International Journal of Multidisciplinary Research and Modern Education (IJMRME)
ISSN (Online): 2454 - 6119
(www.rdmodernresearch.com) Volume II, Issue II, 2016

ECONOMIC DISPATCH WITH MULTI-FUEL OPTION USING IMPROVED BAT ALGORITHM

S. Vijayaraj* & Dr. R. K. Santhi**
* Research Scholar, Department of Electrical and Electronics Engineering, Annamalai University, Chidambaram, Tamilnadu
** Professor, Department of Electrical and Electronics Engineering, Annamalai University, Chidambaram, Tamilnadu

Abstract:

This paper presents application of Improved Bat Algorithm (IBA) for solving Economic Load Dispatch problem considering Valve point loading effect and Multi fuel options. Bat algorithm is an optimization algorithm motivated by the echolocation behaviour of natural bats in finding their foods. Potency of the algorithm is tested on ten unit system with multi fuel options. The promising results show the quick convergence and effectiveness of the Improved Bat algorithm.

Key Words: Economic Load Dispatch, Prohibited Operating Zones, Valve Point Loading Effect, Improved Bat Algorithm & Multi-Fuel

1. Introduction:

Nowadays, the planning and operating power system is a challenging task for power engineers because of its complexity and to satisfy the demand for electric energy of the area served by the system with Continuity of service and reliability. An elite objective here is to perform the service at the lowest possible cost. The role of soft computing techniques has influenced a lot in the field of power system especially in solving optimization problems because of their reliability, speed of convergence and robustness [1]. The ELD problem, one of the different non-linear programming commitments in power system, is about minimizing the fuel cost of generating units for a specific period of operation so as to accomplish optimal generation dispatch among operating units and to satisfy the system load demand and generator operation constraints with ramp rate limits and prohibited operating zones [2]. S. K. Dash [3] was presented a new method to solve the problem of optimal generation dispatch with multiple fuel options using a Radial basis function neural network along with a heuristic rule based search algorithm and a Hopfield neural network. Dr .G. Srinivasan, et al. [4] solved economic load dispatch problem with Valve point effects and multi Fuels using particle swarm algorithm with chaotic sequences and the crossover operation to improve the global searching capability by preventing premature convergence through increased diversity of the population. Radhakrishnan Anandhakumar, et al. [5] was proposed a non-iterative direct Composite Cost Function method, to solve economic dispatches of the online units with less Computation time. Umamaheswari Krishnasamy,et al. [6] presented a Refined Teaching-Learning Based Optimization Algorithm for Dynamic Economic Dispatch of Integrated Multiple Fuel integrated with Wind Power Plants. R. Balamurugan, et al. [7] proposed a self-adaptive mechanism isused to change these control parameters during the evolution process. These control parameters are applied at the individual levels in the population to solve economic dispatch with valve point and multi fuel options. Xin-She Yang. [8] Proposed the Bat algorithm and its characteristic with implementation of various functions for global optimization.

In this paper, Economic load Dispatch problem with inclusion of Multi fuel options and valve point effect has been solved by using the Improved Bat Algorithm. The Bat algorithm approach has been verified by applying it to ten unit system. The performance of the proposed Improved Bat algorithm is analysed and its parameters was self tuned. Because this parameter plays a major role in controlling the searching process of algorithm.

2. Formulation of Economic Load Dispatch Problem:

2.1total Cost Function:

The main objective of Economic Load Dispatch in electrical power system is to reduce the overall production cost of supplying loads while satisfying constraints. The total cost function can be formulated as the following equation.

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

Where $F_i(P_i)$ is the cost function of i_{th} generator and is usually expressed as a quadratic polynomial; a_i, b_i and c_i are the fuel cost coefficients of i_{th} generator; N is the number of generators, P_i is the real power output of i_{th} generator. The Economic Load Dispatch problem minimizes F_t subject to the following constraints and effects.

2.2 Equality Constraints:

The power balance equation is given by

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

Where, P_D is the power demand of the system.

2.3 Inequality Constraints:

The upper and the lower operating region of the generator is given by the equation

$$P_i^{min} \le P_i \le P_i^{max} \; i \in N \qquad (3)$$

Where P_i^{min} and P_i^{max} are the minimum and maximum power outputs of generator i, respectively. The maximum output power of generator is limited by thermal consideration and minimum power generation is limited by the flame instability of a boiler.

