Moderate Random PSO Using For Economic Load Dispatch

Nagendra Singh
Dept. of Electrical Engineering
Mewar University
Chittorgrah, India

Yogendra Kumar
Dept. of Electrical Engineering
MANIT
Bhopal, India

Abstract
Economic load dispatch (ELD) is an important optimization task in power system. It is the process of allocating generation among the committed units such that the constraints imposed are satisfied and the fuel cost is minimized. Particle swarm optimization (PSO) is a population-based optimization technique that can be applied to a wide range of problems but it lacks global search ability in the last stage of iterations. This paper used a novel PSO with a moderate-random-search strategy (MRPSO), which enhances the ability of particles to explore the solution spaces more effectively and increases their convergence rates. In this paper the usefulness of the MRPSO algorithm to solve the ELD problem is demonstrated through its application to three, six and fifteen generator systems with ramp rate limit constraints. The result shows MRPSO work efficiently and give optimal solution.

Key words:- ELD, Ramp rate, PSO, MRPSO.

1. Introduction
Electric utility system is interconnected to achieve the benefits of minimum production cost, maximum reliability and better operating conditions. The economic scheduling is the on-line economic load dispatch, wherein it is required to distribute the load among the generating units, in such a way as to minimize the total operating cost of generating units while satisfying system equality and inequality constraints. For any specified load condition, ELD determines the power output of each plant (and each generating unit within the plant) which will minimize the overall cost of fuel needed to serve the system load [1]. ELD is used in real-time energy management power system control by most programs to allocate the total generation among the available units. ELD focuses upon coordinating the production cost at all power plants operating on the system.

Conventional as well as modern methods have been used for solving economic load dispatch problem employing different objective functions. Various conventional methods like lambda iteration method, gradient-based method, Bundle method [2], Nonlinear programming [3], Mixed integer linear programming [4], Dynamic programming [7], Linear programming [6], Quadratic programming [8], Lagrange relaxation method [9], Newton-based techniques [10] and Interior point methods [5], reported in the literature are used to solve such problems.

Conventional methods have many draw back such as nonlinear programming has algorithmic complexity. Linear programming methods are fast and reliable but require linearization of objective function as well as constraints with non-negative variables. Quadratic programming is a special form of nonlinear programming which has some disadvantages associated with piecewise quadratic cost approximation. Newton-based method has a drawback of the convergence characteristics that are sensitive to initial conditions. The interior point method is computationally efficient but suffers from bad initial termination and optimality criteria.

Recently, different heuristic approaches have been proved to be effective with promising performance, such as evolutionary programming (EP) [11], simulated annealing (SA) [12], Tabu Search (TS) [13], pattern search (PS) [14], Genetic algorithm (GA) [15], [16], Differential evolution (DE) [17], Ant colony optimization [18], Neural network [19], particle swarm optimization (PSO) [20], [21], [22], SOHPSO[23], Modified PSO[24], classical PSO[26], MRPSO[27], WIPOSO[28], MOPSO[29]. Although the heuristic methods do not always guarantee discovering globally optimal solutions in finite time, they often provide a fast and reasonable solution. EP is rather slow converging to a near optimum for some problems. SA is very time consuming, and cannot be utilized easily to tune the control parameters of the annealing schedule. TS is difficult in
defining effective memory structures and strategies which are problem dependent. GA sometimes lacks a strong capacity of producing better offspring and causes slow convergence near global optimum, sometimes may be trapped into local optimum. DE greedy updating principle and intrinsic differential property usually lead the computing process to be trapped at local optima.

Particle-swarm-optimization (PSO) method is a population-based Evolutionary technique and it is inspired by the emergent motion of a flock of birds searching for food. In comparison with other EAs such as GAs and evolutionary programming, the PSO has comparable or even superior search performance with faster and more stable convergence rates but its lacks global search ability in the last stage of iterations. This problem can be solved by using moderate random search technique with PSO. In this paper we used MRPSO to solve the ELD problem. It enhance the global search ability and gives more opportunity of the particles to explore the solution space than is standard PSO.

