamma_2 * P_2^2$$

The Optimal Loading for unit 1 is Po_1 and for unit 2 is Po_2 and the Power Demand is P_d

Then, $Po_1 + Po_2 = P_d$

Incremental Fuel Cost i.e. Lagrange Multiplier $\lambda = dF_1/dP_1 = dF_2/dP_2$

$dF_1/dP_1 = ß_1 + 2\gamma_1 * Po_1$

$dF_2/dP_2 = ß_2 + 2\gamma_2 * Po_2$

$\lambda = ß_1 + 2\gamma_1 * Po_1 = ß_2 + 2\gamma_2 * Po_2 = (\gamma_2 ß_1 + 2\gamma_2 * \gamma_1 * Po_1)/\gamma_2$

$= (\gamma_1 ß_2 + 2\gamma_1 * \gamma_2 * Po_2)/\gamma_1$

$= (\gamma_2 ß_1 + \gamma_1 ß_2 + 2\gamma_2 * \gamma_1 * Po_1 + 2\gamma_1 * \gamma_2 * Po_2)/(\gamma_2 + \gamma_1)$

$= (\gamma_2 ß_1 + \gamma_1 ß_2 + 2\gamma_2 * \gamma_1 * (Po_1 + Po_2)/(\gamma_2 + \gamma_1)$

$= \{\gamma_2 ß_1 + \gamma_1 ß_2 + 2\gamma_2 * \gamma_1 * (P_d)\}/(\gamma_2 + \gamma_1)$

$= (\gamma_2 ß_1 + \gamma_1 ß_2)/\gamma_2\gamma_1 + 2P_d)/\{(\gamma_2 + \gamma_1)/\gamma_2\gamma_1\}$

$= (T + 2P_d)/S$

Where $T = (\gamma_2 ß_1 + \gamma_1 ß_2)/\gamma_2\gamma_1 = ß_1/\gamma_1 + ß_2/\gamma_2$

$S = (\gamma_2 + \gamma_1)/\gamma_2\gamma_1 = 1/\gamma_1 + 1/\gamma_2$

By observation it is seen that when N nos. of Generating units are sharing their common load then

$$T = \sum_{n=1}^{N} (ß_n/\gamma_n) \quad \text{and} \quad S = \sum_{n=1}^{N} (1/\gamma_n)$$

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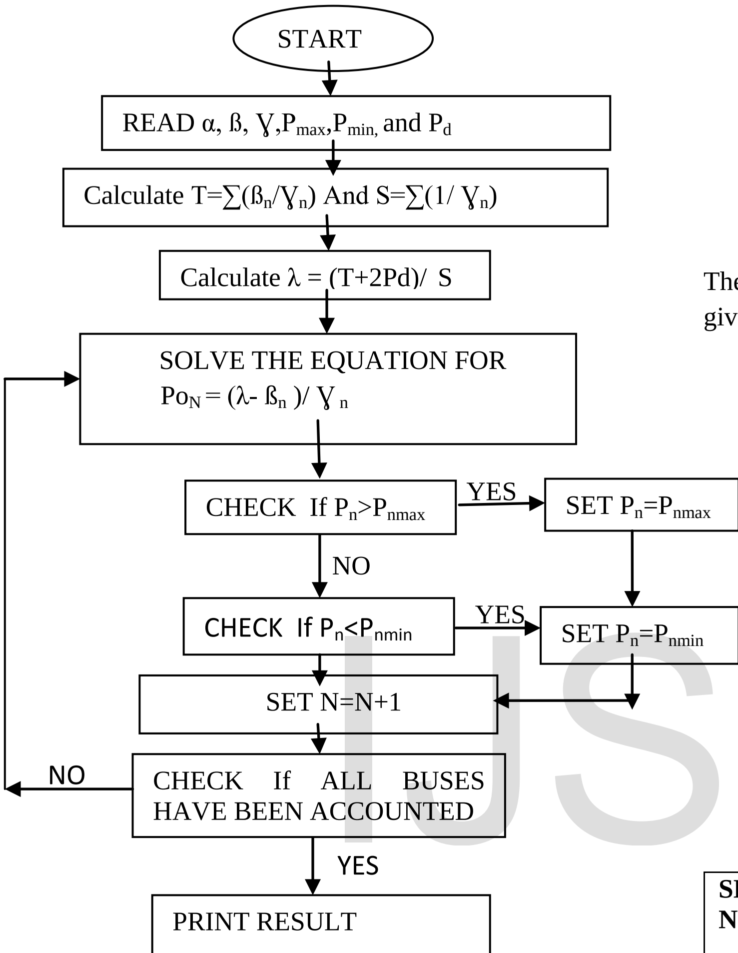

