Hybrid of Lamda and Bee Colony Optimization for Solving Economic Dispatch

Abstract. This paper proposes the method to solve the economic dispatch problem with hybrid of lamda and bee colony optimization (HLBCO). The fundamental constraints of economic dispatch problem are the load demand and power loss into consideration. The generation cost function considering smooth cost function characteristic. To verify the performance of the proposed HLBCO algorithm, it is operated by the simulation on the MATLAB program and tested the two case studies. The simulation results indicate that the HLBCO can provide a better solution than the others in terms of quality performance, computational and convergence efficiently.

Streszczenie. W artykule zaproponoano metodę optymalizacji rozsyłu energii dla wykorzystania hybrydy dwóch metod: lamda i algorytmów rojowych HLBCO. Syntulacja przeprowadzona nakilku przykładach dowodzi ze zaproponowany algorytm lepiej rozwiązuje problemy ekonomicznego rozsyłu biorąc pod uwagę jakość i skuteczność. Optymalizacja ekonomii rozsyłu energii z wykorzystaniem metod rojowych i metody lamda.

Keywords: lamda, bee colony, optimization, economic dispatch.
Słowa kluczowe: metody rojowe, metoda lamda, optymalizacja rozsyłu energii.

Introduction

The electricity is an important for economic and social development. Planning, security and reliability of electrical power are necessary for electrical power generation. Economic dispatch is the method of determinative the most efficient, low cost and reliable operation of a power. The objective function of economic dispatch is to minimize the total fuel cost of electrical power generation which the demand, power loss and constraints are satisfied. There are many methods to solving the economic dispatch problem. The conventional methods for solving economic dispatch problem are lamda iteration method, gradient method, newton’s method, piecewise linear cost functions and dynamic programming [1] that owing to tedious calculations and its incapability to solve multi-model and discontinuous problem. The novel methods have replaced it such as simulated annealing (SA) [2]-[3], genetic algorithm (GA) [4]-[5] and tabu search (TS) [6]-[7]. There are probabilistic heuristic algorithms which have been successfully used to solve the economic problem.

Currently, the swarm intelligence is focused on insect behavior in order to develop some mete-heuristics such as particle swarm optimization (PSO) [8]-[11], ant colony optimization (ACO) [12]-[16] and bee colony optimization (BCO) [17]-[21] to solving the economic dispatch problem. These algorithms can provide better solution in comparison to conventional algorithms. All swarm intelligence, bee colony optimization algorithm is very simple and robust stochastic optimization algorithm. The solution quality and computational efficiency of BCO is better than other algorithm, such as SA, GA, TS and PSO [12]. However, the initial population of BCO is obtained randomly, as a result more time to computational efficiency.

In this paper, the hybrid of lamda iteration and BCO to solving the economic dispatch is proposed. The initial population of BCO is modified. The proposed approach aims to minimize the total fuel cost of electrical power generation with satisfying technical constraint of power balance. Results from previous methods are compared in this paper.

This paper is organized as follows. Section II expresses problem formulation of the economic dispatch. Section III proposes the modified BCO algorithm to provide the economic dispatch. Section IV shows the results. And the last section concludes the paper.

Problem formulation

The purpose of the economic dispatch problem is to search the optimal combination of electrical power generation that minimizes the total generation cost while satisfying the constraints.

Objective function

The objective function of economic dispatch problem can be express as a quadratic function:

\[ \text{Minimize }: \quad TC = \sum_{i=1}^{N} F_i(P_i) = a_i P_i^2 + b_i P_i + c_i \]

where \( TC \) is the total generation cost; \( N \) is the number of generating units; \( F_i(P_i) \) is the total fuel cost of generation; \( P_i \) is the power output of the \( i^{th} \) generator and \( a_i, b_i \) and \( c_i \) are the cost coefficient of the \( i^{th} \) generator.

Constrains

The objective function represented in (1) is subject to the following equality and inequality constraints.

Power balance constraint

The sum of power output of all generator units must be equal to the sum of the total power demand and total power transmission losses.

\[ \sum_{i=1}^{N} P_i = P_{D} + P_{loss} \]

where \( P_D \) and \( P_{loss} \) are the total power demand and total power transmission losses respectively. The transmission losses are expressed as a function of the real power and \( B \) coefficient matrix.

\[ P_{loss} = \sum_{i=1}^{N} \sum_{j=0}^{N} P_j B_{ij} P_i + \sum_{i=1}^{N} B_{i0} P_i + B_{00} \]

where \( B_{00}, B_{0i} \) and \( B_{ij} \) are the loss coefficient of the transmission line which can be assumed to be constant under the normal operating condition.

Generator rating constraint

The power output of each generator units must be operate within lower and upper operating limit which defined as:

\[ P_{i,min} \leq P_i \leq P_{i,max} \]
where \(P_{i,\text{min}}\) and \(P_{i,\text{max}}\) are the minimum and maximum power output of the \(i^{th}\) generator unit.

