A Novel Gravitational Search Algorithm for Combined Economic and Emission Dispatch

[1]Muhammad Yaseen Malik, [2]Himanshu Gupta
[1]Student, [2]Assistant Professor
[1]Electrical Engineering
[1]E-Max Group of Institutions, Haryana, India

Abstract **- Economic Load Dispatch is a well known problem and has been a major concern for researchers and industrialists all around the world. The paper proposes to solve the problem of Economic Load Dispatch using a novel Gravitational Search Algorithm. The target is to implement a meta-heuristic algorithm which will be able to find the optimal capacity of the generating units in multi-generating unit system. The paper implements a novel technique of Modified Gravitational Search Algorithm for combined economic and emission dispatch. Three data sets were used for the testing purpose and the fitness values are compared. The results considered valve point effect and the results were found to be quite encouraging.**

Keywords **- EPD, ELD, GSA.**

I. INTRODUCTION

The economic dispatch problem relates to optimum generation scheduling of present generators in power system to minimize total fuel cost while to satisfy the load demand and operational constraints. The economic dispatch problem plays a vital role in planning operation and control of the modern power systems. Over last few years, a number of approaches were developed for solving operation using classical mathematical programming methods. Moreover, classical optimization methods are largely sensitive to initial point and converge frequently to local optimization solution or diverge altogether. Linear programming methods are fast and reliable but main disadvantages associated with the piecewise linear cost approximation.
The economic operation in the power system plays a main role to decide the electricity price in regulated and deregulated market. The economic load dispatch assigns the generators' powers to complete certain demand while the generating cost minimising under several systems and units'-related the constrained environment. The minimising is a nonlinear optimisation problem whose complexity prolongs when constraints like valve-point effect and generators' have prohibited zones undertaken. Economic load dispatch has been studied by numerous engineers and researchers. These efforts are mathematical programming based on various optimisation techniques.
In the power system, the operation cost needs to be minimized at each time via economic load dispatch. Traditionally, cost function of generator was approximately represented by single quadratic cost function. Practically, operating conditions of multiple generating units need the generation cost function be divided as piecewise quadratic functions. The networks have been used in several different applications. The vital property of the Hopfield neural network is decrease in energy by amount whenever there is change in inputs. Thus, the Hopfield neural network has been used for optimization. Tank and Hopfield defined how various optimization problems rapidly solve highly interconnected networks of simple analogy processor that is an implementation of the Hopfield neural network. Park and others displayed the economic load dispatch for piecewise quadratic cost these functions using Hopfield neural network. The results were compared very well with numerical method in an hierarchical approach applied to Hopfield neural network in economic and environmental dispatch of the electric power systems. These several applications involved a huge number of iterations and shown oscillations during transients. It suggests a need for improvement in convergence through an adaptive method, such as adaptive learning rate technique developed by Ku and Lee for a diagonal recurrent neural network.

The bibliographical study on economic load dispatch suggests, lately as opposed to the mathematical techniques, various heuristic optimisation strategies similar as genetic algorithm and variant real-coded Gravitational Algorithm, tabu search, simulated annealing, ant colony optimisation, fuzzy systems, neural network, particle swarm optimisation, hybrid evolutionary programming and biogeography-based optimisation have capable of generating high-quality economic load dispatch solutions. Although heuristic techniques did not guarantee to discover globally the optimal solutions in the finite time, they mainly offer fast and reasonable solutions. After analyses existing methods like Hopfield neural network do consider piecewise quadratic prohibited zones and fuel cost, the convergence rate are slow causing usage of sigmoid function. Gravitational Algorithm method is usually mainly faster than SA tech due to parallel search capabilities. Although, when objective parameters were highly related to each other, the chromosomes tend to express the similar structure and average fitness become higher. Although Particle Swarm Optimization is capable of generating good solution, however, the performance is largely dependent on parameter sensitivity or

balancing between the local and global search capabilities. Most of the methods are mentioned above used quadratic fuel cost that is an approximation of higher order fuel cost.

