An Efficient Particle Swarm Optimization Technique to Solve Combined Economic Emission Dispatch Problem

S. Muthu Vijaya Pandian  
Assosciate Professor, V.L.B.Janakiammal College of Engg. and Tech  
Coimbatore, India  
E-mail: ajay_vijay@rediffmail.com

K. Thanushkodi  
Director, Akshaya College of Engg. and Tech, Coimbatore, India  
E-mail: dr_thanush@rediffmail.com

P. S. Anjana  
U.G. Final Year Scholars, V.L.B.Janakiammal College of Engg. and Tech  
Coimbatore, India

D. Dilesh  
U.G. Final Year Scholars, V.L.B.Janakiammal College of Engg. and Tech  
Coimbatore, India  
E-mail: ddilesh@gmail.com

B. Kiruthika  
U.G. Final Year Scholars, V.L.B.Janakiammal College of Engg. and Tech  
Coimbatore, India  
E-mail: kiru012@gmail.com

C. S. Ramprabhu  
U.G. Final Year Scholars, V.L.B.Janakiammal College of Engg. and Tech  
Coimbatore, India  
E-mail: ram_vlb@yahoo.com

A. Vibinth  
U.G. Final Year Scholars, V.L.B.Janakiammal College of Engg. and Tech  
Coimbatore, India  
E-mail: vibinth@gmail.com

Abstract

Economic load dispatch (ELD) and economic emission dispatch (CEED) have been applied to obtain optimal fuel cost and optimal emission of generating units, respectively. Combined economic emission dispatch (CEED) problem is obtained by considering both the economy and emission objectives. This biobjective CEED problem is converted into a single objective function using a price penalty factor approach. A novel modified price penalty factor is proposed to solve the CEED problem. In this paper, results of evolutionary computation (EC) methods such as genetic algorithm (GA), micro GA (MGA) and
An Efficient Particle Swarm Optimization Technique to Solve Combined Economic Emission Dispatch Problem

Evolutionary programming (EP) are obtained and compared with the results obtained from EPSO to CEED problem solutions for three unit systems. Investigations showed that EPSO was better among EC methods in solving the CEED problem. The solutions obtained are quite encouraging and useful in economic emission environment.

Index Term: Combined Cycle Cogeneration plant, Combined economic emission dispatch, economic load dispatch, efficient particle swarm optimization, price penalty factor

1. Introduction
Combined Economic Emission Dispatch (CEED) 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. Previous efforts on solving CEED problems have employed various mathematical programming methods and optimization techniques. Eberhart and Kennedy, initially suggested a Particle Swarm Optimization (PSO) based on the analogy of swarm of bird and school of fish [2]. In PSO, each individual makes its decision based on its own experience together with other individual’s experiences. The individual particles are drawn stochastically towards the position of present velocity of each individual, their own previous best performance, and the best previous performance of their neighbours. Other methods such as gradient, newton, linear programming have also been applied to sole the dispatch problem[1]. The main advantages of the PSO algorithm are summarized as: simple concept, easy implementation, and computational efficiency when compared with mathematical algorithm and other heuristic optimization techniques. The cost function is considered to be quadratic in form, however the fuel cost functions are non linear with valve point effects[4]. The objective function is not only confined to valve point effect but in general described as the superposition of sinusoidal and quadratic functions.[8].

The practical CEED problems with valve-point loading effects are represented as a non smooth optimization problem with equality and inequality constraints. To solve this problem, many salient methods have been proposed such as dynamic programming, evolutionary programming, neural network approaches, and genetic algorithm. In this paper, an alternative approach is proposed to the non smooth CEED problem using an Efficient PSO (EPSO), which focuses on the treatment of the equality and inequality constraints when modifying each individual’s search. The equality constraint is easily satisfied by specifying a variable at random in each iteration as a slag generator whose value is determined by the difference between the total system demand and the total generation excluding the slag generator. However, the inequality constraints in the next position of an individual produced by the PSO algorithm can violate the inequality constraints. In this case, the position of any individual violating the constraints is set to maximum or minimum depending on velocity evaluated.

2. Combined Economic Emission Dispatch
In this concept of combined economic emission dispatch, the various parameters of economic dispatch and emission dispatch are combined together to increase the efficiency of operation of the generating units. The economic dispatch refers to the optimal operation of a generating unit producing maximum values of output possible with minimum input values. The emission dispatch process refers to the minimizing the useful energy values lost as emission. The load requirement is divided among a number of units to operate variably as per the load demand at different period of time[3].

The operational efficiency increases in the second case as the various units are operated nearly to their maximum capacity values. Taking the emission dispatch problem also into consideration, the use of Combined Cycle Co-generation plant (CCCP) is done here. The advantage of using a CCCP is here it takes in the exhaust emission of other units and operates on it without or with less additional
input values thus increasing the overall efficiency. The fuel cost characteristics of CCCP is found to be non-smooth and non differentiable[5],[6].

