J. Appl. Environ. Biol. Sci., 7(4S)22-27, 2017

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Comparative Study to Solve Emission Dispatch Problem Using Novel Bat Algorithm Considering Cubic Function and Transmission Loss

Fahad Parvez Mahdi[1], Pandian Vasant[1], Vish Kallimani[2], M. Abdullah-Al-Wadud[3]

[1]Department of Fundamental and Applied Sciences, Universiti Teknologi PETRONAS, Bandar Seri Iskandar, 31750 Tronoh, Perak, Malaysia
[2]Department of Computer and Information Sciences, Universiti Teknologi PETRONAS, Bandar Seri Iskandar, 31750 Tronoh, Perak, Malaysia
[3]Department of Software Engineering, College of Computer and Information Sciences, King Saud University, Riyadh, Saudi Arabia

Received: April 9, 2017
Accepted: June 16, 2017

ABSTRACT

Emission of hazardous gases and particulates from thermal power generation systems is one of the major problems that is causing environmental pollution and posing a threat to the green and sound environment. Large amount of emission of problematic gases especially carbon dioxide (CO2) causes a significant imbalance in the environment, which gives rise to the already existed global warming problem. This paper presents a novel bat algorithm (NBA) to solve emission dispatch problem using cubic emission function and considering transmission loss. Results obtained show that NBA performs better than particle swarm optimization (PSO) and simplified direct search method (SDSM) by giving higher quality, robust and reliable solutions.
KEYWORDS: Emission Dispatch, Novel Bat Algorithm, Optimization, Transmission Loss, Bat Algorithm, Cubic Emission Function, Nature-Inspired Algorithm.

INTRODUCTION

Modern civilization survives on power generation in the form of electricity. From the household to industrial production, everyone needs power/electricity. Scientists have developed many ways to generate electricity, but fossil fuels remain the major ingredient to generate electricity. Thermal plants use fossil fuels in the form of coal, natural gas and oil to generate electricity. During the process of electricity generation, thermal plants emit a large amount of hazardous gases like carbon dioxide (CO2), sulphur dioxide (SO2) and nitrogen dioxide (NO2) into the air which causes significant pollution to the environment. Global warming, acid rain and smog are caused by these gases. Research also shows that burning coal in the thermal plants can even cause radioactive materials [1] and heavy materials like arsenic and mercury [2]. So, it is now necessary to implement measures to control the emission. Emission dispatch is an attractive option for this, where the goal is to minimize the emission of hazardous gases and particulates from the thermal generation system. Authors present a novel bat algorithm (NBA) to emission dispatch problem to minimize the emission of hazardous gases and particulates from thermal power generation system.

Background

As per the best knowledge of the authors, emission as a single objective was not previously considered by the researchers. However, emission dispatch problem is usually addressed with economic dispatch problem as a bi-objective problem [3]. But, both the objectives cannot be minimized simultaneously and hence they need to make some kind of trade-off between these two objectives according to the priority of the decision maker. As world leaders are now more concerned than ever about the environmental issue, it is justifiable that emission dispatch as a single objective is a worth consideration. Different optimization techniques have been exploited to handle single objective optimization problem, of them mathematically program-based or classical techniques like lambda iteration [4], linear programming [5], dynamic programming [6] and Lagrangian relaxation [7] were previously used because they don't have problem specific parameters [8], usually computationally fast [9] and can be applied to large scale problems [10]. However, classical methods suffer from local optimum solution, sensitivity to the initial starting points etc. and are gradually replaced by intelligent techniques like genetic algorithm [11], particle swarm optimization algorithm [12], simulated annealing [13] and more recently by cuckoo search algorithm [14], bat algorithm (BA) [15] etc. for their broad applicability, robustness to dynamic system and global optimum solution. The paper will present an improved version of bat algorithm where bat's habitat selection, self-adaptive compensation of Doppler Effect in echoes and self-adaptive local search strategy have been incorporated with the original BA.