The proposed method focuses on solving the economic load dispatch with Generator Ramp Rate Limits constraint. The feasibility of the proposed method was demonstrated for three, six and fifteen bus system. The results are obtained through the proposed approach and compared with other PSO methods reported in recent literatures.

2. Economic Dispatch problem Formulation

2.1. Basic formulation of ED

ED is one of the most important problem to be solved in the operation and planning of a power system, the primary concern of an ED problem is the minimization the total cost of generation(objective function) in such a way that meets the demand and satisfies all constraints associated is selected as the objective function.

The ED problem objective function is formulated mathematically in (1) and (2).

\[ F_T = \text{Min} \, f(\text{FC}) \]  
\[ \text{FC} = \sum_{i=1}^{n} a_i \times \text{P}_i^2 + b_i \times \text{P}_i + c_i \]  
\[ D = \sum_{i=1}^{n} \text{P}_i - \text{P}_D - \text{P}_L \]

Where, \( F_T \) is the objective function, \( a_i, b_i \) and \( c_i \) are the cost coefficients. \( D \) is power equilibrium; \( \text{P}_D \) and \( \text{P}_L \) represent total demand power and the total transmission loss of the transmission lines respectively.

2.2. Constraints

2.2.1 Real Power Balance Equation

For power balance, an equality constraint should be satisfied. The total generated power should be equal to total load demand plus the total losses,

\[ \sum_{i=1}^{n} \text{P}_i = \text{P}_{\text{Demand}} + \text{P}_L \]  
\[ \text{P}_L = \sum_{i=1}^{n} \sum_{j=1}^{n} \text{P}_{ij} \text{B}_{ij} + \sum_{i=1}^{n} \text{B}_{10} \text{P}_i + \text{B}_{00} \]

Where, \( \text{P}_{\text{Demand}} \) is the total system demand and \( \text{P}_L \) is the total line loss. \( \text{B}_{ij} \) =ijth element of loss coefficient symmetric matrix \( B \), \( \text{B}_{10} \) =ith element of the loss coefficient vector and \( \text{B}_{00} \) =loss coefficient constant.

2.2.2. Unit Operating Limits

There is a limit on the amount of power which a unit can deliver. The power output of any unit should not exceed its rating nor should it be below that necessary for stable operation. Generation output of each unit should lie between maximum and minimum limits.

\[ P_i^{\text{min}} \leq P_i \leq P_i^{\text{max}} \]  

Where, \( P_i \) is the output power of \( \text{i} \)th generator, \( P_i^{\text{min}} \) and \( P_i^{\text{max}} \) are the minimum and maximum power outputs of generator \( \text{i} \) respectively.

2.2.3. Ramp Rate Limit

According to the operating increases and operating decreases of the generators the ramp rate limit constraints described in eq. (7) & (8).

1) As generation increases

\[ P_i(t) + P_i(t - 1) \leq UR_i \]  

2) As generation decreases

\[ P_i(t - 1) - P_i(t) \geq DR_i \]  

When the generator ramp rate limits are considered, the operating limits for each unit, output is limited by time dependent ramp up/down rate at each hour as given below.

\[ \text{if}(t) = \text{max}(P_i^{\text{min}}, P_i(t - 1) - DR_i) \text{ and } P_i^{\text{max}}(t) = \text{min}(P_i^{\text{max}}, P_i(t - 1) - UR_i) \]

\[ P_i^{\text{min}}(t) \leq P_i(t) \leq P_i^{\text{max}}(t) \]

Where, \( P_i(t) \) = current output power of \( \text{i} \)th generating unit, \( P_i(t - 1) \) = Previous operating point of the \( \text{i} \)th generator, \( DR_i \) = Down ramp rate limit (MW/time period) and \( UR_i \) = Up ramp rate limit (MW/time period).
3. Overview of Some PSO Strategies

A number of different PSO strategies are being applied by researchers for solving the economic load dispatch problem and other power system problems. Here, a short review of the significant developments is presented which will serve as a performance measure for the MRPSO technique [27] applied in this paper.

