Optimal Flow of Active Power with Pollution Control Using Multi-objective Particle Swarm Optimization Techniques

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**Abstract**  
This paper gives the solution of optimal power flow (OPF) problem of medium-sized power systems via an artificial intelligence algorithm. The objective is to minimize the total fuel cost of generation and environmental pollution caused by fossil based power generating units. System performance is also maintained by limiting generator real and reactive power outputs and power flow of transmission lines in acceptable limits. The power flow equations and load balance equation are considered as equality constraints. The performance analysis of this OPF problem using the Particle Swarm Optimization technique is carried out by checking various combinations of values of the associated parameters. The bi-objective problem of generation cost and emission dispatch is solved via weighted sum method for different combinations of weights and a multi-objective problem of minimizing power generation cost and flue gases (NOx, COx, SOx), is solved by a new algorithm named as Multi-Objective PSO (MOPSO) technique, to find out optimal solution and optimal value of weights. Simulation results for the IEEE 30-bus network with 6 generators system show that by proposed method, an optimum solution can be given quickly.

**Keywords**: Optimal power dispatch, Swarm Intelligence, Particle swarm optimization (PSO), Multi-Objective Particle swarm optimization (MOPSO), Pareto-Front technique.

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I. INTRODUCTION

Optimal active power dispatch problem is also known as an economic load dispatch problem which can be defined as “the process of allocating generation levels to the generating units, so that the entire system load is supplied most economically”. In economic dispatch strategy, the operating cost is reduced by proper allocation of the amount of power to be generated by units. With the development of our society power demand and per capita energy consumption has also increased. To deliver this demand power generation is increasing which also results in increased pollution. Now a days Indian government and power associations concentrating on the reduction of the amount of pollutants from fossil fuel power generating units. At present power engineers are facing problem of generating power in an effective manner to cope-up with load demand and minimize environmental hazards. Optimization is a good tool to handle such problems which is effectively used in areas of optimal power flow (OPF) such as Power system operation, planning, analysis and energy management. In power system operations and planning, OPF is the best option because it provides facility of handling the multi-objective functions. It also makes calculations and decision making fast and easier. So, here optimal power flow (OPF) is concerned with the minimization of economic generation and minimization of environmental harmful effects like gases extortion from power generating plant.

Today various computer based algorithms are available in mathematics to find the optimum solution of any linear or non-linear function. These algorithms are broadly classified as conventional and evolutionary techniques. Some of conventional methods like Gradient method (GM), Interior point method (IP), Linear programming (LP) have been proposed for the optimal power flow problem successfully[1,9]. But objective function of OPF problem is not a linear one and it is non-differential [10,11], So, the problem with conventional methods while solving the OPF problem is the solution may be local optimum, not a global optimum[9]. The second problem with conventional methods is, if the state variables are defined in very short range than solution may become infeasible[3]. Third problem with conventional methods is calculations of Lagrange Multipliers and step length is required[1]. To overcome these problems, Evolutionary Algorithms (EA) are introduced e.g. GA, PSO, ACO and Stochastic Algorithms (SA) etc. These all algorithms are nature inspired. These further classified as heuristic and meta-heuristic algorithms.

Alan Turing was the first who used heuristic algorithms in 1948. After that in the two decades, 1960s and 1970s Evolutionary Algorithms were developed. Today these algorithms are very popular to solve the real-world optimization problems. These are equally useful in Optimal Power flow problems[3-5]. Genetic Algorithm (GA), Particle swarm optimization (PSO), Differential Evolution (DE)[3,6,9,10,13] have been proposed for minimization of cost of active power as an objective function. Particle swarm optimization have been used in some multi-objective problems[2,7] considering various cost functions like combined cost of active and reactive power[13]. In the optimal dispatch of active power, generators are rescheduled to minimize the cost but minimization of emission effect increases system operating
cost. In order to minimize emission with economic dispatch a combined composite function of cost and emission is considered.

In this paper, performance of PSO and MOPSO is tested in solving the multi-objective problem of optimal active power dispatch. The proposed approach have been examined and tested on the standard IEEE 30-bus system with 6 generators. The objective of this paper is to solve the multi-objective problem of economic power dispatch; having four objectives these are fuel cost and environment impact due to SO2, CO2 and NOx gaseous pollutants.

