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# Combined Economic and Emission Dispatch using various AI techniques: A review

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**ABSTRACT**
This paper presents Combined Economic and Emission Dispatch (CEED) problems and an overview of different techniques such as mathematical optimization method, multi-objective techniques and artificial intelligence techniques like Genetic algorithm(GA), Evolutionary Programming (EP), particle swarm optimisation (PSO), Simulated Annealing(SA), Artificial Bee Colony Algorithm (ABC),Differential evolution(DE) for optimisation of power to the committed units so that overall cost and emission of gases can be minimised. Due to increased public awareness regarding the harmful effects of atmospheric pollutants on the environment like nitrogen oxides ($NO_x$), sulphur oxides ($SO_x$) and carbon-di-oxide ($CO_2$),this study is concerned with minimizing fuel costs as well as minimizing the emission of gaseous pollutants .In this dynamic dispatch problem of power flow is discussed, which is different from static economical dispatch problem in view of incorporation of generator ramp rate. Combined economic-environmental power dispatch considers both optimization problems simultaneously.

**KEY WORDS** - ELD, CEED, equality and inequality constraints, AI Techniques, swarm, ABC etc.

## I. INTRODUCTION

Due to rapid growth in the use of fossil fuels, there is significant reduction of these non-renewable resources worldwide. With the excessive use of fossil fuels there is another problem arises that is release of large amount of atmospheric pollutants. These are the primary reasons why power production utilities have to focus their attention on more optimal ways to use resources [1]. Economic dispatch (ED) is one of the most important problems being dealt with in power system operation and planning

In power generation system our main aim is to generate the required amount of power at minimum cost. Economical load dispatch means that generators real and reactive powers are allowed to vary within certain limits so as to meet a particular load demand with minimum fuel cost and with satisfying unit and system equality and inequality constraints. It is different from load flow studies; it is actually a large scale solution of load flow problem. Allocation of loads are depends upon different constraints.

Most of the real-world problems involve simultaneous optimization of several objective functions [2]. Dynamic economical load dispatch problem is an extension of conventional static economical dispatch problem so that the power output is optimally shared by each units connected in any system so that the total cost is minimized. In recent years, with an increasing awareness of environmental pollution due to fossil fuel operated power plants (thermal power plants), limitation of these pollutants become a crucial issue in ELD. (Economical power dispatch problem).

**2. Bi-objective CEED Problem formulation:**

In the economic/environmental problem main aim is to minimize the emission and fuel cost while satisfying different equality and inequality constraints. Economical load dispatch problem can be considered as a multi-objective optimisation problem with two objectives economic and environmental [3]

**(1) Minimization of fuel cost**: Generator cost curves are represented by quadratic function and the total fuel cost F ($P_G$) ($/h) in terms of real power output can be expressed as

$$F(PG) = \sum_{i=1}^{N}\left(a_i + b_i\ \mathrm{PG}_i + C_i\ \mathrm{PG}_i^{\,2}\right)$$

Where,
N-Number of generators
$P_{Gi}$ -Real power output of $i^{th}$ generator
$a_i$, $b_i$, $c_i$ - Cost coefficient of ith generator
$P_G$- Vector of real power output of generators
$P_G$ can be given by,
$P_G = [P_{G1}, P_{G2}, \ldots, P_{GN}]^T$

**(2) Minimization of pollutant emission:** The emission function includes all type of emission such as $SO_2$, $NO_X$, $CO_2$ etc. The amount of emission is given as a function of generator output.

$$E(P_G) = \sum_{i=1}^{N} 10^{-2}\left(\alpha_i + \beta_i\ \mathrm{PG}_i + \gamma_i\ \mathrm{PG}_i^{\,2}\right) + \xi_i \exp\left(\lambda_i\ \mathrm{PG}_i\right)$$

Where,
$\alpha_i, \beta_i, \gamma_i$ - Coefficients of the $i^{th}$ generator emission characteristics.