3.1. Standard particle swarm optimization (PSO)

Particle swarm optimization was first introduced by Kennedy and Eberhart in the year 1995. It is an exciting new methodology in evolutionary computation and a population-based optimization tool. PSO is motivated from the simulation of the behavior of social systems such as fish schooling and birds flocking. It is a simple and powerful optimization tool which scatters random particles, i.e., solutions into the problem space. These particles, called swarms collect information from each array constructed by their respective positions. The particles update their positions using the velocity of particles. Position and velocity are both updated in a heuristic manner using guidance from particles’ own experience and the experience of its neighbors.

The position and velocity vectors of the ith particle of a d-dimensional search space can be represented as \( P_i = (p_{i1}, p_{i2}, \ldots, p_{id}) \) and \( V_i = (v_{i1}, v_{i2}, \ldots, v_{id}) \) respectively. On the basis of the value of the evaluation function, the best previous position of a particle is recorded and represented as \( \text{Pbest}_i = (p_{i1}, p_{i2}, \ldots, p_{id}) \). If the gth particle is the best among all particles in the group so far, it is represented as \( \text{gbest} = (p_{g1}, p_{g2}, \ldots, p_{gd}) \).

The particle updates its velocity and position using (10) and (11).

\[
V_i^{(k+1)} = W V_i^k + c_1 \text{Rand}_1() \times (\text{Pbest}_i - S_i^k) + c_2 \text{Rand}_2() \times (\text{gbest} - S_i^k) \\
S_i^{(k+1)} = S_i^k + V_i^{(k+1)} \tag{10}
\]

\[
\text{Where, } V_i^k \text{ is velocity of individual } i \text{ at iteration } k, \\
S_i^k \text{ is current position of individual } i \text{ at iteration } k, \\
P_{\text{best}}^i \text{ is the best position of individual } i \text{ and} \\
G_{\text{best}} \text{is the best position of the group.}
\]

The coefficients \( c_1 \) and \( c_2 \) pull each particle towards pbest and gbest positions. Low values of acceleration coefficients allow particles to roam far from the target regions, before being tugged back. On the other hand, high values result in abrupt movement towards or past the target regions. Hence, the acceleration coefficients \( c_1 \) and \( c_2 \) are often set to be 2 according to past experiences. The term \( c_1 \text{rand}_1() \times (\text{pbest} - S_i^k) \) is called particle memory influence or cognition part which represents the private thinking of the itself and the term \( c_2 \text{rand}_2() \times (\text{gbest} - S_i^k) \) is called swarm influence or the social part which represents the collaboration among the particles.

In the procedure of the particle swarm paradigm, the value of maximum allowed particle velocity \( V_{\text{max}} \) determines the resolution or fitness, with which regions are to be searched between the present position and the target position. If \( V_{\text{max}} \) is too high, particles may fly past good solutions. If \( V_{\text{max}} \) is too small, particles may not explore sufficiently beyond local solutions. Thus, the system parameter \( V_{\text{max}} \) has the beneficial effect of preventing explosion and scales the exploration of the particle search. The choice of a value for \( V_{\text{max}} \) is often set at 10-20% of the dynamic range of the variable for each problem.

\( W \) is the inertia weight parameter which provides a balance between global and local explorations, thus requiring less iteration on an average to find a sufficiently optimal solution. Since \( W \) decreases linearly from about 0.9 to 0.4 quite often during a run, the following weighing function is used in (10).

\[
W = W_{\text{max}} - \frac{(W_{\text{max}} - W_{\text{min}})}{\text{Iter}_{\text{max}}} \times \text{iter} \tag{12}
\]

Where, \( W_{\text{max}} \) is the initial weight, \( W_{\text{min}} \) is the final weight, \( \text{Iter}_{\text{max}} \) is the maximum iteration number and \( \text{iter} \) is the current iteration position.

3.2. CLASSICAL PSO

In this section, for getting better solution the standard PSO algorithm, used classical PSO [26]. The constriction factor is used in this algorithm given as

\[
C = \frac{2}{\left[1-\frac{c^2}{\phi^2} \right]} \tag{13}
\]

Where, \( \phi \) is define as 4.1≤\( \phi \)≤4.2

As \( \phi \) increases, the factor \( c \) decreases and convergence becomes slower because population diversity is reduced.