III . SIMULATION RESULTS

The cost function of the 3 units are given as follows

F1=0.00156P12+7.92P1+561 Rs/Hr

F2=0.00194P22+7.85P2+310 Rs/Hr

F3=0.00482P32+7.97P3+78 Rs/Hr

The unit operating ranges are

100 MW ≤ P1 ≤ 600 MW

100 MW ≤ P2 ≤ 400 MW

50 MW ≤ P3 ≤ 200 MW

The result found from Non iterative Zero tolerance Technique are given by:

SL NO	**Power demand (MW)**	**P1 (MW)**	**P2 (MW)**	**P3 (MW)**	**Ft Rs/Hr**
1	450	205.41	183.22	61.2	4651.8
2	585	268.85	234.27	81.83	5821.1
3	700	322.92	277.70	99.32	6838.4
4	800	369.93	315.52	114.54	7739.5
5	900	416.95	353.32	129.76	8653.6

The result found from GA Method are given by:

SL NO	**Power demand (MW)**	**P1 (MW)**	**P2 (MW)**	**P3 (MW)**	**Ft Rs/Hr**
1	450	205.41	183.21	61.37	4652.34
2	585	268.83	234.32	81.83	5821.40
3	700	322.50	277.60	99.64	6838.40
4	800	369.80	315.50	114.63	7738.50
5	900	417.95	352.72	129.55	8653.20

New Proposed Method

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Results for ELD Solution by Non iterative zero tolerance technique and GA Method for 3 unit System are given by :

E. Economic Dispatch using Ant Colony Optimization Algorithm

The ACS belongs to biologically inspired heuristic algorithms. It was developed mainly based on the observation of the foraging behavior of a real ant. It will be useful to understand how ants, which are almost blind animals with very simple individual capacities acting together in a colony, can find the shortest route between the ant nest and a source of food.

Artificial ants follow similar patterns as real ants in
(i) being a colony of co-operative agents,
(ii) using stigmergistic communication based on pheromone trails,
(iii) using a sequence of moves to find a shortest path, and
(iv) using local information to progress, with no hint of the global situation.

In ant systems, the artificial ants build a tour as they sequentially visit each city, probabilistically choosing which city to visit next. As ants travel along the edges between cities, they build and maintain an artificial pheromone trail, denoted by $\tau_{ij}(t)$, the amount of pheromone on edge (i, j) at a given time t. These values help govern the way the tours are built. Each time an ant completes a tour, it updates the specific edges used in that tour by adding pheromone levels proportional to the quality of the tour. Generally, tour quality is a function of tour length. Thus, the value of the pheromone trail, $\tau_{ij}(t)$, is updated by each artificial ant completing its tour.

The logic of pheromone trail creation and modification is best perceived by considering the *t th* time period or iteration.

Ants choose a city based on a probabilistic transition rule. The probability of the ant choosing a city j after having stationed itself in city i at iteration t is a function of the following three items:

 Whether city j has been visited. Artificial ants are endowed with a memory of the cities they have visited in the tour. This avoids the ant re-visiting a city. This list of cities visited within the tour grows until all the cities are included.

 A heuristic function η_{ij} of the desirability of adding edge (i, j) to the solution. The heuristic value is set as the inverse of the distance between the cities i and j.

 The amount of artificial pheromone $\tau_{ij}^{k}(t)$ on the edge connecting cities i and j.

