Artificial Intelligence Techniques For Optimum Allocation of Generating Units

Chinmaya Ranjan Pradhan, Soumya Ranjita Nayak

Abstract— Economic load dispatch (ELD) is a sub problem of the optimal power flow (OPF) having the objective of fuel cost minimization. The fuel cost equation of a thermal plant is generally expressed as continuous quadratic equation. In real situations the fuel cost equations can be discontinuous. Recent advancements in artificial intelligence especially in evolutionary algorithms have enabled much efficient way to solve the constrained optimization problems in various fields of engineering. In this paper we applied Particle Swarm optimization (PSO) technique to a 3-generator test system having continuous fuel cost equations. Results are compared to conventional quadratic programming method to show the superiority of the proposed computational intelligence technique.

Index Terms— Economic Load Dispatch, Fuel Cost, Particle Swarm Optimization (PSO), Quadratic Programming

1 INTRODUCTION

Economic load dispatch is defined as the process of allocating generation levels to the generating units in the mix, so that the system load is supplied entirely and most economically. Economic load dispatch (ELD) is a sub problem of the optimal power flow (OPF) having the objective of fuel cost minimization. The classical solutions for ELD problems have used equal incremental cost criterion for the loss-less system and use of penalty factors for considering the system losses. The lambda-iterative method has been used for ELD. Many other methods such as gradient methods, Newton’s methods, linear and quadratic programming, etc have also been applied to the solution of ELD problems. However, all these methods are based on assumption of continuity and differentiability of cost functions. Hence, the cost functions have been approximated in the differentiable form, mostly in the quadratic form. Further, these methods also suffer on two main counts. One is their inability to provide global optimal solution and getting stuck at local optima. The second problem is handling the integer or discrete variables. In recent years, one of the most promising research fields has been “Evolutionary Techniques”, an area utilizing analogies with nature or social systems. Evolutionary techniques are finding popularity within research community as design tools and problem solvers because of their versatility and ability to optimize in complex multimodal search spaces applied to non-differentiable cost functions. Recently, genetic algorithm (GA) and particle swarm optimization (PSO) techniques appeared as promising algorithms for handling the optimization problems. These techniques are finding popularity within research community as design tools and problem solvers because of their versatility and ability to optimize in complex multimodal search spaces applied to non-differentiable cost functions. Particle Swarm Optimization (PSO) is inspired by the ability of flocks of birds, schools of fish, and herds of animals to adapt to their environment, find rich sources of food, and avoid predators by implementing an information sharing approach. PSO technique was invented in the mid 1990s while attempting to simulate the choreographed, graceful motion of swarms of birds as part of a sociocognitive study investigating the notion of collective intelligence in biological populations. In PSO, a set of randomly generated solutions propagates in the design space towards the optimal solution over a number of iterations based on large amount of information about the design space that is assimilated and shared by all members of the swarm.

PROBLEM STATEMENT

The basic economic dispatch problem can described mathematically as a minimization of problem of minimizing the total fuel cost of all committed plants subject to the constraints.

\[
\text{Min} F = \sum_{i=1}^{N} F_i(P_i) \tag{1}
\]

Subject to the constraints

\[
\sum_{i=1}^{N} P_i - P_D - P_L \leq 0, \quad i = 1, 2, ..., N \tag{2}
\]

Where

- \( F = \) Total operating cost
- \( N = \) Number of generating units
- \( P_i = \) Power output of \( i \) th generating unit
- \( F_i(P_i) = \) Fuel cost function of \( i \) th Generating unit
- \( P_D = \) Total load demand
- \( P_L = \) Total losses
- \( P_i_{\text{min}} = \) Minimum output power limit of \( i \) th generating unit
- \( P_i_{\text{max}} = \) Maximum output power limit of \( i \) th generating unit

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The total fuel cost is to be minimized subject to the constraints. The transmission loss can be determined from $B_{mn}$ coefficients. The conditions for optimality can be obtained by using Lagrangian multipliers method and Kuhn tucker conditions as follows:

$$2a_i P_i + b_i = \lambda (1 - 2) \sum_{j=1}^{N} (B_{ij}), i=1,2,\ldots, N \quad (4)$$

2. Genetic Algorithm

Genetic Algorithm (GA) was first introduced by John Holland of Michigan University in 1970’s. The GA is a stochastic global search method that mimics the metaphor of natural biological evolution such as selection, crossover, and mutation. The artificial principal is the Darwinians survival of fittest principal and genetic operation is abstracted from nature form a robust mechanism that is very effective at finding optimal solutions to complex real world problems.