Now the update its velocity using (14).

\[
V_i^{(k+1)} = C [W V_i^k + c_1 \text{Rand}_1() \times (\text{Pbest}_i - S_i^k) + c_2 \text{Rand}_2() \times (\text{gbest} - S_i^k)] \\
\]  

\[
\text{(14)}
\]

3.3. WEIGHT IMPROVED PSO (WIPSO)

In this section, for getting the better global solution, the traditional PSO algorithm is improved by adjusting the weight parameter, cognitive and social factors. Based on the velocity of individual \( i \) of WIPSO algorithm [28] is rewritten as,

\[
V_i^{(k+1)} = w_{new} V_i^k + c_1 \text{Rand}_1() \times (\text{Pbest}_i - S_i^k) + c_2 \text{Rand}_2() \times (\text{gbest} - S_i^k) \tag{15}
\]

www.ijert.org
Step1: Initialization of the swarm: For a population size of the generators.

Step2: Initialize velocity and position for all particles by randomly set to within their legal range.

Step3: Set generation counter t=1.

Step4: Evaluate the fitness for each particle according to the objective function.

Step5: Compare particles fitness evaluation with its Pbest and Gbest.

Step6: Update position by using (20).

Step7: Apply stopping criteria.

5. Case Study

5.1. Test Case I

The first test results are obtained for 3-generator systems in which all units with their ramp-rate limits. The unit characteristics data are given in Table 1. The load demand is 850 MW. The \( B \) loss coefficients are given in Table 2. The best solutions of the proposed MRPSO, PSO, CPSO & WIPSO methods are shown in Table 6.

<table>
<thead>
<tr>
<th>Unit</th>
<th>( a_i )</th>
<th>( b_i )</th>
<th>( c_i )</th>
<th>( F_{\text{min}} )</th>
<th>( F_{\text{max}} )</th>
<th>( P_i )</th>
<th>( UR_i )</th>
<th>( DR_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.004820</td>
<td>7.97</td>
<td>78</td>
<td>200</td>
<td>50</td>
<td>170</td>
<td>50</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>0.001940</td>
<td>7.85</td>
<td>310</td>
<td>400</td>
<td>100</td>
<td>350</td>
<td>80</td>
<td>120</td>
</tr>
<tr>
<td>3</td>
<td>0.001562</td>
<td>7.92</td>
<td>562</td>
<td>600</td>
<td>100</td>
<td>440</td>
<td>80</td>
<td>120</td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>B coefficient (in mw(^{-1})) for 3 generator system</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0006760</td>
</tr>
<tr>
<td>0.0000953</td>
</tr>
<tr>
<td>-0.0000507</td>
</tr>
</tbody>
</table>

Bio = [-0.007660, -0.00342, 0.01890] and \( Boo = 0.40357 \).

5.2. Test Case II

The second test results are obtained for six-generating unit system in which all units with their ramp-rate limits. This system supplies a 1263 MW load demand.

<table>
<thead>
<tr>
<th>Unit</th>
<th>( a_i )</th>
<th>( b_i )</th>
<th>( c_i )</th>
<th>( F_{\text{min}} )</th>
<th>( F_{\text{max}} )</th>
<th>( P_i )</th>
<th>( UR_i )</th>
<th>( DR_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>240</td>
<td>7</td>
<td>0.0070</td>
<td>100</td>
<td>500</td>
<td>440</td>
<td>80</td>
<td>120</td>
</tr>
<tr>
<td>2</td>
<td>200</td>
<td>10</td>
<td>0.0095</td>
<td>50</td>
<td>200</td>
<td>170</td>
<td>50</td>
<td>90</td>
</tr>
<tr>
<td>3</td>
<td>220</td>
<td>8.5</td>
<td>0.0090</td>
<td>80</td>
<td>300</td>
<td>200</td>
<td>65</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>200</td>
<td>11</td>
<td>0.0090</td>
<td>50</td>
<td>150</td>
<td>150</td>
<td>50</td>
<td>90</td>
</tr>
<tr>
<td>5</td>
<td>220</td>
<td>10.5</td>
<td>0.0080</td>
<td>50</td>
<td>200</td>
<td>190</td>
<td>50</td>
<td>90</td>
</tr>
<tr>
<td>6</td>
<td>190</td>
<td>12.0</td>
<td>0.0075</td>
<td>50</td>
<td>120</td>
<td>110</td>
<td>50</td>
<td>90</td>
</tr>
</tbody>
</table>
The data for the individual units are given in Table 3. The $B$ matrix of the transmission loss coefficient is given in Table 4. The best solutions of the proposed MRPSO, PSO, CPSO and WIPSO methods are shown in Table 7.