A probabilistic transition relation that defines the method

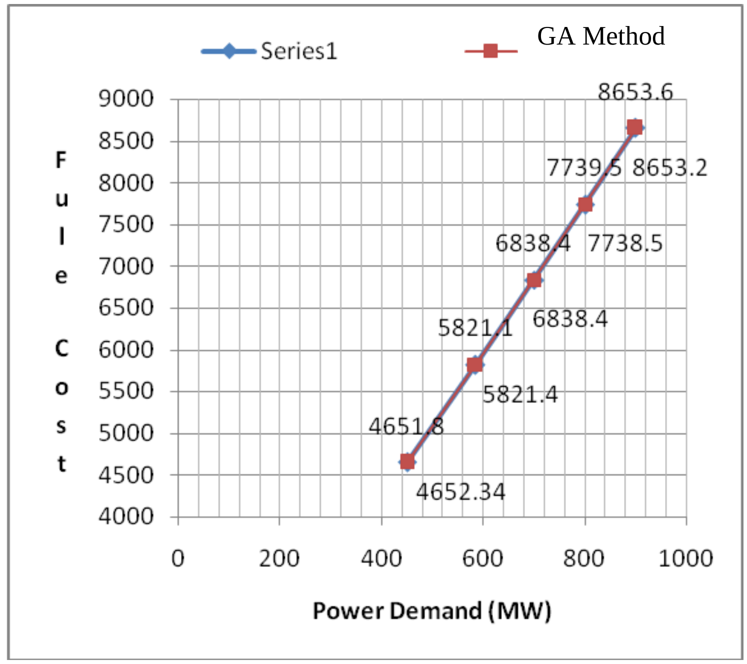


Fig. Comparison Between Fuel Cost found by Non iterative Zero Tolerance Method and GA Method

In the above expression, α and β are user adjustable variables that control the influence of the pheromone trail and the heuristic desirability, respectively, on the decision- making tendencies of the ant. The $J_k(i)$ is the set of cities still to be visited by the k^{th} ant currently in city i. If $\alpha = 0$, then the closest cities, in terms of distance, are favored. This causes the ants to choose cities similar to how a stochastic greedy algorithm chooses cities. When $\beta = 0$, the pheromone is the key factor. At this extreme, ant movement can lead to a stagnating algorithm, as all the ants generate essentially the same solution, a solution
that is usually sub-optimal. A mix of values for the two variables is used to compromise between edge length and
pheromone intensity. Empirical findings to date show it is important to also include pheromone evaporation or decay in the ant system. Pheromone decay is a direct implication of negative feedback, or the un-coordinated phase, as observed in the behavior of social insects. It is important that the system slowly erase the initial pheromone trail laid to avoid early convergence and to arrive at a better solution in each progressive tour. As the pheromone decay occurs on a particular edge, the possibility of the edge getting selected again diminishes gradually (because the probability value is directly proportional to the pheromone content on an edge). Poor edges (not likely to give good solutions) are not reinforced often enough to overcome the decay and are thus picked less often. Pheromone decay is implemented by using a coefficient of evaporation, 〉, such that the pheromone on edge (i, j) in a subsequent time period is given by

$$\tau_{ij}(t + 1) = (1 - \rho)\,\tau_{ij}(t) + \Delta\tau_{ij}(t)$$

where

$$\Delta\tau_{ij}(t) = \sum_{K=1}^{m} \Delta\tau_{ij}(t)$$

In the actual implementation of ACO, the initial pheromone deposit on the edges (at time t = 0) is homogeneous, and is assumed to be a of choosing the next city can be stated as:

$$p_{ij}^{k}(t) = \frac{[\tau_{ij}(t)]^{\alpha}[\eta_{ij}]^{\beta}}{\sum_{l \in J_k(i)} [\tau_{il}(t)]^{\alpha}[\eta_{il}]^{\beta}} \quad \text{if } j \in J_k(i)$$

$$= 0 \quad \text{if } j \notin J_k(i)$$

Operating ranges of the units are

100 MW ≤ P1 ≤ 600 MW

100 MW ≤ P2 ≤ 400 MW

50 MW ≤ P3 ≤ 200 MW

The result found from GA Method are given by:

SL NO	Power demand (MW)	P1 (MW)	P2 (MW)	P3 (MW)	Ft Rs/Hr
1	450	205.4102	183.2202	57.7	4650.9
2	585	268.8502	234.2702	81.8302	5821.0
3	700	322.9202	277.7002	99.3202	6837.9
4	800	369.9302	315.5202	114.5402	7738.4
5	900	416.9502	353.3202	129.7602	8653.5

If the same problem is solved by Genetic Algorithm Method then the result is:

SL NO	Power demand (MW)	P1 (MW)	P2 (MW)	P3 (MW)	Ft Rs/Hr
1	450	203.1	189.8	57.7	4664.2
2	585	268.19	241.6	77.54	5842.7
3	700	321.45	287.63	94.29	6868.82
4	800	369.5	326.07	108.6	7779.37
5	900	416.04	366.9	122.61	8705.53

From the above results it is seen that ACO Method provides better result than GA method.

small positive constant, *c*. After the first tour, this quantity changes based on pheromone updates. The number of ants used in the ant system is also carefully determined. If the ant population is too small, then the expected synergistic effects leading to a co-coordinated stigmergistic process is impossible to attain. However, too many ants lead to an inefficient computational system, where the quality of results does not change significantly and each run of the algorithm takes a large amount of time.

