A NEW APPROACH TO SOLVE ECONOMIC LOAD DISPATCH USING PARTICLE SWARM OPTIMIZATION

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ABSTRACT
This paper presents a new approach to economic load dispatch (ELD) problems using a particle swarm optimization (PSO). In practice, ELD problems have objective functions with equality and inequality constraints that make it difficult to find the global optimum using any mathematical approaches. In this paper, a new PSO technique is suggested to deal with the equality and inequality constraints in ELD problems. The algorithm has been implemented using MATLAB optimization toolbox and tested on a ten generating unit system.

Index Terms: Particle swarm optimization, Economic dispatch, fuel cost function, Power demand.

1. INTRODUCTION
Most of power system optimization problems including economic dispatch (ED) have complex and nonlinear characteristics with heavy equality and inequality constraints. Recently, as an alternative to the conventional mathematical approaches, the heuristic optimization techniques such as genetic algorithms, Tabu search, simulated annealing, and recently-introduced particle swarm optimization (PSO) are considered as realistic and powerful solution schemes to obtain the global or quasiglobal optimums in power system optimization problems [1]. Recently, Eberhart and Kennedy suggested a particle swarm optimization (PSO) based on the analogy of swarm of bird and school of fish [2]. The PSO mimics the behaviour of individuals in a swarm to maximize the survival of the species. In PSO, each individual makes his decision using his own experience together with other individuals’ experiences [1]. Economic Dispatch (ED) optimization problem is the most important issue which is to be taken into consideration in power systems. The concept of economic dispatch suggests that the distribution among the different units can be done such that the total cost of production is minimized. The demand is not met by a single generating unit. Many generating units share the load and thus the total generation capacity is thus achieved by the individual generations put together. The economic dispatch problem in a power system is to determine the optimal combination of power outputs for all generating units which will minimize the total fuel cost while satisfying load and operational constraints. The solution of economic dispatch problems using genetic algorithm required a large number of generations when the power generating system has the large number of units. A number of conventional optimization techniques have been applied to solve the ED problem such as linear Programming (LP) [3], nonlinear programming (NLP) [4], quadratic programming (QP) [5], and interior point methods [6]. Partial swarm optimization (PSO) is one of the modern heuristic algorithms, which can be used to solve nonlinear and non-continuous optimization problems [7]. It is a population-based search algorithm and searches in parallel using a group of particles similar to other AI-based heuristic optimization techniques. The original PSO suggested by Kennedy and Eberhart is based on the analogy of swarm of bird and school of fish [4]. Each particle in PSO makes its decision using its own experience and its neighbor’s experiences for evolution. That is, particles approach to the optimum through its present velocity, previous experience, and the best experience of its neighbors [7].

The main objective of this study is to introduce the use of Particle Swarm Optimization (PSO) technique to the subject of power system economic load dispatch. In this paper, the PSO method has been employed to solve economic dispatch problem with valve point loading effect.

2. FORMULATION OF ED PROBLEM
2.1 Objective Function
The generating units should be loaded in such a way that minimizes the total fuel cost while satisfying the power balance and other constraints. The simplified cost function of each generator can be represented as a quadratic function as described in (1).

\[ F_T = \sum_{i=1}^{N} F_i(P_i) \]  

(1)

\[ F_i(P_i) = a_i + b_iP_i + c_iP_i^2 \]  

(2)
In a PSO system, particles fly around in a multidimensional search space. During flight, each particle adjusts its position (searching point in the solution space) can be modified by the following equation. [Equation]

\[ v_{ij}^{t+1} = w \times v_{ij}^t + C_1 \times R_1 \times (P_{best} - X_{ij}^t) + C_2 \times R_2 \times (G_{best} - X_{ij}^t) \]

Where, 
- \( F_D \) Total generation cost. 
- \( F_G \) Cost function of generator \( i \). 
- \( C_1, C_2 \) cost coefficients of generator \( i \). 
- \( P_i \) Power of generator \( i \). 
- \( N \) number of generators.

### 2.2 Equality and Inequality Constraints

#### 2.2.1 Equality Constraints

The total generated power should be the same as total load demand plus the total line loss.

\[ \sum_{i=1}^{N} P_i = P_D + P_{line} \]  \hspace{1cm} (3)

Where \( P_D \) the total demand and \( P_{line} \) is the total line loss.

The exact value of the system losses can only be determined by means of a power flow solution. The most popular approach for finding an approximate value of the losses is by way of Kron’s loss formula (4), which approximates the losses as a function of the output level of the system generators.

\[ L = B_{00} + \sum_{j} B_{0j} P_j + \sum_{j} \sum_{k} B_{jk} P_j P_k + B_{dd} N \]

Where, 
- \( B_{00}, B_{0j}, B_{dd} \) are the loss coefficients which are constant under certain assumed conditions.

#### 2.2.2 Inequality Constraints

Generation output of each generator should be laid between maximum and minimum limits. The corresponding inequality constraints for each generator are:

\[ P_{i_{min}} \leq P_i \leq P_{i_{max}} \]  \hspace{1cm} (5)

Where \( P_{i_{min}} \) and \( P_{i_{max}} \) are the minimum and maximum output of generator \( i \), respectively.