The data for the individual units are given in Table 6. The best solutions of the proposed MRPSO, PSO, CPSO and WIPSO methods are shown in Table 8.

### Table 4

<table>
<thead>
<tr>
<th>Bi($10^{-5}$) coefficients (in mw$^2$) for six generator systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.17 0.12 0.7 -0.1 -0.5 0.02</td>
</tr>
<tr>
<td>0.12 0.14 0.09 0.01 -0.06 0.01</td>
</tr>
<tr>
<td>0.07 0.09 0.31 -0.00000 -0.10 0.06</td>
</tr>
<tr>
<td>-0.01 0.01 0.00000 2.4 -0.06 0.08</td>
</tr>
<tr>
<td>-0.05 -0.06 -0.10 -0.06 1.29 0.2</td>
</tr>
<tr>
<td>-0.02 -0.01 -0.06 -0.8 -0.2 1.50</td>
</tr>
</tbody>
</table>

### 5.3. Test Case III

The third test results are obtained for fifteen-generating unit system in which all units with their ramp-rate limits. This system supplies a 2650 MW load demand.

Table 5

Capacity, cost coefficients and ramp-rate limits of 6 generator systems.

<table>
<thead>
<tr>
<th>Unit</th>
<th>$a_i$</th>
<th>$b_i$</th>
<th>$c_i$</th>
<th>$d_i$</th>
<th>$e_i$</th>
<th>$f_i$</th>
<th>$p_i$</th>
<th>$U_{R_{ik}}$</th>
<th>$D_{R_{ik}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>671</td>
<td>10.1</td>
<td>0.000299</td>
<td>150</td>
<td>455</td>
<td>400</td>
<td>80</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>574</td>
<td>10.2</td>
<td>0.000183</td>
<td>150</td>
<td>455</td>
<td>300</td>
<td>80</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>374</td>
<td>8.8</td>
<td>0.001126</td>
<td>20</td>
<td>130</td>
<td>105</td>
<td>130</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>374</td>
<td>8.8</td>
<td>0.001126</td>
<td>20</td>
<td>130</td>
<td>105</td>
<td>130</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>461</td>
<td>10.4</td>
<td>0.000205</td>
<td>150</td>
<td>470</td>
<td>90</td>
<td>80</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>630</td>
<td>10.1</td>
<td>0.000301</td>
<td>135</td>
<td>460</td>
<td>400</td>
<td>80</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>548</td>
<td>9.8</td>
<td>0.000364</td>
<td>135</td>
<td>465</td>
<td>350</td>
<td>80</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>227</td>
<td>11.2</td>
<td>0.000338</td>
<td>60</td>
<td>300</td>
<td>95</td>
<td>65</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>173</td>
<td>11.2</td>
<td>0.000807</td>
<td>25</td>
<td>162</td>
<td>105</td>
<td>60</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>175</td>
<td>10.7</td>
<td>0.001203</td>
<td>25</td>
<td>160</td>
<td>110</td>
<td>60</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>186</td>
<td>10.2</td>
<td>0.003586</td>
<td>20</td>
<td>80</td>
<td>60</td>
<td>80</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>230</td>
<td>9.9</td>
<td>0.005513</td>
<td>20</td>
<td>80</td>
<td>40</td>
<td>80</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>225</td>
<td>13.1</td>
<td>0.000371</td>
<td>25</td>
<td>85</td>
<td>30</td>
<td>80</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>309</td>
<td>12.1</td>
<td>0.001929</td>
<td>15</td>
<td>55</td>
<td>20</td>
<td>55</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>323</td>
<td>12.4</td>
<td>0.004447</td>
<td>15</td>
<td>55</td>
<td>20</td>
<td>55</td>
<td>55</td>
<td></td>
</tr>
</tbody>
</table>