The process of GA follows this pattern:

1) An initial population of a random solution is created.
2) Each member of the population is assigned a fitness value based on its evaluation against the current problem.
3) Solution with highest fitness value is most likely to parent new solutions during reproduction.
4) The new solution set replaces the old, a generation is completed and the process continues at step (2).

ALGORITHM FOR ECONOMIC LOAD DISPATCH USING PSO

The search procedure for calculating the optimal generation quantity of each unit is follows:

1. In the ELD problems the number of online generating units is the ‘dimension’ of this problem. The particles are randomly generated between the maximum and the minimum operating limits of the generators.
2. To each individual of the population calculate the dependent unit output from power balance.
3. Calculate the evaluation value of each particle $p_{gi}$ in the population using the evaluation function.
4. Compare each particle’s evaluation value with its $p_{best}$. The best evaluation value among them $p_{best}$ is identified as $g_{best}$.
5. Modify the velocity of each particle.
6. Check the velocity constraint of the members of each particle from the following:
   - If $V_{ij}^{n+1} > V_{ij}^{\text{max}}$, then $V_{ij}^{n+1} = V_{ij}^{\text{max}}$
   - If $V_{ij}^{n+1} < V_{ij}^{\text{min}}$, then $V_{ij}^{n+1} = V_{ij}^{\text{min}}$
7. Modify the position of each particle. $P_{ij}^{n+1}$ must satisfy the constraint, namely the generating limits. If $p_{ij}^{n+1}$ violate the constraints, then $p_{ij}^{n+1}$ must be modified towards the nearest margin of feasible solution.
8. If the evaluation value of each particle is better than previous $p{best}$, the current value is set to be $p{best}$. If the current value is set to be $p{best}$. If the best $p{best}$ is better than gbest, the best $p{best}$ is set to be gbest.
9. If the number of iterations reaches the maximum, then go to step 10. Otherwise, go to step 2.
10. The individual that generates the latest gbest is the optimal generation power of each unit with the minimum total generation cost.
4. Result and Discussion

CASE STUDY: 3 GENERATOR TEST SYSTEMS

The coefficient of fuel cost and maximum and minimum power limits are given in Table 1. The power demand is to be 850(MW). The results corresponding to GA and PSO are detailed in Section 2 and 3 respectively and the comparison of results of both methods shown in Table 4.

Table 1 Specification for three generator system

<table>
<thead>
<tr>
<th>Unit no.</th>
<th>$a_i$</th>
<th>$b_i$</th>
<th>$C_i$</th>
<th>$P_i^{min}$</th>
<th>$P_i^{max}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.001562</td>
<td>7.92</td>
<td>561</td>
<td>150</td>
<td>600</td>
</tr>
<tr>
<td>2</td>
<td>0.00194</td>
<td>7.85</td>
<td>310</td>
<td>100</td>
<td>400</td>
</tr>
<tr>
<td>3</td>
<td>0.00482</td>
<td>7.97</td>
<td>78</td>
<td>50</td>
<td>200</td>
</tr>
</tbody>
</table>

Table 2: Optimal results of GA

<table>
<thead>
<tr>
<th>$P_1$(MW)</th>
<th>393.0103</th>
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<tbody>
<tr>
<td>$P_2$(MW)</td>
<td>319.2256</td>
</tr>
<tr>
<td>$P_3$(MW)</td>
<td>137.7642</td>
</tr>
<tr>
<td>Total power</td>
<td>850.00</td>
</tr>
<tr>
<td>Total cost</td>
<td>8195.9790</td>
</tr>
</tbody>
</table>

Table 3: Optimal results of PSO

<table>
<thead>
<tr>
<th>$P_1$(MW)</th>
<th>387.9446</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_2$(MW)</td>
<td>340.52180</td>
</tr>
<tr>
<td>$P_3$(MW)</td>
<td>121.5336</td>
</tr>
<tr>
<td>Total power</td>
<td>850.0</td>
</tr>
<tr>
<td>Total cost</td>
<td>8194.45</td>
</tr>
</tbody>
</table>

Table 4: Comparison of GA and PSO

<table>
<thead>
<tr>
<th>Technique</th>
<th>Total Cost</th>
</tr>
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<tbody>
<tr>
<td>GA</td>
<td>8195.9790</td>
</tr>
<tr>
<td>PSO</td>
<td>8194.45</td>
</tr>
</tbody>
</table>

5. CONCLUSION

Genetic algorithm and particle swarm optimization have been successfully introduced to obtain the optimum solution of Economic Load Dispatch. Power system has large variation in load from time to time and it is not possible to have the load dispatch for every possible load demand as there is no general procedure for finding out optimum solution of economic load dispatch. This is where PSO plays an important role to find out optimum solution in a fraction of second.

6. ACKNOWLEDGMENT

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7. REFERENCES


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