### 3. IMPLEMENTATION OF PSO FOR ED PROBLEMS

#### 3.1 Particle Swarm Optimization

Particle swarm optimization (PSO) is a population-based optimization method first proposed by Kennedy and Eberhart in 1995, inspired by social behaviour of bird flocking or fish schooling. The PSO as an optimization tool provides a population-based search procedure in which individuals called particles change their position (state) with time. In a PSO system, particles fly around in a multidimensional search space. During flight, each particle adjusts its position according to its own experience (This value is called pbest), and according to the experience of a neighboring particle (This value is called gbest), made use of the best position encountered by itself and its neighbor (Fig.1).

![Concept of a searching point by PSO](image)

This modification can be represented by the concept of velocity. Velocity of each agent can be modified by the following equation:

\[ v_{ij}^{t+1} = w \times v_{ij}^t + C_1 \times R_1 \times (P_{best} - X_{ij}^t) + C_2 \times R_2 \times (G_{best} - X_{ij}^t) \]

Using the above equation, a certain velocity, which gradually gets close to pbest and gbest, can be calculated. The current position (searching point in the solution space) can be modified by the following equation.

\[ X_{ij}^{t+1} = X_{ij}^t + \sum_{\epsilon = 1,2,\ldots, NP} \sum_{f = 1,2,\ldots, NG} v_{ij}^{t+1 \epsilon} \]

Where, 
- \( NP \) is the number of particles in a group. 
- \( NG \) is the number of members in particles.
\( w \) is the pointer of iterations (generations).

\( w \) is the inertia weight factor.

\( C_1 \) and \( C_2 \) are the acceleration constant.

\( R_1 \) and \( R_2 \) are uniform random values in the range \([0, 1]\).

\( v_{ji}^{r} \) is the velocity of \( j \)th member of \( i \)th particle at \( r \)th iteration.

\( P_{ji}^{r} \) is the current position of \( j \)th member of \( i \)th particle at \( r \)th iteration.

Suitable selection of inertia weight \( w \) provides a balance between global and local explorations, thus requiring less iteration on average to find a sufficiently optimal solution. As originally developed, \( w \) often decreases linearly from about 0.9 to 0.4 during a run. In general, the inertia weight \( w \) is set according to the following equation [4].

\[
    w = w^{\text{max}} - \frac{w^{\text{max}} - w^{\text{min}}}{IT^{\text{max}}} \times IT
\]

Where,

\( IT^{\text{max}} \) is the maximum number of iterations (generations).

\( IT \) is the current number of iterations.

3.2 Applied to Optimal Power Flow.

In this section, a new approach to implement the PSO algorithm will be described in solving the ED problems. Especially, a suggestion will be given on how to deal with the equality and inequality constraints of the ED problems when modifying each individual’s search point in the PSO algorithm. To minimize \( F \) is equivalent to getting a minimum fitness value in the searching process. The particle that has lower cost function should be assigned a larger fitness value.

The PSO-based approach for solving the OPF problem to minimize the cost takes the following steps:

Step 1: Randomly generated initial population.

Step 2: For each particle, the construction operators are applied.

Step 3: The PSO is applied to each particle.

Step 4: Fitness function evaluation.

Step 5: Compare particles fitness function and determine pbest and gbest.

Step 6: Change of particles velocity and position according to (6) and (7) respectively.

Step 7: If the iteration number reaches the maximum limit, go to.

Step 8: Otherwise, set iteration index \( k = k + 1 \), and go back to Step 2.

Step 8: Print out the optimal solution to the target problem.

![Figure 2. Flow diagram of particle swarm optimization.](image)
4. SIMULATION RESULTS AND DISCUSSION
The proposed PSO algorithm is tested on standard 10 generating units. The test system consists of 10 thermal units without losses (Table 1) for twenty four hours load. The optimal setting of the PSO control parameters are: c1=2, c2=2, numbers of particles is 10 and number of iterations is 100. The Inertia weight was kept between 0.4 and 0.9.

Table 1: Ten-unit generator characteristics.

<table>
<thead>
<tr>
<th>Hours</th>
<th>Without losses P(MW)</th>
<th>With losses P(MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5600</td>
<td>20.1910</td>
</tr>
<tr>
<td>2</td>
<td>0.5895</td>
<td>25.4732</td>
</tr>
<tr>
<td>3</td>
<td>0.6593</td>
<td>33.1569</td>
</tr>
<tr>
<td>4</td>
<td>0.7322</td>
<td>41.1007</td>
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<tr>
<td>5</td>
<td>0.7700</td>
<td>45.5406</td>
</tr>
<tr>
<td>6</td>
<td>0.8489</td>
<td>55.6869</td>
</tr>
<tr>
<td>7</td>
<td>0.8886</td>
<td>63.9678</td>
</tr>
<tr>
<td>8</td>
<td>0.9285</td>
<td>68.9701</td>
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<tr>
<td>9</td>
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<td>80.4268</td>
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<tr>
<td>10</td>
<td>1.1314</td>
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<td>11</td>
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<td>14</td>
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<td>23</td>
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<td>24</td>
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<td>Total Cost</td>
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<tr>
<td>CPU Time</td>
<td>6.368598</td>
<td>16.488173</td>
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<tr>
<td>Losses</td>
<td>-------</td>
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Figure 3. Convergence curve for Test problem.
5. CONCLUSION
The objective function is minimized based on efficient Particle Swarm Optimization. The effectiveness of the proposed algorithm has been tested on the 10 generating units with and without considering losses. Results show that the total cost increased as considering the case of including losses. The PSO is successfully and effectively implemented to find the optimal solution that the total cost is minimized.

REFERENCE

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