Hybrid lambda and bee colony optimization

Bee Colony Optimization (BCO) is one of the most recent popular based meta-heuristics optimization techniques proposed by Karaboga [25]. The BCO algorithm has an advantage in providing global optimal solutions and it has the capability of solving difficult combinatorial optimization problems.

The collection and processing of nectar by bees colony consists of two groups, that are, scout bees and worker bees. The scout bees are responsible for searching for sources of nectar, while the worker bees are responsible for taking a load of the nectar to the honeycomb. The processes of the intelligent behaviors of bees can be summarized as follows: scout bees search the sources of nectar in different directions and return to the honeycomb. After that, the scout bees dance to apprise the quality, quantity, direction and distance of the nectar sources. Then, the colony of bees decides to send worker bees to bring nectar to the honeycomb. This bee behavior is converted to a meta-heuristic search algorithm including the steps of initialization, search, evaluation, and update. However, the initial population step is obtained randomly, as a result more time to computational efficiency.

The hybrid of lambda iteration and BCO algorithm to solve economic dispatch is shown in Figure 1 and described as follows:

Step 1: Specify the HLBCO parameter as shown in Table 1.

Step 2: Calculate the value of \(\lambda\) that the power output of the \(i^{th}\) generator sum to the total load plus losses using the following:

\[
\lambda = \frac{P_D + \sum_{i=1}^{N} b_i}{\sum_{i=1}^{N} c_i}
\]

Step 3: Find boundary of the power output of the \(i^{th}\) generator using the following:

\[
P_{i,\text{lower}} = \frac{\lambda - b_i}{c_i}(1 - \text{rank})
\]

and

\[
P_{i,\text{upper}} = \frac{\lambda - b_i}{c_i}(1 + \text{rank})
\]

where \(P_{i,\text{lower}}\) and \(P_{i,\text{upper}}\) are the minimum and maximum power output of the \(i^{th}\) generator unit; rank is rank power output generation and \(b_i\) and \(c_i\) are the cost coefficient of the \(i^{th}\) generator.

Step 4: Create the initial populations (N) of the power output of the \(i^{th}\) generator, while satisfying the constraints can be expressed as follows:

\[
P_i = P_{i,\text{lower}} + \left(\left( P_{i,\text{upper}} - P_{i,\text{lower}}\right) \times \text{rand}(0,1)\right)
\]

Step 5: Evaluate the fitness value of the initial population and arrange the fitness in ascending order.

Step 6: Select \(S\) best solutions for the neighborhood search and separate the \(S\) best solutions into two groups \((E, S-E)\).

Step 7: Determine the size of neighborhood for each best solution. Note that neighborhood sizes are equal to \(NE\) for solution group \(E\) and \(NO\) for solution group \((S-E)\).

Step 8: Generate solutions around the selected solutions within the neighborhood sizes \((NE, NO)\) and evaluate the fitness value from each patch. Then, select the best solution from each patch.

Step 9: Check the stopping criterion. If no, increase the iteration.

Step 10: Assign the new population \((N-S)\) to generate new power output of the \(i^{th}\) generator. Then, return to Step 4.

Table 1. The parameters of HLBCO

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population size (N)</td>
<td>20</td>
</tr>
<tr>
<td>Number of selected sites (S)</td>
<td>14</td>
</tr>
<tr>
<td>Number of best sites (E)</td>
<td>10</td>
</tr>
<tr>
<td>Number of bees around best sites (NE)</td>
<td>20</td>
</tr>
<tr>
<td>Number of bees around other sites (NO)</td>
<td>10</td>
</tr>
</tbody>
</table>

Simulation results

The proposed hybrid of lambda iteration and BCO algorithm is implemented in the MATLAB to solve the economic dispatch. In this study, the two difference test cases are considered for verifying the effectiveness of the proposed approach.

Fig. 1. Proposed hybrid of lambda iteration and BCO algorithm.
Test Case 1: Three Units System
This case study is the simple system with three generators and a total load demand of 300 MW. The system data is shown in Table 2. The system loss coefficients matrix as follow [26]:

Table 2. Generator data for case 1

<table>
<thead>
<tr>
<th>Unit</th>
<th>( P_{\text{min}} )</th>
<th>( P_{\text{max}} )</th>
<th>( a_i )</th>
<th>( b_i )</th>
<th>( c_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>250</td>
<td>0.00525</td>
<td>8.663</td>
<td>328.13</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>150</td>
<td>0.00699</td>
<td>10.04</td>
<td>136.91</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>100</td>
<td>0.00592</td>
<td>9.76</td>
<td>59.16</td>
</tr>
</tbody>
</table>

\[
B = \begin{bmatrix}
0.0136 & 0.00175 & 0.0184 \\
0.00175 & 0.0154 & 0.0283 \\
0.0184 & 0.0283 & 0.161
\end{bmatrix} \times 10^{-2}
\]

