Wanchai KHAMSEN, Chiraphon TAKEANG

Faculty of Engineering, Rajamangala University of Technology Lanna, Lampag, Thailand

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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 solution, computational and convergence efficiently.*

***Streszczenie.** W artykule zapropponowano metode optymalizacji rozsyłu energii prze wykorzystanie hybrydy dwóch metod: lamda i algorytmów rojowych HLBCO. Symulacja przeprowadzona nakilku przykładach dowodzi że zaproponowany algorytm lepiej rozwiązuje prtoblemy ekonomicznego rozsyłu biorąc pod uwagę jakość I skuteczność. **Optymalizacja ekonomii rozsyłu enegii z wykorzystaniem metod rojowych I metody lamda.**.*

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

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:

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

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 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.

$$\text{(2)} \qquad \sum_{i=1}^{N} (P_i) = P_D + P_{loss}$$

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.

$$\text{(3)} \qquad P_{loss} = \sum_{i=1}^{N} \sum_{j=1}^{N} P_i B_{ij} P_j + \sum_{j=1}^{N} B_{io} P_i + B_{00}$$

where B_{00}, B_{i0} 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:

$$\text{(4)} \qquad P_{i,\min} \le P_i \le P_{i,\max}$$

where $P_{i,min}$ and $P_{i,max}$ are the minimum and maximum power output of the i^{th} generator unit.

Hybrid lamda and bee colony optimization

Bee Colony Optimization (BCO) is the one of most recent popular based mete-heuristics optimization technique and it was 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 nectar of 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 apprize 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 mete-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 lamda 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 λ that the power output of the i^{th} generator sum to the total load plus losses using the following:

$$\lambda = \frac{P_D + \sum_{i=1}^{N} \frac{b_i}{c_i}}{\sum_{i=1}^{N} \frac{1}{c_i}} \tag{5}$$

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

$$P_{i,lower} = \frac{\lambda - b_i}{c_i}(1 - rank) \tag{6}$$

ad

$$P_{i,upper} = \frac{\lambda - b_i}{c_i}(1 + rank) \tag{7}$$

where $P_{i,lower}$ and $P_{i,upper}$ 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 expresses as follows:

$$P_i = P_{i,lower} + \left(\left(P_{i,upper} - P_{i,lower}\right) \bullet rand(0,1)\right) \tag{7}$$

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

Parameters	Number
Population size (N)	20
Number of selected sites (S)	14
Number of best sites (E)	10
Number of bees around best sites (NE)	20
Number of bees around other sites (NO)	10

Simulation results

The proposed hybrid of lamda 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.

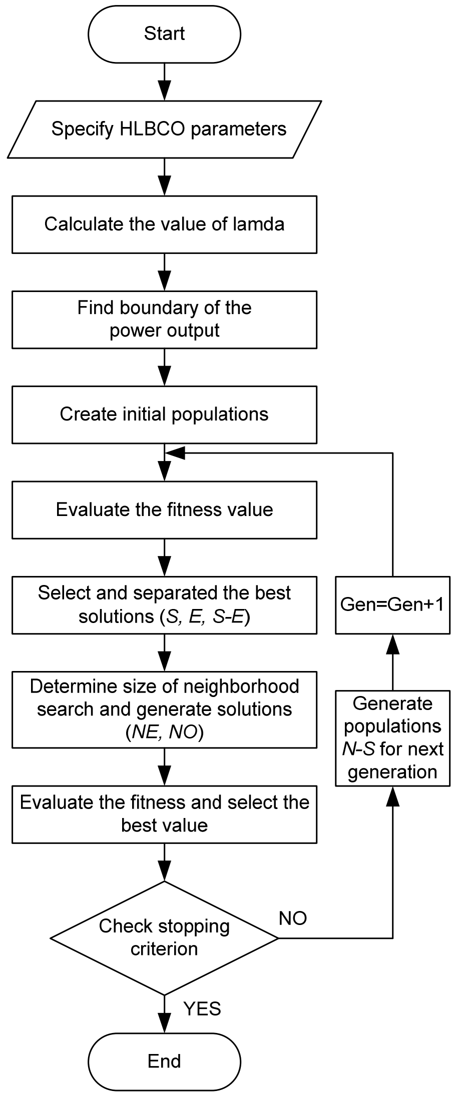

Fig.1. Proposed hybrid of lamda iteration and BCO algorithm.

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

Unit	$P_{i,min}$	$P_{i,max}$	a_i	b_i	c_i
1	50	250	0.00525	8.663	328.13
2	5	150	0.00609	10.04	136.91
3	15	100	0.00592	9.76	59.16

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

Table 3. Comparison of difference method for case 1

Units	PSO [26]	SA [26]	DE [26]	HLBCO
P_1	209.001	207.64	207.637	207.644
P_2	85.92	87.2783	87.2833	87.277
P_3	15	15	15	15
P_T	309.9211	309.9205	309.9203	309.92
P_L	9.9833	9.9204	9.9204	9.9205
T_C	3621.75	3619.75	3619.8	**3619.75**

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.