II. RELATED WORK

In this paper, **Balamurugan R** *et al.* [1] proposed an efficient scheme with hybrid integer differential evolution – dynamic programming approach is used to solve economic dispatch problem with several fuel options. A dynamic programming has based on the simplified recursive algorithm which has developed for a fixed scheduling of generating units in economic dispatch problem. The test result displays the hybrid ICDEDP algorithm with superior convergence, shorter computation time and high quality solution characteristics.
In this paper, **Rayapudi, S. Rao** *et al.* [2] proposed ELD is a technique to determine low-cost, reliable operation and most efficient power system to dispatch present electricity generation resources to transfer the load on system. The main objective of economic dispatch is to decrease total cost of generated operational constraints of presently generation resources. Numerical results displayed good convergence property and better in quality of the solution.
In this paper**, Sinha, Nidul** *et al.* [3] proposed a hybrid method which integrates the all major features of evolutionary programming and particle swarm optimization for solution of non-convex ELD problems having non-linearities such as valve point loadings.
Park, J *et al.* [4] proposed a method to solve a problem of EPD with the piecewise quadratic cost function while using Hopfield neural network. Additionally a cost function for each generator is supposed. Though more realistic to display cost function as piecewise quadratic function rather to the convex function.
In this paper, **Baskar, G**. *et al.* [5]. proposed an objective to involve effective and simple methods to economic load dispatch problem with security constraints in thermal units that are obtaining economic scheduling for the utility system. In this, improved particle swarm optimization method, a newest velocity equation has been formulated for large scale system or characteristics of constriction factor approach are also incorporated into this approach.
Basu, M. *et al.* [6] proposed multi-objective optimization technique for ELD of fixed thermal plants and head hydro plants with emission level functions and non-smooth fuel cost is presented. The problem deals with economic and emission as the competing objectives.
Bhattacharya Aniruddha *et al.* [7] proposed biogeography-based optimization algorithm to solve non-convex and convex economic load dispatch problems of thermal generators of power system. T
Nanda, J *et al.* [8] Proposed emission load dispatch problem that measures for minimization both emission and cost which is multiple, conflict objective of function problem. A goal programming technique has suitable for these type of problems. In this, emission load dispatch problem can be solved with non-linear and linear goal programming algorithms. The application and validity of the proposed algorithms are demonstrated for a system having six generators.
In this paper, **Chiang, C-L** *et al.* [9] proposed genetic algorithm to solve practical power economic load dispatch problems of individual complexities and sizes with cost curves, where mathematical conventional methods are developed inapplicable. An improved genetic algorithm gives a well evolutionary migrating operator and direction operator to enable efficient actively explore and search solutions.
Baskar G., *et al.* [10] proposed a contingency constrained ELD using conventional particle swarm optimization, improved swarm optimization, programming methods like, fast-EP classical EP and classical and fast EP to alleviate line overloading.

III. PROBLEM FORMULATION

Economic Load Dispatch is a well known problem and has been a major concern for researchers and industrialists all around the world. This paper aims to solve the problem of Economic Load Dispatch with a novel proposed Gravitational Search Algorithm. The problem consists of division of formulation of the model for fuel consumption and then development of the minimizing algorithm and applying the same on the economic load dispatch problem. It is not as simple as is sounds as the solutions not only have to find the global minima but also are constrained. Thus it forms a constrained optimization problem.
To determine the economic distribution of a load amongst the different units of a plant, the variable operating costs of each unit must be expressed in terms of its power output. The fuel cost is the main cost in a thermal or nuclear unit. Then the fuel cost must be expressed in terms of the power output. Other costs, such as the operation and maintenance costs, can also be expressed in terms of the power output. Fixed costs, such as the capital cost, depreciation etc., are not included in the fuel cost.