### Table 6

Results of Three generator system (100 trails)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Power Output</th>
<th>PSO</th>
<th>CPSO</th>
<th>WPSO</th>
<th>MRPSO</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>145.73</td>
<td>144.8978</td>
<td>146.408</td>
<td>143.34</td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>338.45</td>
<td>340.9597</td>
<td>343.45</td>
<td>346.45</td>
<td></td>
</tr>
<tr>
<td>P3</td>
<td>549.7817</td>
<td>547.8717</td>
<td>543.563</td>
<td>534.565</td>
<td></td>
</tr>
<tr>
<td>Power loss(MW)</td>
<td>183.043</td>
<td>183.7293</td>
<td>183.689</td>
<td>183.645</td>
<td></td>
</tr>
<tr>
<td>Total Power Output</td>
<td>1033.958</td>
<td>1033.7</td>
<td>1033.421</td>
<td>1033.355</td>
<td></td>
</tr>
<tr>
<td>Total Cost($/h)</td>
<td>9842.228</td>
<td>9839.228</td>
<td>9834.781</td>
<td>9833.605</td>
<td></td>
</tr>
<tr>
<td>Computation time (sec.)</td>
<td>0.368939</td>
<td>0.356130</td>
<td>0.479264</td>
<td>0.350648</td>
<td></td>
</tr>
</tbody>
</table>

### Table 7

Generator output for six generator system (100 trails)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Power Output</th>
<th>PSO</th>
<th>CPSO</th>
<th>WPSO</th>
<th>MRPSO</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>493.24</td>
<td>471.66</td>
<td>454.39</td>
<td>462.6651</td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>114.63</td>
<td>140.03</td>
<td>164.279</td>
<td>195.36</td>
<td></td>
</tr>
<tr>
<td>P3</td>
<td>263.41</td>
<td>240.06</td>
<td>246.223</td>
<td>237.2409</td>
<td></td>
</tr>
<tr>
<td>P4</td>
<td>139.71</td>
<td>149.97</td>
<td>123.21</td>
<td>98.00</td>
<td></td>
</tr>
<tr>
<td>P5</td>
<td>179.65</td>
<td>173.78</td>
<td>167.22</td>
<td>197.7415</td>
<td></td>
</tr>
<tr>
<td>P6</td>
<td>84.83</td>
<td>99.97</td>
<td>120.00</td>
<td>83.4235</td>
<td></td>
</tr>
<tr>
<td>Loss</td>
<td>12.22</td>
<td>12.38</td>
<td>12.24</td>
<td>12.11</td>
<td></td>
</tr>
<tr>
<td>Total Power Output</td>
<td>1275.46</td>
<td>1275.31</td>
<td>1275.3</td>
<td>1275.116</td>
<td></td>
</tr>
<tr>
<td>Total Cost($/h)</td>
<td>15489</td>
<td>15481.87</td>
<td>15453.13</td>
<td>15441.9</td>
<td></td>
</tr>
<tr>
<td>Computation Time(sec)</td>
<td>0.524359</td>
<td>0.479387</td>
<td>0.459492</td>
<td>0.464212</td>
<td></td>
</tr>
</tbody>
</table>

### 6. Result and Analysis

The Economic load dispatch problem solved by using the MRPSO and its performance is compared with PSO, CPSO and WIPSO. Data given for different generating units in Table 1, Table 3 and Table 5. The result obtained for these data by PSO, CPSO, WPSO and MRPSO. The program for these pso to solve ELD problem are developed in Matlab 7.5 on a 1.4-GHz, core-2 solo processor with 2GB DDR of RAM.

The constants used in this study was, acceleration coefficient $c_1=c_2=2$, $W_{max}=0.9$ and $W_{max}=0.4$.

The performance of MRPSO in this study the value of $\alpha$ taken 3.5.