Corresponding Author: Fahad Parvez Mahdi, Department of Fundamental and Applied Sciences, Universiti Teknologi PETRONAS, Bandar Seri Iskandar, 31750 Tronoh, Perak, Malaysia,
E-mail: fahadapecedu@gmail.com

Problem Formulation

Emission dispatch problem has been formulated in this paper using cubic emission function and described as below:

$$E(P_{gi}) = \sum_{i=1}^{n} a_i P_{gi}^{\ 3} + b_i P_{gi}^{\ 2} + c_i P_{gi} + d_i \quad \text{kg/hr} \tag{1}$$

where E and Pgi denote the emission function (measured in kilogram per hour) and the total generated power (in MW) in the generating unit i respectively. ai, bi, ci and di are the emission coefficients of ith generating unit. Three constraints have been considered into this paper, which is given below:

Power Balance Constraint

Total generated output power must be equal to total load demand plus transmission loss and can be described as below:

$$P = \sum_{i-1}^{n} P_{gi} = P_D + P_L \tag{2}$$

where P, P_D and P_L stand for total generated output power (in MW), total load demand (in MW) and total transmission loss (in MW) respectively.

Transmission Loss Constraint

Loss of power during the transmission of electricity into the grid due to various reason is known as transmission loss and can be defined as below:

$$P_L = \sum_{i}^{n} \sum_{j}^{n} P_{gi} B_{ij} P_{gj} \tag{3}$$

where Bij is a square matrix also known as loss coefficient of

George's Formula

Generator limit constraint: To operate properly, the generating power of each generator should be in between its maximum and minimum limit. This constraint can be formulated as below:

$$P_{gi,min} \leq P_{gi} \leq P_{gi,max} \tag{4}$$

where, Pgi, min and Pgi, max are the minimum and maximum limit of generating unit i respectively.

METHODOLOGY

In this paper, authors have exploited novel bat algorithm (NBA) to solve emission dispatch problem. NBA is an extended version of BA. Bat algorithm (BA) was developed by [16] and was based on the echolocation phenomena of bats. It is relatively a new nature-inspired metaheuristic technique that is known for its ability to successfully combine the advantages of many well-known algorithm [17]. Bat can prey, avoid obstacles and search food by their advanced echolocation capability as well as its self-adaptive ability to compensate Doppler Effect in echoes. In original BA, Doppler Effect was not considered. Moreover, foraging habitats of bats were not considered rather it was considered that bats forage in only one habitat which was not true and did not reflect the actual behaviour of bats [18].

Algorithm 1: The Novel Bat Algorithm

Define basic BA parameters: α, γ, f_{min}, f_{max}, A_0 and r_0;
Initialize the number of individuals (N) contained by the population, iterations (M), probability of habitat selection (P), inertia weight (w), compensation rates for Doppler Effect in echoes (C), contraction/expansion coefficient (θ), the frequency of updating the loudness and emission pulse rate (G);
Evaluation of objective function value for each individual. while (iteration<M)
if (rand(0,1)<P)
Generate new solution
End if
if (rand(0,1)>r_i)
Generate a local solution around the selected best solution
End if
Evaluate the objective function value of each individual. Update solutions, the loudness and emission pulse rate Rank the solutions and find the current best g^t
If g^t does not improve in G time step.
Re-initialize the loudness A_i and set temporary pulse rates r_i
End if t=t+1; End while

To make the algorithm more similar to the actual scenario of bats and thus make it more efficient, two more idealized rules have been proposed with the three basic idealized rule [16] found in the basic BA. They are: (1) depending on stochastic selection, bats have different forage habitats, (2) bats have the self-adaptive capability to compensate for Doppler Effect in echoes. Algorithm 1 shows the pseudo code of NBA. Detail description of NBA is out of the scope of this paper. However, interested reader may check the paper of [19] to learn more details about NBA.

RESULTS AND DISCUSSION

The proposed NBA algorithm described earlier is applied to solve emission dispatch problem for 3-unit system using cubic function and considering transmission loss. Authors implement this proposed algorithm in MATLAB R2015a and executed with Intel® Core™ i5-3470 CPU @ 3.20 GHz (4 CPUs), ~3.2GHz and 4GB RAM personal computer. Table 1 shows the parameter settings used in this research.