The fuel requirement of each generator is given in terms of the Rupees/hour. Let us define the input cost of an unit-*i*, f_i in Rs./h and the power output of the unit as P_i. Then the input cost can be expressed in terms of the power output as

$$f_i = \frac{a_i}{2} P_i^2 + b_i P_i + c_i \text{ Rs./h}$$

The operating cost given by the above quadratic equation is obtained by approximating the power in MW versus the cost in Rupees curve. The incremental operating cost of each unit is then computed as

$$\lambda_i = \frac{df_i}{dP_i} = a_i P_i + b_i \text{ Rs./MWh}$$

IV. PROPOSED METHODOLOGY

The paper proposes to solve the problem of Economic Load Dispatch using a novel Gravitational Search Algorithm. The target is to implement a meta-heuristic algorithm which will be able to find the optimal capacity of the generating units in multi-generating unit system. The system of different number of generator sets would be taken so that the algorithm is tested for different datasets. The framework for the development of Gravitational Search algorithm is first developed. The rules for the GSA to work are laid down which forms the basis of the optimizing process. The particles are initialized randomly and moved in the search space as they search for the global optima and care also needs to be taken for keeping the particles in the feasible space so that both equality and inequality constraints are not violated.

GRAVITATIONAL SEARCH ALGORITHM

GSA is a heuristic optimization algorithm which has been gaining interest among the scientific community recently. GSA is a nature inspired algorithm which is based on the Newton's law of gravity and the law of motion . GSA is grouped under the population based approach and is reported to be more intuitive. The algorithm is intended to improve the performance in the exploration and exploitation capabilities of a population based algorithm, based on gravity rules. However, recently GSA has been criticized for not genuinely based on the law of gravity [3]. GSA is reported to exclude the distance between masses in its formula, whereas mass and distance are both integral parts of the law of gravity. Despite the criticism, the algorithm is still being explored and accepted by the scientific community. GSA was introduced by Rashedi et al. in 2009 and is intended to solve optimization problems. The population-based heuristic algorithm is based on the law of gravity and mass interactions. The algorithm is comprised of collection of searcher agents that interact with each other through the gravity force. The agents are considered as objects and their performance is measured by their masses. The gravity force causes a global movement where all objects move towards other objects with heavier masses. The slow movement of heavier masses guarantees the exploitation step of the algorithm and corresponds to good solutions.

V. RESULTS

The various simulation results obtained by implementing the proposed algorithm. All the simulations have been done MATLAB R 2013b with a 6GB RAM computer with core i5 processor. Three types of datasets have been utilized

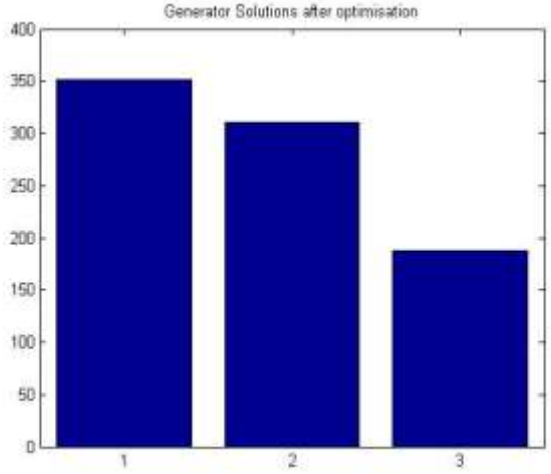

Fig.5.1: Optimal generating capacity for three generator

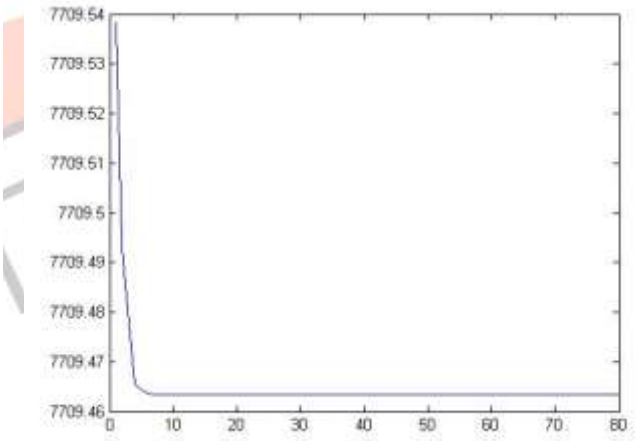

Fig.5.2: Convergence plot of three generator data

Figure 5.1 shows the optimal capacity of the generating units of each generator sets. As can be observed each units are within the minimum and maximum limits and follows the equality constraints also.