**(3)Constraints**

**(i)Equality constraints**

Equality constraints are the basic load flow equations given by

$$P_P = \sum_{q=1}^{n}\left(e_q\left(e_q G_{pq} + f_q B_{pq}\right) + f_p\left(f_q G_{pq} - e_q B_{pq}\right)\right)$$

$$Q_P = \sum_{q=1}^{n}\left(f_P\left(e_q G_{pq} + f_q B_{pq}\right) - e_p\left(f_q G_{pq} - e_q B_{pq}\right)\right)$$

Where p=1,2 …..,n
$e_p$ & $f_p$ – real and imaginary component of voltage at $p^{th}$ node
$e_q$ & $f_q$– real and imaginary component of voltage at $q^{th}$ node
$G_{pq}$&$B_{pq}$–nodal conductance and susceptance between the $p^{th}$ and $q^{th}$ nodes

**(ii) Inequality Constraints**

*(a) Generator Constraints*

The maximum active power generation of a source is limited by thermal consideration and also minimum power generation is limited by the flame instability of a boiler. If the power output of generator for optimal scheduling of the system is less than a pre specified value $P_{min,}$ the unit is not synchronised with the bus bar because it is not possible to generate the low value of power from the unit. Hence the generator power cannot be outsides the range stated by inequality. Similarly the maximum and minimum power generation are limited.

$P_{P\ min} \leq P_P \leq P_{P\ max}$
$Q_{P\ min} \leq Q_P \leq Q_{P\ max}$

*(b) Voltage Constraints*

It is essential that the voltage magnitudes should vary within certain limites because otherwise most of the equipments connected to the system will not operate satisfactorily or additional use of voltage regulating devices will make the system uneconomical.

$V_{P\ min} \leq V_P \leq V_{P\ max}$
$\square_{P\ min} \leq \square_P \leq \square_{P\ max}$

*(c)Running Spare capacity constraints*

The total generation should be such that in addition to meeting load demand and losses a minimum spare capacity should be available i.e.
$G >> P_P + P_{SO}$
where,
G – Total generation
$P_{SO}$ – Specified Power

## 3. AI Techniques

Different types of intelligent techniques are used for the regulated power system to ensure a practical, economical and secure generation schedule. Over view of these techniques are given over here.

### 3.1 Artificial bee colony optimization

It is one of the swarm intelligence techniques. This algorithm mimics the foraging behaviour of real honey bee colonies. Real bee colonies consist of three different types of bee: employed bees, onlooker bees and scout bees. Different responsibilities are associated with different types of bees. Such as duty of employed bees is searching for food source and after finding it they give information to onlooker bees about the food source means distance and direction from the hive and quality rating (nectar amount),this information is conveyed by dancing known as waggle dance. Onlooker bees assess the food source after watching dancing of employed bees.

Then they decide one of them for foraging. When a food source is abandoned some employed bees turn to scout bees. The scout bees search for a new food sources in the environment [4].In classical ABC algorithm, while the location of a food source indicates a solution, nectar amount in food source refers to the fitness value. Employed and onlooker bees look around a food source for finding better food sources. The scouts are assigned to find new food sources if few food sources reach their limits similar as real bee swarms do.

**Artificial bee colony algorithm**

In ABC algorithm, the colony of bees consists of two groups, scout and employed bees. The scout bees seek a new food source and the employed bees look for a food source within the neighbourhood of the food source in their memories. Both scout and employed bees share their information with other bees within the hive. Flow chart for the artificial bee colony algorithm is given below.