The convergence behavior of MRPSO was tested for Economic load dispatch with ramp rate constraint on different cases. The first test case is taken for three-generating units, the data for first test case given in table 1, with ramp rate limit constraints. The B-coefficients are given in table 2 for calculation of power loss of the considered system. For testing of this case a total load of 850 MW was taken. The result obtained by PSO, CPSO, WIPSO and MRPSO is given in table 6. The result of test data shows the best value of cost in this test case calculated in table 6.
by MRPSO is $ 9833.605/h and its computation time is 0.350648 sec., total power loss calculated by MRPSO in this test case is 183.645 MW and obtained total generated output power is 1033.355 MW. All these result obtained for test case shows that MRPSO take less computing time and obtain least value of cost and loss of the 3 generating system.

The second test case is taken for six-generating units, the data for second test case given in table 3, with ramp rate limit constraints. The B-coefficients are given in table 4 for calculation of power loss of the considered system. For testing of this case a total load of 1250 MW was taken. The result obtained by PSO, CPSO, WIPSO and MRPSO is given in table 7. The result of test data shows the best value of cost in this test case calculated by MRPSO is $ 15441.9/h and its computation time is 0.464212 sec., total power loss calculated by MRPSO in this test case is 12.11 MW and obtained total generated output power is 1275.116 MW. All these result obtained for second test case shows that MRPSO take less computing time and obtain least value of cost and loss of the 6 generating system.

The third test case is taken for fifteen -generating units, the data for second test case given in table 5, with ramp rate limit constraints. In this case not considered the loss of the system. For testing of this case a total load of 2650 MW was taken. The result obtained by PSO, CPSO, WIPSO and MRPSO is given in table 8. The result of test data shows the best value of cost in this test case calculated by MRPSO is $ 32462.15/h and its computation time is 0.461147 sec., obtained total generated output power is 2650 MW. All these result obtained for third test case shows that MRPSO take less computing time and obtain least value of cost.

Table 8
| Generator output for 15 generator system (100 trails) |
|---------------------------------|--------|--------|--------|--------|
| **Unit Power Output** | **PSO** | **CPSO** | **WIPSO** | **MRPSO** |
| P1(MW)  | 454.3  | 454.98 | 455    | 422    |
| P2(MW)  | 452.8  | 455    | 448.3  | 455    |
| P3(MW)  | 132    | 130    | 130    | 131    |
| P4(MW)  | 129    | 130    | 130    | 131.6  |
| P5(MW)  | 336.9  | 335.02 | 265.02 | 341    |
| P6(MW)  | 423    | 424.25 | 460    | 460    |
| P7(MW)  | 462.5  | 464.98 | 465    | 465    |
| P8(MW)  | 61.7   | 60     | 62     | 70     |
| P9(MW)  | 24.9   | 25     | 25     | 21.6   |
| P10(MW) | 20.98  | 20     | 20     | 20     |
| P11(MW) | 19.08  | 20     | 59     | 20     |
| P12(MW) | 73.5   | 75     | 75     | 63.2   |
| P13(MW) | 25.08  | 25     | 25     | 20.6   |
| P14(MW) | 16.5   | 15     | 15     | 13.89  |
| P15(MW) | 17.06  | 15     | 15     | 15     |
| Total Power Output | 2649.30 | 2649.23 | 2649.32 | 2650.0 |
| Total Cost($/h) | 32476.7 | 32467.77 | 32464.03 | **32462.15** |
| Computation time (sec.) | 0.4821058 | 0.422924 | 0.613154 | 0.461147 |

Figure 1, figure 2 and figure 3 show the graph between object final V/s itermax in each iteration for the 3,6 and 15 generation unit system respectively.

7. Conclusion

In this paper MRPSO is used to solve the economic dispatch with ramp rate limit constraints. The test results obtained by MRPSO clearly demonstrated that it is capable of achieving global solution, it is computationally efficient and give better optimal results (minimum cost) than other PSO methods. Overall, the MRPSO algorithms have been shown to be very helpful in studying optimization problems in economic load dispatch problem.

REFERENCES