Table 1: Parameter settings of NBA for solving emission dispatch problem

Parameters	Values
Maximal generations (iterations)	100
Population size	100
Dimension	20
The maximal and minimal pulse rate	1 and 0
The maximal and minimal frequency	2 and 1
The maximal and minimal loudness	1.5 and 0
The frequency of updating the loudness and pulse emission rate	10
The maximal and minimal probability of habitat selection	0.9 and 0.6
The maximal and minimal compensation rate for Doppler effect in echoes	0.9 and 0.1
The maximal and minimal contraction expansion coefficient	1 and 0.5
The maximal and minimal inertia weight	0.9 and 0.5

From Table 1, it is clear that unlike PSO, NBA needs less number of iterations and less population to converge to the optimal solution. Therefore, the computational time is relatively less compared to PSO. Table 2 shows the emission coefficients values for 3-unit system, B coefficient values, minimum and maximum limit of each generating unit. Same coefficients values have been used for SDSM, PSO and NBA to run a fair comparison among them.

Table 2: Cubic emission function coefficients for 3-unit system transmission loss

Unit No.	1	2	3
Generator Data			
a_i (kg/MW^{3}h)	2.2×10^{-6}	3.3×10^{-6}	2.3×10^{-6}
b_i (kg/MW^{2}h)	0.00419	0.00683	0.00461
c_i (kg/MWh)	0.32767	-0.54551	-0.51116
d_i (kg/h)	13.85932	40.2699	42.89553
$P_{i,min}$ (MW)	50	75	200
$P_{i,max}$ (MW)	175	200	375
a_i (kg/MW^{3}h)	2.2×10^{-6}	3.3×10^{-6}	2.3×10^{-6}
b_i (kg/MW^{2}h)	0.00419	0.00683	0.00461
B Coefficients			
1	0.00014	0.000015	0.000026
2	0.00015	0.000065	0.000024
3	0.000026	0.000024	0.000069

Table 3 shows the comparison results for 3-unit system. It is clear from the Table 3 that NBA outperforms both SDSM and PSO by optimizing least amount of emission of hazardous gases and particulates for the same coefficients values. Transmission loss is almost same for both PSO and NBA, but more for SDSM. The 3 also shows that NBA is computationally efficient and thus take less time to converge to the final value. Several test runs have made and average computational time has been taken to compare between these optimization techniques.

Table 3: Comparison of results for 3-unit system considering transmission loss

	SDSM [20]	PSO [21]	NBA
P_1 (MW)	65	155.17	155.19
P_2 (MW)	92	156.39	156.37
P_3 (MW)	355.71	200	200
E (kg/h)	646.06	540.72	540.7
P_L (MW)	12.71	11.56	11.56
Time (sec)	-	4.47	1.32

Figures 1 and 2 show the convergence curves for emission dispatch of NBA and PSO respectively. It can be seen that PSO takes more iterations (approximately 250, however it varies for different runs) to converge to the final value, whereas NBA takes very few number of iterations to get to the final value.

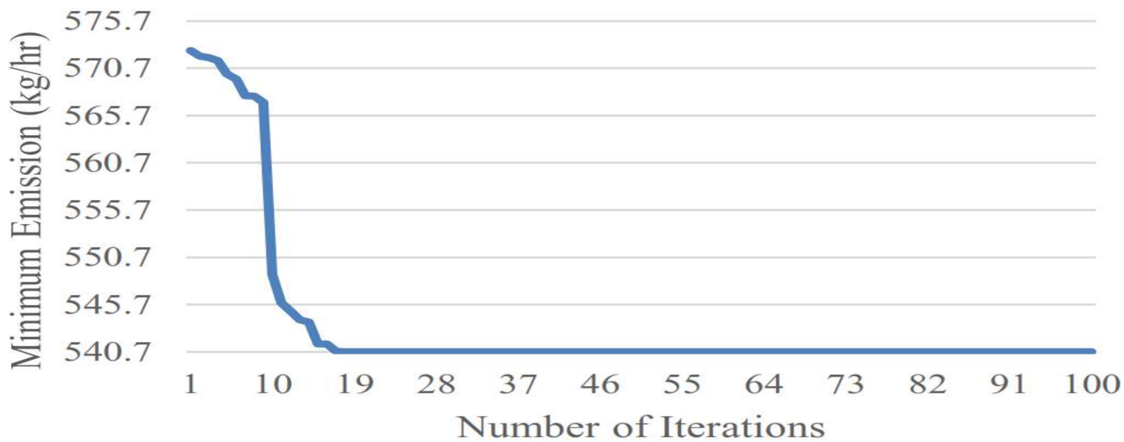

Figure 1: Convergence curve of NBA for emission dispatch problem for 3-unit system considering transmission loss

Thus, it can be said that NBA has a faster convergence than PSO and takes less time to get to the final value. Moreover, PSO also needs larger populations to reach the final point, otherwise it may easily fall into local optima.