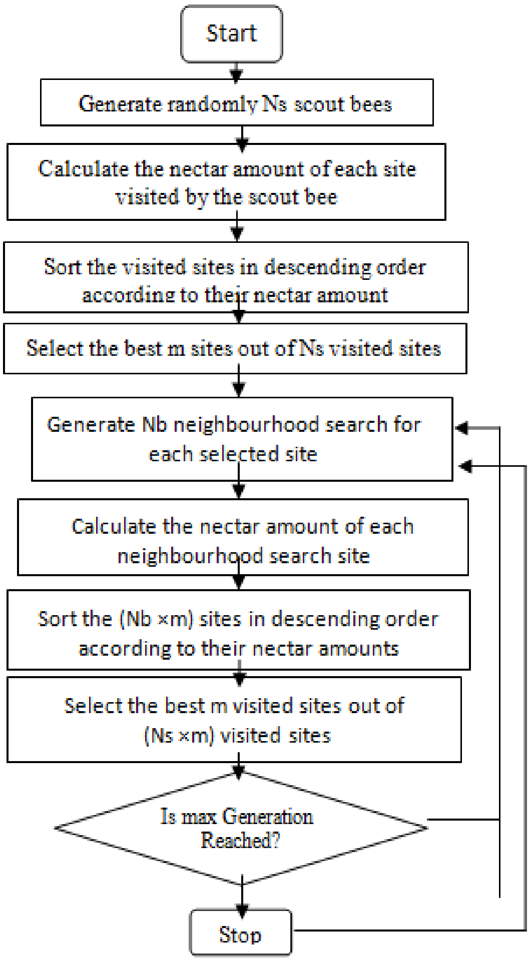


Fig1. Flow chart of artificial bee colony optimization

### 3.2 Genetic Algorithm

GA is one of the heuristics-based optimization techniques. Genetic algorithm is based on genetical process of biological organism based on evolution theory, this algorithm provides robust and powerful adaptive search mechanism.GA use only pay off information (objective function) and hence independent of nature of search space such as smoothness and convexity (unimodality).

GA is different from classical optimization techniques in that it works on the population of solution and searching are on a bit string encoding of real parameter rather than the parameters themselves.GA uses probabilistic transition rules. Each string in the population represents possible solution, which is made up of sub string. In this algorithm, firstly population is generated randomly this population undergoes three genetic operations such as selection crossover and mutation, after this new generation is produced with consideration of fitness function which corresponds to the objective function for the concerned problem. Several trials are done to evaluate the overall best objective function .The best value of the fitness of the strings is depends on the number of the population in a generation, number of generations and number of trials [5]

### 3.3 Particle Swarm Optimization

PSO is first introduced by Kennedy and Eberhart in year 1995. It is population based optimization algorithm, its population is called a swarm and each individual is called a particle. This technique is motivated from the simulation of the behaviour of the social systems such as fish schooling and bird's flocking. It requires less computational time and less memory because of the simplicity inherent in the above system [6]. It is flexible and well balanced mechanism to enhance and adapt to the global and local exploration abilities with non convex or non smooth objective function.

The basic assumption behind the PSO algorithm is birds find food by flocking and not individually. This leads to the assumption that the information is owned jointly in flocking. Basically the PSO was developed for two dimension solution space by Kennedy and Eberhart [7].position of each individual is represented by XY axis position and its velocity is represented by $V_X$ in x direction and $V_X$ in Y direction. Modification of the individual position is realised by the velocity and position information.PSO algorithm searches in parallel using a swarm consisting of a number of particles to explore optimal solutions. Position of each particle represents a candidate's solution to the optimization problem. In PSO system particles change their position by flying around in a multi-dimensional search space until a relatively unchanging position has been encountered [8]. Firstly each particle is initialised with a random position and random velocity within the feasible range. Fitness value is assigned to each particle. Best position among all particles and best position of each particle up to the current iteration is assigned. At each iteration position of each particle is updated. The procedure is repeated until the convergence criteria are satisfied.

### 3.4 Differential Evolution

DE is one of the most prominent new generation EAs (evolutionary algorithm).it is proposed by Stom and Price to exhibit consistent and reliable performance in nonlinear and multimodal environment. Advantages of DE over other evolutionary algorithm are its simple and compact structure; number of parameters is few, highly convergent. Due to these DE is a popular stochastic optimizer [9]

DE starts with a initial population of feasible target vectors called parent and generates new solution which is called off springs, by the three operators known as mutation, crossover and selection and until the optimal solution is reached. Three vectors are selected randomly from the population in the step of mutation, and after that mutant vector is created by perturbing one vector with the difference of two other vectors. In the operation of crossover a new trial vector called offspring is created by replacing certain parameters of the target vector by the corresponding parameter of the mutant vector in the basis of a probability distribution. In DE competition between the parents and offspring is one to one .individuals which has best fitness will remain till the next generation .Iterative process continues until stopping criteria given by user is met.