Unit	$P_{i,min}$	$P_{i,max}$	a_i	b_i	c_i
1	100	500	0.0070	7.0	240
2	50	200	0.0095	10.0	200
3	80	300	0.0090	8.5	220
4	50	150	0.0090	11.0	200
5	50	200	0.0080	10.5	220
6	50	120	0.0075	12.0	190

$$B = \begin{bmatrix} 0.17 & 0.12 & 0.07 & -0.01 & -0.05 & -0.02 \\ 0.12 & 0.14 & 0.09 & 0.01 & -0.06 & -0.01 \\ 0.07 & 0.09 & 0.31 & 0.00 & -0.10 & -0.06 \\ -0.01 & 0.01 & 0.00 & 0.24 & -0.06 & -0.08 \\ -0.05 & -0.06 & -0.10 & -0.06 & 1.29 & -0.02 \\ -0.02 & -0.01 & -0.06 & -0.08 & -0.02 & 1.50 \end{bmatrix} \times 10^{-2}$$

$$B_0 = \left[-0.3908 \ \ -0.1297 \ \ 0.7047 \ \ 0.0591 \ \ 0.2161 \ \ 0.6635\right] \times 10^{-2}$$

$$B_{00} = 0.056$$

Table 5. Comparison of difference method for case 2.

Units	MPSO[8]	PSO [11]	ABC [17]	HLBCO
P_1	446.71	440.5766	445.8099	449.0285
P_2	173.01	167.4369	172.9227	172.4836
P_3	265.00	278.2356	262.1240	258.0493
P_4	139.00	150.00	142.7788	137.7193
P_5	165.23	157.6061	166.3730	166.5165
P_6	86.78	81.2244	85.4557	91.3657
P_T	1275.7	1275.0796	1275.4641	1275.1630
P_L	12.733	12.0796	12.4641	12.1630
T_C	15447	15445.4866	15444.2616	**15439.6303**

The performance of the economic problem is investigated with different optimization techniques. Both the quality solution, computational and convergence efficiently. In the simulation results from the proposed HLBCO, ABC, PSO and MPSO algorithms are compared in table 3 and 5. The results indicate that HLBCO can provide a better solution than the other approaches in total generation cost and convergence efficiently.

Convergence Characteristic

The selected convergence solutions are shown in Figures 2-3. The solutions converge within 2 iterations. The results show the effectiveness and performance of the MBCO better solution than the others in terms of function cost value, computational and convergence time as shown in Figure 2-3.

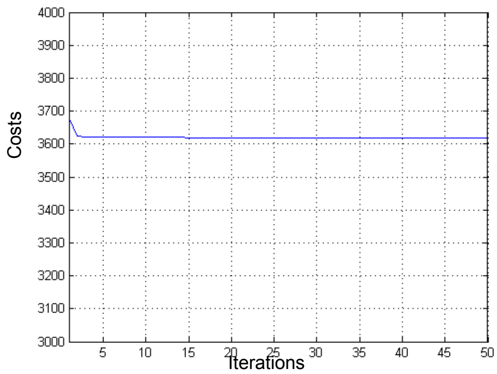

Fig.2. Solution convergence of MBCO in case 1.

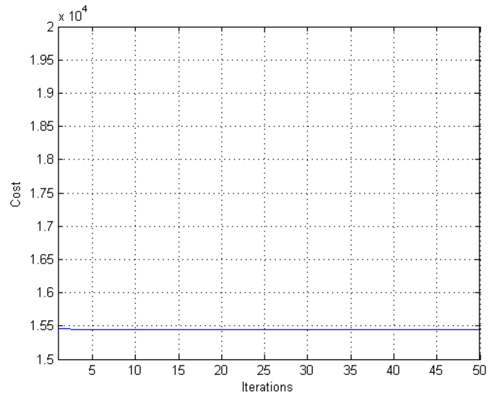

Fig.3. Solution convergence of MBCO in case 2.

Conclusion

This paper proposes a methodology for solving the economic dispatch using hybrid of lamda 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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***Authors**: The authors are with the Department of Electrical Engineering, Faculty of Engineering, Rajamangala University of Technology Lanna, Lampang, Thailand*
E-mail: wanchai_kh@rmutl.ac.th; Asst.Prof.Dr. Wanchai Khamsen
E-mail: chiraphon@rmutl.ac.th; Mr. Chiraphon Takeang
The correspondence address is:
E-mail: *wanchai_kh@rmutl.ac.th*

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