As it can be observed from Figure. 5.2 the convergence of fitness function is shown. The deviation among the solutions initially is very high while it starts to converge after certain iterations. This is desirable and shows the efficacy of our algorithm.

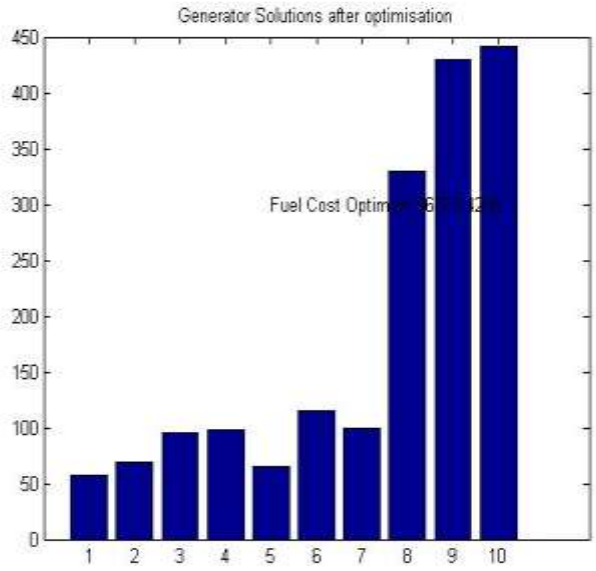

Fig.5.4: Convergence plot of three generator data

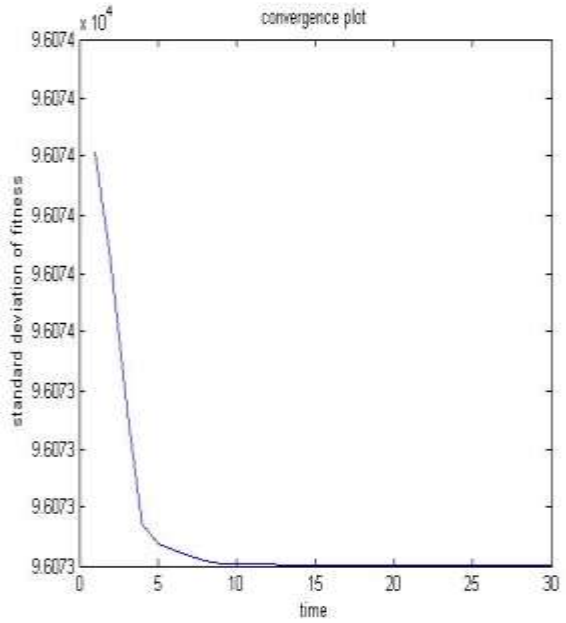

Fig.5.3:Optimal generating capacity for three generator

Figure5.3 shows the optimal capacity of the generating units of each generator sets. As can be observed each units are within the minimum and maximum limits and follows the equality constraints also.

As can be observed from Figure 5.4 the convergence of fitness function is shown. The deviation among the solutions initially is very high while it starts to converge after certain iterations. This is desirable and shows the efficacy of our algorithm.