### 3.5 Evolutionary programming

EP is originally conceived by Lawrence J. Fogel in 1960, it is a stochastic optimization strategy applied to discrete search spaces similar to genetic algorithm. Main stages of this technique are initialization, creation of offspring vectors by mutation and competition and selection of best solution. EP is capable of global and near global solution. The ability of EP method to find the global optimum solution is independent of the size of the discrete load step assigned to each parent vector in the solution process. In the investigations it is shown that Evolutionary Programming is better among other evolutionary computation methods such as genetic algorithm and micro genetic algorithm [10]

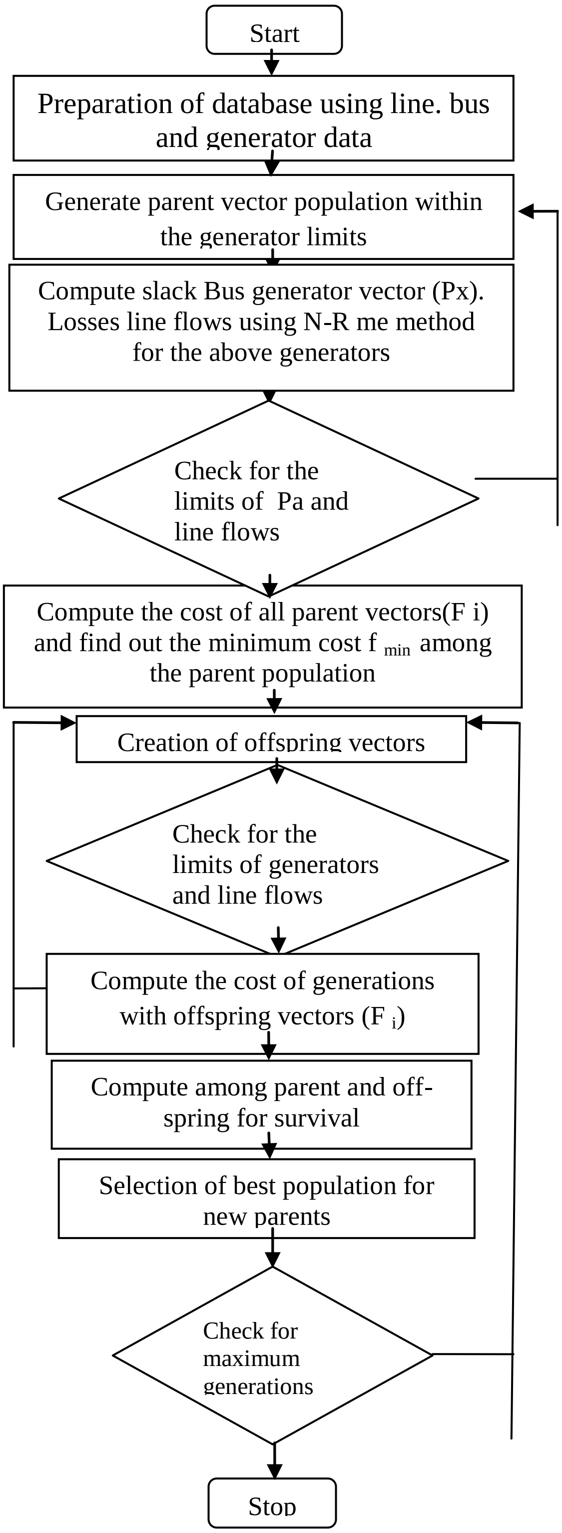


Fig.2. Flow chart for EP based ELD

### 3.6 Simulated Annealing

SA algorithm is derived from the annealing process of metals. In the Annealing process metal is heated up to a high temperature followed by slow cooling achieved by decreasing the temperature in steps. At each step, the temperature is fixed for a period of time until the system reaches thermal equilibrium. Finally the system reaches its minimum energy crystalline structure [11].SA technique is a random search technique for optimization developed by Kirkpatrick [12].The objective function in SA corresponds to the metal energy and the number of iterations is equivalent to the temperature level in the annealing process. The temperature is a control parameter for the optimization problem. The SA strategy starts with a high temperature and initial feasible solution. SA consists of a number of iterations and each iteration contains a number of trials. A new feasible solution is generated in each trial by adding random perturbation to the current solution. If the objective function of new solution is less than that of the current solution then the new solution is accepted. Otherwise the new solution is accepted with a certain probability. The accepted solution will be used to generate another solution. SA has the ability to avoid getting local solutions; then it can generate global or near global optimal solutions for optimization problems without any restriction on the shape of the objective functions.

## 4. Conclusion

This paper presents economical load dispatch problem with equality and inequality constraints. In this paper brief knowledge of artificial intelligence techniques like GA, PSO, EP, DE,SA and ABC is given. Due to fossil operated power plants there is emission of pollutants which is dangerous to our nature so with fuel cost minimisation, emission of these dangerous gases is also taken into account.

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