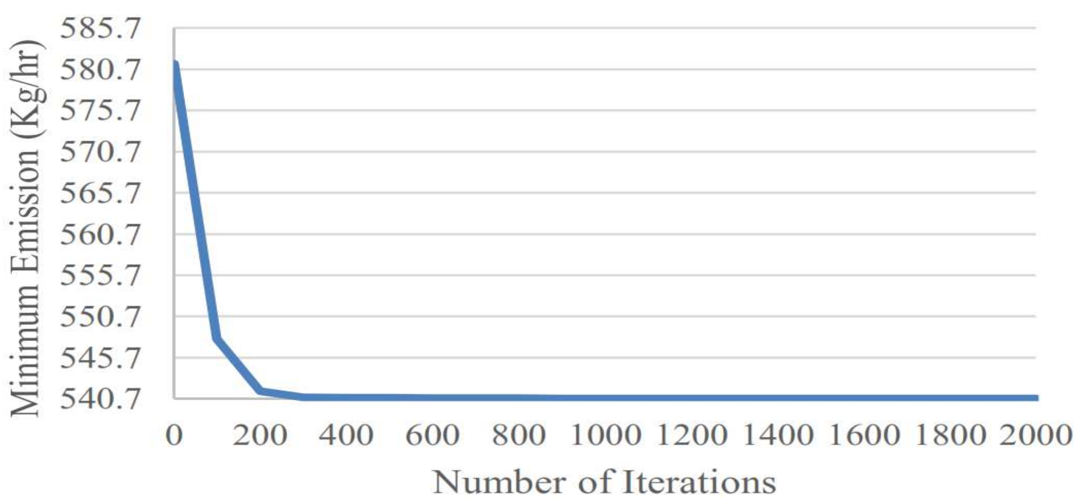

Figure 2: Convergence curve of PSO for emission dispatch problem for 3-unit system considering transmission loss

CONCLUSION

In this research, a novel bat algorithm has been proposed and utilized to solve single objective emission dispatch problem. NBA is the variant of BA where two more idealized rules such as self-adaptive compensation capability for Doppler Effect in echoes and diversified foraging habitats have been considered to make the algorithm more realistic and efficient. Comparing with classical simplified direct search method (SDSM) and meta-heuristic PSO method the following points can be concluded:

Reliability

Unlike PSO, this proposed novel bat algorithm can provide reliable solution as the percentage of deviation to the final answer in each run is highly negligible. PSO provides a wide range of fluctuation and thus need to take the average of the final value by running it many number of times.

Computational time

As mentioned in the previous section, NBA need less number of iterations and fewer population to evolves into the final value and thus is computationally efficient and feasible. PSO takes more number of iteration and larger population to evolve to the final answer without trapping into the local optima.

Convergence characteristics

NBA provides better convergence properties with faster convergence than PSO. The solutions are found to be more stable and robust than the other two methods (SDSM and PSO). The main disadvantage identified in this research is NBA needs too many parameters to be defined.

In future, multiobjective problem like combined economic emission dispatch problem can be investigated using this method using cubic function. Quantum computing (QC) phenomena should be investigated to incorporate QC ideas into the domain of NBA to make it more efficient and stronger optimizing tool.

ACKNOWLEDGMENT

The authors would like to thank Universiti Teknologi PETRONAS for supporting the research under Graduate Assistance Scheme and FRGS. This research paper is financially supported by FRGS with the support of the Centre of Graduate study and the Department of Fundamental & Applied Sciences, Universiti Teknologi PETRONAS.