II. PROBLEM FORMULATION

The objective of optimal power flow is to identify the control variables which minimize the objective function of cost and pollution. This is formulated mathematically as follows:

A. Bi-Objective Problem of Optimal Active Power Dispatch

1) Minimization of fuel cost with real power output

The fuel cost of each fossil fuel fired generator can be expressed as a single quadratic function. Total fuel cost in terms of real power output and cost coefficients (a, b, c) can be expressed as [13]:

\[ f(P_g) = \sum_{i=1}^{NG} a_i P_{g_i}^2 + b_i P_{g_i} + c_i \text{($/h$)} \]  

(1)

2) Minimization of emission dispatch

The emission function can be expressed as the sum of all types of emissions as flue gases, particulate materials and thermal radiation with suitable pricing for each pollutant emitted. The emission dispatch problem can be formulated as an optimization function in terms power output and emission coefficients (d, e, f) of each unit [2].

\[ E(P_g) = \sum_{i=1}^{NG} d_i P_{g_i}^2 + e_i P_{g_i} + f_i \text{(Kg/h)} \]  

(2)

By introducing a price penalty factor Pf (H) the above mentioned optimization problems can be converted into a single bi-objective function. Here the function of H in terms of max Pg of each unit is given as [2]

\[
H = \frac{\sum_{i=1}^{NG} a_i P \max_{g_i}^2 + b_i P \max_{g_i} + c_i}{\sum_{i=1}^{NG} d_i P \max_{g_i}^2 + e_i P \max_{g_i} + f_i} \text{($/kg$)} 
\]

(3)

Here, H is price penalty factor, which combines the emission cost with the normal fuel costs. Thus the total cost function (CF) of the system is the addition of fuel cost and the implied cost of emission[2].

\[ CF = f(P_g) + H * E(P_g) \]  

(4)

The above bi-objective function solved by weighted sum method by introducing weighting factors \( w_{eco} \) and \( w_{emi} \). and combined cost function can be expressed as follows[6]:

\[
CF = w_{eco} * f(P_g) + w_{emi} * \{H * E(P_g)\} \]

(5)

The two weighting factors \( w_{eco} \) and \( w_{emi} \) respectively for fuel cost and emission cost function may vary in the range of 0.0 to 1.0. In case of \( w_{eco} = 1.0 \) and \( w_{emi} = 0.0 \) it yields the classical economic dispatch problem while the pure emission dispatch is the case of \( w_{eco} = 0.0 \) and \( w_{emi} = 1.0 \). To establish the combined economic and emission dispatch problem, both weighting factors should be greater than 0.0 and less than 1.0.

B. Multi-Objective Problem of Optimal Active Power Dispatch

The generation of electricity from fossil fuel releases several contaminants, such as sulphur dioxide (SO2), nitro-gen oxides (NOX), and carbon dioxide (CO2) into the atmosphere. Atmospheric pollution affects not only humans but also other life forms such as animals, birds, fish and plants. It also causes damage to materials, reducing visibility as well as causing global warming. Minimization of all these chemicals with the cost minimization forms a multi-objective problem.

1) Minimization of power generation cost

The generation cost of each fossil fuel fired generator can be expressed as a single quadratic function in terms of real power output and cost coefficients (a, b, c) as [18]:

\[
F(1) = \sum_{i=1}^{NG} a_i P_{g_i}^2 + b_i P_{g_i} + c_i \text{($/h$)} 
\]

(6)

2) Minimization of emission of SO2 gas

The emission of SO2 gas of fossil fuel fired generator can be expressed as a single quadratic [18]:

\[
F(2) = \sum_{i=1}^{NG} l_i P_{g_i}^2 + m_i P_{g_i} + n_i \text{(kg/h)} 
\]

(7)

3) Minimization of emission of CO2 gas

The emission of CO2 gas of fossil fuel fired generator can be expressed as a single quadratic [18]:

\[
F(3) = \sum_{i=1}^{NG} x_i P_{g_i}^2 + y_i P_{g_i} + z_i \text{(kg/h)} 
\]

(8)