Table 3. Comparison of difference method for case 1

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_1 )</td>
<td>209.001</td>
<td>207.64</td>
<td>207.637</td>
<td>207.644</td>
</tr>
<tr>
<td>( P_2 )</td>
<td>85.92</td>
<td>87.2763</td>
<td>87.2833</td>
<td>87.277</td>
</tr>
<tr>
<td>( P_3 )</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>( P_4 )</td>
<td>50</td>
<td>15</td>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td>( P_5 )</td>
<td>80</td>
<td>300</td>
<td>0.0095</td>
<td>10.0</td>
</tr>
<tr>
<td>( P_6 )</td>
<td>50</td>
<td>220</td>
<td>0.0080</td>
<td>11.0</td>
</tr>
<tr>
<td>( P_T )</td>
<td>309.92</td>
<td>309.9205</td>
<td>309.9203</td>
<td>309.92</td>
</tr>
<tr>
<td>( TC )</td>
<td>3621.75</td>
<td>3619.75</td>
<td>3619.8</td>
<td>3619.75</td>
</tr>
</tbody>
</table>

Test Case 2: Six Units System
In this case, the system consists of six generators with characteristic given in Table 4. The total load demand is 1263 MW and loss coefficients matrix as follow [11]:

Table 4. Generator data for case 2.

<table>
<thead>
<tr>
<th>Unit</th>
<th>( P_{\text{min}} )</th>
<th>( P_{\text{max}} )</th>
<th>( a_i )</th>
<th>( b_i )</th>
<th>( c_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>500</td>
<td>0.0070</td>
<td>7.0</td>
<td>240</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>200</td>
<td>0.0095</td>
<td>10.0</td>
<td>200</td>
</tr>
<tr>
<td>3</td>
<td>80</td>
<td>300</td>
<td>0.0090</td>
<td>8.5</td>
<td>220</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
<td>150</td>
<td>0.0090</td>
<td>11.0</td>
<td>200</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>200</td>
<td>0.0080</td>
<td>10.5</td>
<td>220</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>120</td>
<td>0.0075</td>
<td>12.0</td>
<td>190</td>
</tr>
</tbody>
</table>

\[
B = \begin{bmatrix}
0.17 & 0.12 & 0.07 & -0.01 & -0.05 & -0.02 \\
0.12 & 0.14 & 0.09 & 0.01 & -0.06 & -0.01 \\
0.07 & 0.09 & 0.31 & 0.00 & -0.10 & -0.06 \\
-0.01 & 0.01 & 0.24 & -0.06 & -0.08 \\
-0.05 & -0.06 & -0.10 & -0.06 & -1.69 & -0.02 \\
-0.02 & -0.01 & -0.06 & -0.08 & -0.02 & 1.50
\end{bmatrix} \times 10^{-1}
\]

\[
B_a = \begin{bmatrix}
0.3908 & -0.1297 & 0.7047 & 0.0591 & 0.2161 & 0.6635
\end{bmatrix} \times 10^{-1}
\]

\[
B = 0.056
\]

Table 5. Comparison of difference method for case 2.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_1 )</td>
<td>446.71</td>
<td>440.576</td>
<td>445.8099</td>
<td>449.0285</td>
</tr>
<tr>
<td>( P_2 )</td>
<td>173.01</td>
<td>167.4369</td>
<td>172.9257</td>
<td>172.4836</td>
</tr>
<tr>
<td>( P_3 )</td>
<td>265.00</td>
<td>278.2356</td>
<td>262.1240</td>
<td>258.0493</td>
</tr>
<tr>
<td>( P_4 )</td>
<td>139.00</td>
<td>150.00</td>
<td>142.7788</td>
<td>137.7193</td>
</tr>
<tr>
<td>( P_5 )</td>
<td>165.23</td>
<td>157.6061</td>
<td>166.3730</td>
<td>166.5165</td>
</tr>
<tr>
<td>( P_6 )</td>
<td>86.76</td>
<td>81.2244</td>
<td>85.4657</td>
<td>91.3657</td>
</tr>
<tr>
<td>( P_T )</td>
<td>1275.7</td>
<td>1275.4641</td>
<td>1275.4641</td>
<td>1275.1630</td>
</tr>
<tr>
<td>( P_L )</td>
<td>12.73</td>
<td>12.4641</td>
<td>12.4641</td>
<td>12.1630</td>
</tr>
<tr>
<td>( TC )</td>
<td>15447</td>
<td>15444.2616</td>
<td>15444.2616</td>
<td>15439.6303</td>
</tr>
</tbody>
</table>

Fig. 2. Solution convergence of MBCO in case 1.

Fig. 3. Solution convergence of MBCO in case 2.

Conclusion
This paper proposes a methodology for solving the economic dispatch using hybrid of lambda iteration and bee colony optimization with taking various generator constraints. Two case systems are tested evaluates the performance proposed approach. The HLBCO shown that algorithm is robust and can provide an optimal solution with fast computation and small number of iterations. The studied results confirm the HLBCO proposed approach are indeed capable of obtaining higher quality solution, computation time and convergence characteristic in comparison with other method.

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