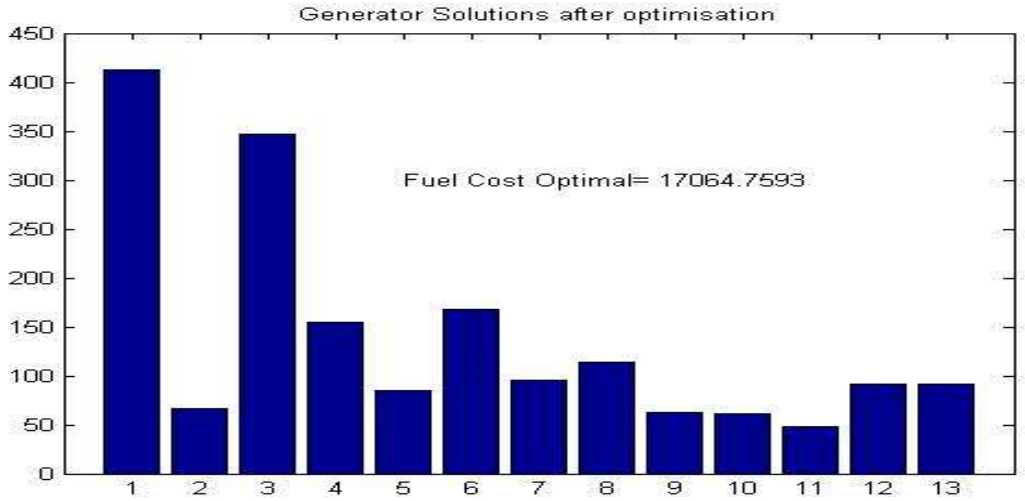

Fig. 5.5 : Optimal generating capacity for three generator

Figure 5.5 shows the optimal capacity of the generating units of each generator sets. As can be observed each units are within the minimum and maximum limits and follows the equality constraints also.

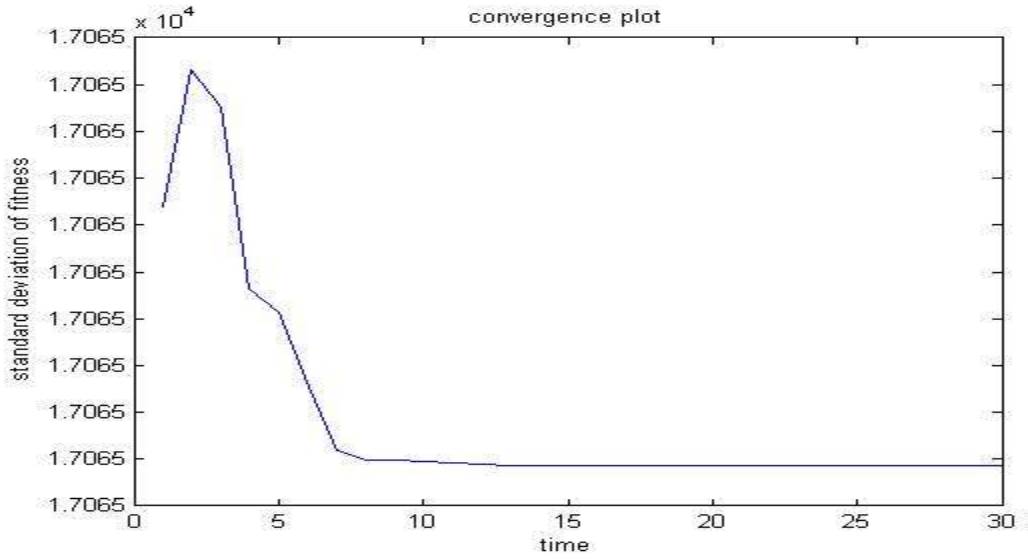

Figure 5.6: Convergence plot of three generator data

As can be observed from Fig. 5.6 the convergence of fitness function is shown. The deviation among the solutions initially is very high while it starts to converge after certain iterations. This is desirable and shows the efficacy of our algorithm.

VI. CONCLUSION AND FUTURE SCOPE

The paper implements a novel technique of Modified Gravitational Search Algorithm for combined economic and emission dispatch. The problem taken is a multi-objective problem and the algorithm was implemented to find the optimal generation capacity of all the generators. Three data sets were used for the testing purpose and the fitness values are compared. The results considered valve point effect and the results were found to be quite encouraging.

In future other algorithms can be implemented for the same and the problem can be tested for other datasets. Furthermore the results can be analysed in terms of convergence and hybrid algorithms can be utilised for the same.

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