4) Minimization of emission of NOx gas

The emission of NOx gas of fossil fuel fired generator can be expressed as a single quadratic [18]:

\[
F(4) = \sum_{i=1}^{NG} d_i P_{g_i}^2 + e_i P_{g_i} + f_i \text{(kg/h)} 
\]

(9)

A. System Constraints

In this paper following equality and inequality constraints are considered:

1) Equality Constraints
\[ \sum_{i=1}^{NG} P_{gi} - \sum_{i=1}^{NB} P_{di} - P_{loss} = 0 \]  

(10)

Above equation is known as “Power balance equation”. Where 
NG is no. of generating units and NB is the number of load 
buses, P<sub>gi</sub> is the active power generated; P<sub>di</sub> is the active power 
load, respectively.

2) Inequality Constraints

Generator power limits: generated power output of all the 6 
generators is varied in their upper and lower range:

\[ P_{gi, min} \leq P_{gi} \leq P_{gi, max} \]  

(7)

Here NG shows the number of generators, (i= 1, 2 .....NG)

III. MULTI-OBJECTIVE PARTICLE SWARM OPTIMIZATION

1) Overview

PSO is one of the evolutionary algorithms (EA), which is 
inspired by the social flocking behavior of birds and the 
schooling behavior of fish. As like other EAs, PSO is also 
initialized with some random solutions. All the particles in the 
PSO fly through-out the problem space. To have all the 
particles being located in the optimal position in a multi-
dimensional space, is the ultimate goal of PSO technique.

Thus the behavior of the flock or swarm is based on a 
combination of three important features:

1. Cohesion—Stick together.
2. Separation—doesn’t come too close.
3. Alignment—Follow the general heading of the flock.

2) Initialization

Inte the PSO algorithm, each individual “i”, called particle, 
represents a solution to the optimization problem and set of 
these individual solutions forms a vector of decision variables, 
X<sub>i</sub>. The initial particles are generated randomly in between 
their limits by uniform distribution following equation [23].

\[ X_i = X_{i, min} + rand() \ast (X_{i, max} - X_{i, min}) \]  

(8)

Here, NP shows the number of particles, (i=1, 2.....NP)

3) Velocity of Particles

In PSO algorithm particles follow the fittest member of the 
swarm and move toward historically good areas of the 
provided space. In order to achieve this, individuals are 
associated with some velocity, v<sub>i</sub>. Starting from zero value in 
each iteration velocity is updated by the global best position in 
the problem space called as Gbest and the best known 
individual position of a particle called as Pbest using following 
equation[1].

\[ v_{i}^{t+1} = w \ast v_{i}^{t} + c_1 R_1 (P_{best} - X_i^{*}) + c_2 R_2 (G_{best} - X_i^{*}) \]  

(9)

Where \( v_{i} \) is velocity of jth member of ith particle which is 
bounded in its min-max limits and w is inertia-weight[18]:

\[ w = w_{max} - \frac{(w_{max} - w_{min}) \ast iteration}{max \ iteration} \]  

(10)

Here, R<sub>1</sub>& R<sub>2</sub> are the random numbers generated between 0 
and 1. C<sub>1</sub>& C<sub>2</sub> can vary range of 0-4 but these are adjusted 
such as C<sub>1</sub> = C<sub>2</sub> = 2 [13].

4) Update the solution vector

At each iteration (generation), the position vector of swarms is 
updated by adding the velocity ‘v’ [18].

\[ X_i^{t+1} = X_i^{t} + v_i^{t+1} \]  

(11)

5) Constriction Factor

With the aim of eliminating velocity clamp and encouraging 
convergence, Clerc and Kennedy[2] proposed a constriction 
factor. Constriction factor can lie in interval of 0.5 to 1.0[23]. 
This constriction factor, “k” is involved in the equation of 
velocity update as follows:

\[ v_i^{t+1} = k \ast (w v_i^{t} + c_1 R_1 P_{best} - X_i^{*}) + c_2 R_2 G_{best} - X_i^{*}) \]  

(12)

6) Multi-Objective PSO

The difficulty of finding an optimal solution for a multi-
objective problem lies in the possible conflicts that may exist 
between the optimal solutions for the separate objectives. The 
best solution for a certain objective might be the worst for 
another. Solving these conflicts is the essence of finding an 
“optimal” solution on multi-objective ground. There are two 
approaches for solving multi-objective problems. First isby 
converting the multi-objective problem into a single objective 
problem. This often carried out by gathering all objectives in a 
weighted function. But there is a problem of adjusting 
weighting factor with this approach.