2.1. Problem Formulation

The total fuel cost has been analysed and recorded using EPSO method. The fuel cost calculated is used in the calculation of Emission values and the parameters are similar. The biobjective combined economic emission dispatch problem is converted into single optimization problem by introducing price penalty factor $h$ as follows:

$$\text{Cost} = \text{Fuel cost} + h \times \text{Emission value} \$/hr.$$  \hspace{1cm} (2.1)

The price penalty factor $h$ blends the emission with fuel cost and the fuel cost is the total operating cost in US dollars per hour. The price penalty factor $h$ is the ratio between the maximum fuel cost and maximum emission of corresponding generator.

The following steps are used to find the price penalty factor for a particular load demand.

- Find the ratio between maximum fuel cost and maximum emission of each generator.
- Arrange the values of price penalty factor in ascending order.
- Add the maximum capacity of each unit one at a time, starting from the smallest $h$ unit, until generated value is greater than demand.
- At this stage $h$ associated with the last unit is the price penalty factor $h$ for the given load.

The procedure just shown gives the approximate value of price penalty factor computation for the corresponding load demand.

2.2. Fuel Cost Function

The Fuel Cost (FC) function of generating unit is usually described by a quadratic function of power output $P_i$ as:

$$\text{FC} = \alpha_i P_i^2 + b_i P_i + c_i \$/hr.$$  \hspace{1cm} (2.1)

where $\alpha_i, b_i, c_i$ are the cost coefficients of the unit $i$.

2.3. Emission Function

Emission(E) equation of a generating unit is usually described by a quadratic function of power output $P_i$ as:

$$\text{E} = d_i P_i^2 + e_i P_i + f_i \text{ lb/hr.}$$  \hspace{1cm} (2.2)

where $d_i$, $e_i$, $f_i$ are the emission coefficients relating to alpha, beta and gamma.

2.4. Emission Constrained Cost Equation

The Emission constrained cost equation is now formulated as:

$$\text{TC} = (\alpha_i P_i^2 + b_i P_i + c_i) + h(d_i P_i^2 + e_i P_i + f_i) \$/hr.$$  \hspace{1cm} (2.3)

Here the emission factor is found to influence the Total Cost (TC) and the variation of the value is controlled by the price penalty factor. The product of the emission value calculated and price penalty factor decides the cost function of emission.

2.5. Power Balance Constraints

The total generation must supply the demand

$$\sum P_g (i) = P_d$$  \hspace{1cm} (2.4)

where, $P_g (i)$ and $P_d$ are the generated value of $i^{th}$ unit and the demand respectively.
3. Softcomputing Techniques

CEED in Power System deals with the determination of optimum generation schedule of available generators so that total cost of generation is minimized within the system constraint. Several classical optimization techniques such as lambda-iteration method, gradient method, Newton’s method, linear programming, Interior point method and dynamic programming have been used to solve the basic economic dispatch problem. Lambda iteration method has the difficulty of adjusting lambda for complex cost functions. Gradient methods suffer from the problem of convergence in the presence of inequality constraints. Newton’s method is very much sensitive to the selection of initial conditions. Linear programming approach provides optimal results in less computational time but results are not accurate due to linearization of the problem. Interior point method is faster than linear programming but it may provide infeasible solution if the step size is not chosen properly. Dynamic programming suffers from curse of dimensionality. Most of the classical optimization techniques need derivative information of the objective function to determine the search direction. Recently some heuristic techniques such as genetic algorithm, genetic algorithm combined with simulated annealing, evolutionary programming, improved tabu search, ant swarm optimization and particle swarm optimization and efficient particle swarm optimization have been used to solve the complex non-linear optimization problem. Some of the algorithms are explained below and results of all algorithms are compared.

3.1. Efficient Particle Swarm Optimization

Efficient Particle swarm optimization (EPSO) is a method for performing numerical optimization without explicit knowledge of the gradient of the problem to be optimized. PSO is originally attributed to Kennedy, Eberhart and Shi and was first intended for simulating social behaviour. The algorithm was simplified and it was observed to be performing optimization. The intelligence.. EPSO optimizes a problem by maintaining a population of candidate solutions called particles and moving these particles around in the search-space according to simple formulae. The movements of the particles are guided by the best found positions in the search-space, which are continually updated as better positions are found by the particles.

3.2. EPSO Control Parameters

(i) **Number of Particles**
   The typical range of the number of particles is 20-40. Actually for most of the problems 10 particles is large enough to get good results. For some difficult or special problems, one can try 100 or 200 particles as well.

(ii) **Dimension of Particles**
    Dimension of particles is determined by the problem to be optimized.

(iii) **Maximum Velocity**
    \( V_{max} \) determines the maximum change that one particle can take during each iteration.