IV. SIMULATION RESULTS

The cost function of the 6 units are given as follows

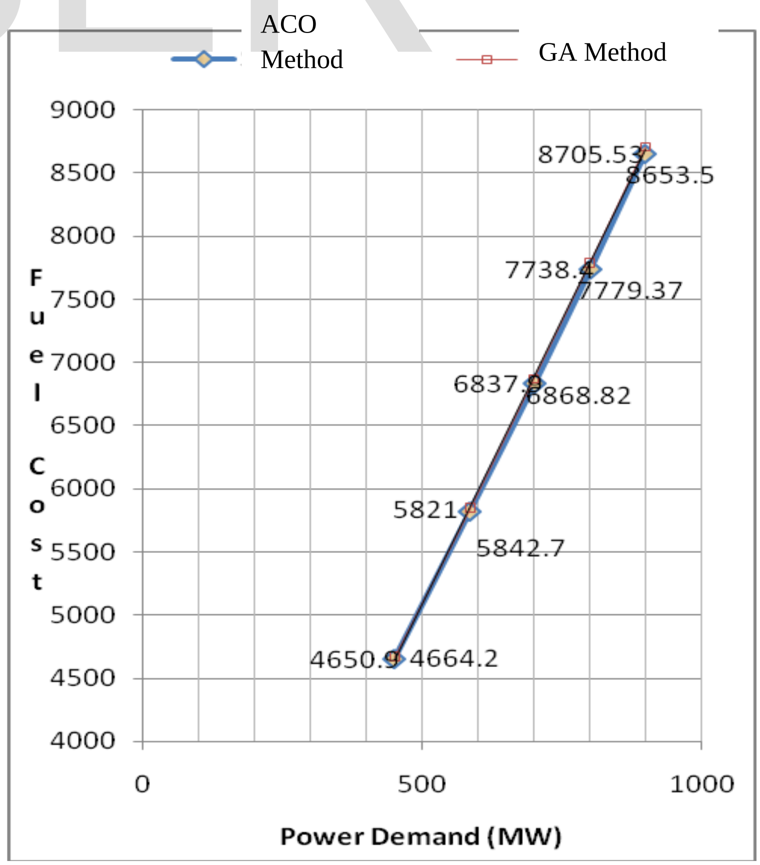
F1=0.00156P12+7.92P1+561 Rs/Hr

F2=0.00194P22+7.85P2+310 Rs/Hr

F3=0.00482P32+7.97P3+78 Rs/Hr

The loss coefficient matrix is given by

$$Bmn(3X3) = \begin{bmatrix} 0.000075 & 0.000005 & 0.0000075 \\ 0.001940 & 0.000015 & 0.0000100 \\ 0.004820 & 0.000100 & 0.0000450 \end{bmatrix}$$



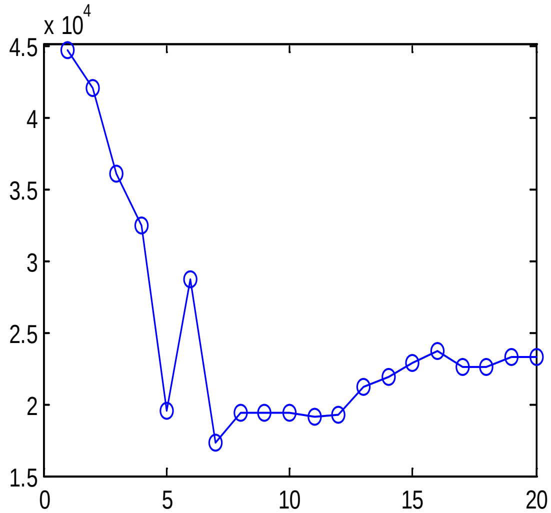


Fig. Distribution of ants for the best solution (for 900 MW).

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Fig. Comparison Between Fuel Cost found by ACO Method and GA Method

SCOPE OF FUTURE WORK:

The novel Non iterative Zero Tolerance Method can be applied for ELD problem including the Transmission Losses.

These techniques can also be applied for Reactive Power minimization i.e. multi objective optimization.

ACO method is applied to different optimization problems including vehicle routine [15, 16, 17], telecommunication network [18], graph colouring [19].

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