The second approach is based on Pareto optimality (PO) 
concept, where a set of optimal solutions is found, instead of 
one optimal solution. The reason for the optimality of many 
solutions is that no one can be considered to be better than any 
other with respect to all objective functions. Compared with 
traditional algorithms, PO is more suitable for solving multi-
objective problems[14]. The proposed approach-Multi-
Objective PSO is proposed to solve the problem of adjusting 
weighting factors by uniting “Pareto-dominance principles” 
with PSO[5].

a) Efficient solution: A feasible solution is called efficient 
solution if there is no other feasible solution where all the 
objectives perform better[5].
b) **Efficient Frontier:** The set of all efficient solutions is called an efficient frontier. Clearly, under any reasonable definition of optimality, an optimal solution to a multi-objective problem must come from within the efficient frontier.

c) **Pareto Curve:** The image of the efficient set, i.e., the image of all the efficient solutions, is called Pareto front or Pareto curve/surface. The shape of the Pareto surface indicates the nature of the trade-off between the different objective functions.

The relationship between the weights of objective function and the Pareto curve is such that, a uniform spread of weight parameters does not produce a uniform spread of points on the Pareto curve. It is observed about this fact is, all the points are grouped in certain portion of the Pareto front, while some portion of the trade-off curve have not been produced.

To demonstrate the effectiveness of Particle swarm optimization (PSO) on IEEE 30 bus system MATLAB programs have been developed for Bi-objective optimal active power dispatch problem. Here objective is to minimize the generation cost and emission dispatch with satisfying load and losses. As mentioned above, the real power outputs of all the generators are varied in their range.

**TABLE-II** Fuel cost ($$/h) and Emission dispatch (Kg/h) with different weights

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Weco</th>
<th>Wemi</th>
<th>Fuel cost ($$/h)</th>
<th>Emission dispatch (Kg/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0</td>
<td>0.0</td>
<td>805.93</td>
<td>466.43</td>
</tr>
<tr>
<td>2</td>
<td>0.7</td>
<td>0.3</td>
<td>811.26</td>
<td>417.66</td>
</tr>
<tr>
<td>3</td>
<td>0.5</td>
<td>0.5</td>
<td>823.93</td>
<td>372.83</td>
</tr>
<tr>
<td>4</td>
<td>0.3</td>
<td>0.7</td>
<td>848.42</td>
<td>355.07</td>
</tr>
<tr>
<td>5</td>
<td>0.0</td>
<td>1.0</td>
<td>899.23</td>
<td>350.10</td>
</tr>
</tbody>
</table>

Minimized fuel cost and emission dispatch are calculated by PSO with different sets of weights. In all the cases results obtained by PSO technique are in equal proportion. The problem occurred while solving multi-objective problem by weighted sum method is deciding optimal value of weights.

**Case-II Solution of Multi-Objective Problem of Optimal Active Power Dispatch**

**a) System under study**

IEEE-30 bus 6-gen system is considered for study of multi-objective optimal active power dispatch problem. The system data like fuel cost coefficients and emission coefficients of CO$_2$, SO$_2$, NO$_x$ gases are considered as follows[6].

**TABLE-III** Fuel cost Coefficients of System

<table>
<thead>
<tr>
<th>Gen. Unit</th>
<th>a ($$/MWh)$</th>
<th>b ($$/MWh)</th>
<th>c ($$/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0020</td>
<td>8.43</td>
<td>85.63</td>
</tr>
<tr>
<td>2</td>
<td>0.0038</td>
<td>6.41</td>
<td>303.77</td>
</tr>
<tr>
<td>3</td>
<td>0.0021</td>
<td>7.42</td>
<td>847.14</td>
</tr>
<tr>
<td>4</td>
<td>0.0013</td>
<td>8.30</td>
<td>274.22</td>
</tr>
<tr>
<td>5</td>
<td>0.0021</td>
<td>7.42</td>
<td>847.14</td>
</tr>
<tr>
<td>6</td>
<td>0.0059</td>
<td>6.91</td>
<td>202.02</td>
</tr>
</tbody>
</table>