REFERENCES

1. McBride, J., R. Moore, J. Witherspoon and R. Blanco, 1978. Radiological Impact of Airborne Effluents of Coal and Nuclear Plants. Science, 202 (4372): 1045-1050.
2. Goodarzi, F., F.E. Huggins and H. Sanei, 2008. Assessment of Elements, Speciation of As, Cr, Ni and Emitted Hg for a Canadian Power Plant Burning Bituminous Coal. International Journal of Coal Geology, 74 (1): 1-12.
3. Dieu, V.N. and W. Ongsakul, 2010. Economic Dispatch with Emission and Transmission Constraints by Augmented Lagrange Hopfield Network. Transaction in Power System Optimization, 1: 77-83.
4. Wood, W., 1982. Spinning Reserve Constrained Static and Dynamic Economic Dispatch. IEEE Transactions on Power Apparatus and Systems, 101 (2): 381-388.
5. Somuah, C. and N. Khunaizi, 1990. Application of Linear Programming Redispatch Technique to Dynamic Generation Allocation. IEEE Transactions on Power Systems, 5 (1): 20-26.
6. Liang, Z.X. and J.D. Glover, 1992. A Zoom Feature for a Dynamic Programming Solution to Economic Dispatch Including Transmission Losses. IEEE Transactions on Power Systems, 7 (2): 544-550.
7. Hindi, K.S. and M.A. Ghani, 1991. Dynamic Economic Dispatch for Large Scale Power Systems: A Lagrangian Relaxation Approach. International Journal of Electrical Power and Energy Systems, 13 (1): 51-56.
8. Papageorgiou, L.G. and E.S. Fraga, 2007. A Mixed Integer Quadratic Programming Formulation for the Economic Dispatch of Generators with Prohibited Operating Zones. Electric Power Systems Research, 77 (10): 1292-1296.
9. Xia, X. and A. Elaiw, 2010. Optimal Dynamic Economic Dispatch of Generation: A Review. Electric Power Systems Research, 80 (8): 975-986.

10. Bansal, R., 2005. Optimization Methods for Electric Power Systems: An Overview. International Journal of Emerging Electric Power Systems, 2 (1): 1-23.
11. Li, F., R. Morgan and D. Williams, 1997. Towards More Cost Saving Under Stricter Ramping Rate Constraints of Dynamic Economic Dispatch Problems-A Genetic Based Approach. In the Proceedings of the 2nd International Conference on Genetic Algorithms in Engineering Systems: Innovations and Applications, pp: 221-225.
12. Panigrahi, B.K., V.R. Pandi and S. Das, 2008. Adaptive Particle Swarm Optimization Approach for Static and Dynamic Economic Load Dispatch. Energy Conversion and Management, 49 (6): 1407-1415.
13. Panigrahi, C., P. Chattopadhyay, R. Chakrabarti and M. Basu, 2006. Simulated Annealing Technique for Dynamic Economic Dispatch. Electric Power Components and Systems, 34 (5): 577-586.
14. Basu, M. and A. Chowdhury, 2013. Cuckoo Search Algorithm for Economic Dispatch. Energy, 60: 99-108.
15. Gherbi, Y.A., H. Bouzeboudja and F. Lakdja, 2014. Economic Dispatch Problem Using Bat Algorithm. Leonardo Journal of Sciences, 13 (24): 75-84.
16. Yang, X.S., 2010. A new metaheuristic bat-inspired algorithm. In: Nature Inspired Cooperative Strategies for Optimization (eds J.R. González, D.A. Pelta, C. Cruz, G. Terrazas and N. Krasnogor) pp. 65-74. Springer Berlin, Heidelberg.
17. Yang, X.S. and A.H. Gandomi, 2012. Bat Algorithm: A Novel Approach for Global Engineering Optimization. Engineering Computations, 29 (5): 464-483.
18. Schnitzler, H.U. and E.K. Kalko, 2001. Echolocation by Insect-Eating Bats: We Define Four Distinct Functional Groups of Bats and Find Differences in Signal Structure that Correlate with the Typical Echolocation Tasks Faced by Each Group. Bioscience, 51 (7): 557-569.
19. Meng, X.B., X. Gao, Y. Liu and H. Zhang, 2015. A Novel Bat Algorithm with Habitat Selection and Doppler Effect in Echoes for Optimization. Expert Systems with Applications, 42 (17): 6350-6364.
20. Ganesan, S. and S. Subramanian, 2012. Non-Convex Economic Thermal Power Management with Transmission Loss and Environmental Factors: Exploration from Direct Search Method. International Journal of Energy Sector Management, 6 (2): 228-238.
21. Mahdi, F.P., P. Vasant, V. Kallimani, P.S.Y. Fai and M.A. Wadud, 2016. Emission Dispatch Problem with Cubic Function Considering Transmission Loss Using Particle Swarm Optimization. Journal of Telecommunication, Electronic and Computer Engineering, 8 (12): 17-21.