(iv) **Acceleration Constants**
    The acceleration coefficients should be set sufficiently high. Higher acceleration coefficients result in less stable systems in which the velocity has a tendency to explode. To fix this, the velocity \( V_i \) is usually kept within the range of \([V_{max}, V_{max}]\). However, other settings were also used in different papers.

(v) **Stopping Condition**
    The maximum numbers of iterations that PSO executes or the minimum error requirement are the stopping conditions.

(vi) **Inertia Weight**
    The weight factor \( W \) in equation is given by,
Suitable selection of inertia weight in above equation provides a balance between global and local explorations, thus requiring less number of iterations on an average to find a sufficient optimal solution. As originally developed, inertia weight often decreases linearly from about 0.9 to 0.4 during a run.

4. Simulation Results and Discussion

The solution for CEED problem has been dealt for three unit systems with different computational methods and cost value has been determined in many previous trials by research scholars. Computer programs were developed for GA and MGA to solve CEED problem. To determine the effectiveness of EC methods, the results of the conventional methods were compared with EC methods such as GA, MGA and EP. EPSO was found better than other methods.

4.1. Three Unit System

The input data for standard three unit system is given in Table 4.1. EPSO has provided the global solution with very high probability exactly satisfying equality and inequality constraints.

<table>
<thead>
<tr>
<th>Unit</th>
<th>(a_i)</th>
<th>(b_i)</th>
<th>(c_i)</th>
<th>(e_i)</th>
<th>(f_i)</th>
<th>(P_{\text{min}})</th>
<th>(P_{\text{max}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>561</td>
<td>7.92</td>
<td>0.001562</td>
<td>300</td>
<td>0.0315</td>
<td>100</td>
<td>600</td>
</tr>
<tr>
<td>2</td>
<td>310</td>
<td>7.85</td>
<td>0.001940</td>
<td>200</td>
<td>0.0420</td>
<td>100</td>
<td>400</td>
</tr>
<tr>
<td>3</td>
<td>78</td>
<td>7.97</td>
<td>0.004820</td>
<td>150</td>
<td>0.0630</td>
<td>50</td>
<td>200</td>
</tr>
</tbody>
</table>

The results of three unit system obtained through EPSO method for the purpose of optimization and considering the CEED problem is as shown below in Table 4.2. and the convergence plot for the same is also shown below in fig.4.1.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Method</th>
<th>(P_a) (MW)</th>
<th>(P_1) (MW)</th>
<th>(P_2) (MW)</th>
<th>(P_3) (MW)</th>
<th>Fuel Cost $/hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DP [3]</td>
<td>869</td>
<td>328</td>
<td>374</td>
<td>182</td>
<td>8407</td>
</tr>
<tr>
<td></td>
<td>GA [3]</td>
<td></td>
<td>434</td>
<td>277</td>
<td>177</td>
<td>8398</td>
</tr>
<tr>
<td></td>
<td>MGA[3]</td>
<td></td>
<td>399</td>
<td>310</td>
<td>176</td>
<td>8368</td>
</tr>
<tr>
<td></td>
<td>EPSO</td>
<td>362</td>
<td>324</td>
<td>188</td>
<td></td>
<td>8277</td>
</tr>
<tr>
<td></td>
<td>GA[3]</td>
<td></td>
<td>216</td>
<td>387</td>
<td>82</td>
<td>6639</td>
</tr>
<tr>
<td></td>
<td>MGA[3]</td>
<td></td>
<td>356</td>
<td>252</td>
<td>83</td>
<td>6625</td>
</tr>
<tr>
<td></td>
<td>EPSO</td>
<td>283</td>
<td>254</td>
<td>147</td>
<td></td>
<td>6477</td>
</tr>
</tbody>
</table>
Figure 4.1: Convergence plot of CEED for 3-Unit system using EPSO ($P_d=869$ MW).

From the results, it is inferred that, the optimal solution of EPSO is better than any other methods and results in a saving of cost.

5. Conclusion
The EPSO algorithm was tested for CEED problem and the results were presented for comparison with various test systems such as GA, DP, MGA and EP. Results showed that EPSO method is well suited for obtaining the best solution for fuel cost functions. Savings of approximately U.S.$ 50/h and above were obtained by applying EPSO method for the test system containing CCCP. The combined economic emission dispatch results were compared with those obtained from classical technique and sequential quadratic programming technique to validate the effectiveness of the proposed algorithm. The validation of modified price penalty factor to solve CEED problem corresponding to the load demands was carried out to obtain exact best solution. The effectiveness of EPSO with nonlinear scaling factor to obtain best values was illustrated.

References
[3] Comparison and application of evolutionary programming technique to CEED with line flow constraints, P.Venkatesh, R.Gnanadass, Narayana Prasad Padhy.