**TABLE-IV** CO$_2$ emission Coefficients of System

<table>
<thead>
<tr>
<th>Gen. Unit</th>
<th>x (Kg/MWh)</th>
<th>y (Kg/MWh)</th>
<th>z ($$/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.26</td>
<td>-61.01</td>
<td>5080.14</td>
</tr>
<tr>
<td>2</td>
<td>0.14</td>
<td>-29.95</td>
<td>3824.77</td>
</tr>
<tr>
<td>3</td>
<td>0.10</td>
<td>-9.55</td>
<td>1342.85</td>
</tr>
<tr>
<td>Gen. Unit</td>
<td>l (Kg/MWh2)</td>
<td>m (Kg/MWh)</td>
<td>n ($/h)</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
<td>------------</td>
<td>--------</td>
</tr>
<tr>
<td>1</td>
<td>0.0012</td>
<td>5.05</td>
<td>51.37</td>
</tr>
<tr>
<td>2</td>
<td>0.0023</td>
<td>3.84</td>
<td>182.26</td>
</tr>
<tr>
<td>3</td>
<td>0.0012</td>
<td>4.45</td>
<td>508.52</td>
</tr>
<tr>
<td>4</td>
<td>0.0008</td>
<td>4.97</td>
<td>165.34</td>
</tr>
<tr>
<td>5</td>
<td>0.0012</td>
<td>4.45</td>
<td>508.52</td>
</tr>
<tr>
<td>6</td>
<td>0.0035</td>
<td>4.14</td>
<td>121.21</td>
</tr>
</tbody>
</table>

**TABLE-VISO\textsubscript{2} emission Coefficients of System**

<table>
<thead>
<tr>
<th>Gen. Unit</th>
<th>d (Kg/MWh2)</th>
<th>e (Kg/MWh)</th>
<th>f ($/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0063</td>
<td>-0.38</td>
<td>80.90</td>
</tr>
<tr>
<td>2</td>
<td>0.0064</td>
<td>-0.79</td>
<td>28.82</td>
</tr>
<tr>
<td>3</td>
<td>0.0031</td>
<td>-1.36</td>
<td>324.17</td>
</tr>
<tr>
<td>4</td>
<td>0.0067</td>
<td>-2.39</td>
<td>610.25</td>
</tr>
<tr>
<td>5</td>
<td>0.0031</td>
<td>-1.36</td>
<td>324.17</td>
</tr>
<tr>
<td>6</td>
<td>0.0061</td>
<td>-0.39</td>
<td>50.38</td>
</tr>
</tbody>
</table>

**TABLE-VIIdifferent sets of weighting factors and corresponding optimized results of fuel cost and emitted gases**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>W4</th>
<th>Fuel Cost ($/h)</th>
<th>CO2 emission (Kg/h)</th>
<th>SO2 emission (Kg/h)</th>
<th>NOx emission (Kg/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.45</td>
<td>0.3644</td>
<td>0.0633</td>
<td>0.1223</td>
<td>4906.88</td>
<td>17247.16</td>
<td>2943.39</td>
<td>1315.34</td>
</tr>
<tr>
<td>2</td>
<td>0.45</td>
<td>0.1271</td>
<td>0.3843</td>
<td>0.0385</td>
<td>4844.43</td>
<td>15299.58</td>
<td>2906.00</td>
<td>1278.80</td>
</tr>
<tr>
<td>3</td>
<td>0.45</td>
<td>0.1558</td>
<td>0.2558</td>
<td>0.1382</td>
<td>4854.52</td>
<td>15361.76</td>
<td>2912.04</td>
<td>1316.88</td>
</tr>
<tr>
<td>4</td>
<td>0.45</td>
<td>0.5433</td>
<td>0.0151</td>
<td>0.0324</td>
<td>4906.46</td>
<td>16959.56</td>
<td>2943.16</td>
<td>1376.44</td>
</tr>
<tr>
<td>5</td>
<td>0.45</td>
<td>0.3939</td>
<td>0.1409</td>
<td>0.0151</td>
<td>4821.13</td>
<td>15200.21</td>
<td>2882.10</td>
<td>1270.68</td>
</tr>
<tr>
<td>6</td>
<td>0.45</td>
<td>0.1596</td>
<td>0.1462</td>
<td>0.2440</td>
<td>4837.52</td>
<td>15258.53</td>
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<td>1289.26</td>
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<tr>
<td>7</td>
<td>0.45</td>
<td>0.1271</td>
<td>0.2058</td>
<td>0.2169</td>
<td>4855.00</td>
<td>15259.28</td>
<td>2912.31</td>
<td>1305.44</td>
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<tr>
<td>8</td>
<td>0.45</td>
<td>0.2478</td>
<td>0.2719</td>
<td>0.0302</td>
<td>4915.72</td>
<td>16809.03</td>
<td>2948.70</td>
<td>1363.44</td>
</tr>
<tr>
<td>9</td>
<td>0.45</td>
<td>0.4865</td>
<td>0.0642</td>
<td>0.3140</td>
<td>4857.65</td>
<td>16566.20</td>
<td>2913.95</td>
<td>1318.44</td>
</tr>
<tr>
<td>10</td>
<td>0.45</td>
<td>0.2803</td>
<td>0.1857</td>
<td>0.0838</td>
<td>4875.06</td>
<td>16002.32</td>
<td>2824.36</td>
<td>1336.86</td>
</tr>
</tbody>
</table>

**TABLE-VIIIOptimal setting of weights and control variables for multi-objective function**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Weighting Factors, W\textsubscript{i}</th>
<th>S. No.</th>
<th>Generator’s Power Output, P\textsubscript{gi} (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>W1</td>
<td>1</td>
<td>P\textsubscript{g1}</td>
</tr>
<tr>
<td>2</td>
<td>W2</td>
<td>2</td>
<td>P\textsubscript{g2}</td>
</tr>
<tr>
<td>3</td>
<td>W3</td>
<td>3</td>
<td>P\textsubscript{g5}</td>
</tr>
<tr>
<td>4</td>
<td>W4</td>
<td>4</td>
<td>P\textsubscript{g8}</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>5</td>
<td>P\textsubscript{g11}</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>6</td>
<td>P\textsubscript{g13}</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>7</td>
<td>Total Power Gen (MW)</td>
</tr>
</tbody>
</table>
TABLE IX

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Parameter</th>
<th>With initial settings of generator output</th>
<th>With optimal setting of generator output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total Cost of gen. ($/h)</td>
<td>4833.40</td>
<td>4821.10</td>
</tr>
<tr>
<td>2</td>
<td>Total NOx dispatch (Kg/h)</td>
<td>1288.95</td>
<td>1270.70</td>
</tr>
<tr>
<td>3</td>
<td>Total SO2 dispatch (Kg/h)</td>
<td>2899.48</td>
<td>2882.10</td>
</tr>
<tr>
<td>4</td>
<td>Total CO2 dispatch (Kg/h)</td>
<td>16881.55</td>
<td>15200.0</td>
</tr>
</tbody>
</table>

Figure 2 Characteristics curve for Bi-objective ELD problem solved by PSO for case of equal weights

V. CONCLUSION

This paper shows the solution of an optimal power flow (OPF) problem for medium-sized power systems using an artificial intelligence algorithm of real type. The bi-objective problem of generation cost and emission dispatch is solved via weighted sum method for different combinations of weights. The objective, minimization of total fuel cost and environmental pollution caused by fossil based thermal generating units of IEEE 30 bus 6 generator systems is considered. It is minimized by 10.42% and 3.54% respectively using particle swarm optimization technique (PSO). The power flow equations and load balance equation are considered as equality constraints. A multi-objective problem of minimization of power generation cost and flue gases (NOx, CO2, SO2) dispatch for the same system is also solved to find-out optimal solution by proposed technique. Results of analysis claims that the proposed technique i.e. Multi-objective PSO performs better than the classical approach of weighted sum method in solving multi-objective optimal power flow problems.

REFERENCES