2.4 Valve-Point Effects:

The generator cost function is obtained from a data point taken during "heat run" tests when input and output data are measured as the unit slowly varies through its operating region. Wire drawing effects, which occur as each steam admission valve in a turbine starts to open, produce a rippling effect on the unit curve. To consider the accurate cost curve of each generating unit, the valve point results in as each steam valve starts to open, the ripples like the cost function addressing valve-point loadings of generating units is accurately represented as

$$F_t = \sum_{i=1}^{N} F_i(P_i = \sum_{i=1}^{N} a_i + b_i P_i + c_i + \left| d_i \times \sin\{e_i \times (p_i^{min} - P_i\} \right| \qquad (4)$$

2.5 Valve-Point Effects and Multi Fuels Effect:

To obtain an accurate and practical economic dispatch solution, the realistic operation of the ELD problem should be considered both valve-point effects and multiple fuels. This project proposed an incorporated cost model, which combines the valve-point loadings and the fuel changes into one frame. as explained .

$$F_i(P_i) = \begin{cases} a_{i1} + b_{i1}P_{i1} + c_{i1}P_{i1}^2 + \left|d_{i1} \times \sin\{e_{i1} \times (p_{i1}^{min} - P_{i1}\}\right|, & \text{for fuel } 1, p_i^{min} \le P_i \le P_{i1} \\ a_{i2} + b_{i2}P_{i1} + c_{i2}P_{i2}^2 + \left|d_{i2} \times \sin\{e_{i2} \times (p_{i2}^{min} - P_{i2}\}\right|, & \text{for fuel } 2, p_i^{min} \le P_i \le P_{i2} \\ \vdots & \\ a_{ik} + b_{ik}P_{ik} + c_{ik}P_{ik}^2 + \left|d_{ik} \times \sin\{e_{ik} \times (p_{ik}^{min} - P_{ik}\}\right|, & \text{for fuel } k, p_{ik-1}^{min} \le P_i \le P_i^{max} \end{cases} \qquad (5)$$

3. Bat Algorithm:

Bat algorithm is an optimization algorithm motivated by the echolocation behaviour of natural bats in finding their foods. It is introduced by Yang and is used for solving many real world optimization problems. Each virtual bat in the initial population employs a homologous manner by doing echolocation for updating its position. Bat echolocation is a perceptual system in which a series of loud ultrasound waves are released to produce echoes. These waves are returned with delays and various sound levels which make bats to discover a specific prey as shown in Fig-1. Some guidelines are studied to enhance the structure of BAT algorithm and use the echolocation nature of bats.

- ✓ Each bats identify the distance between the prey and background barriers using echolocation.
- ✓ Bats fly randomly with velocity v_i at position x_i with a fixed frequency f_{min}(or Wavelength λ), varying wavelength λ (or frequency f) and loudness A_o to search for prey. They can naturally adopt the wavelength (or frequency) of their emitted pulses and adjust the rate of pulse emission r ∈ [0, 1], depending on the closeness of their prey;
- ✓ Although the loudness of the bats can be modified in many ways, we consider that the loudness varies from a large (positive) A_o to a minimum value A_{min} according to the problem taken.

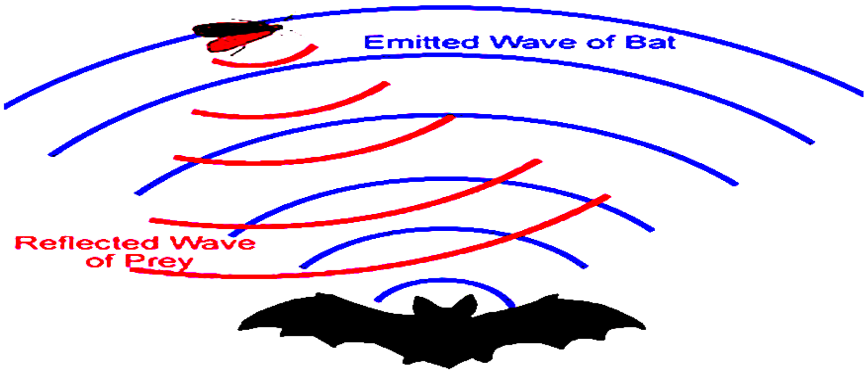

Figure 1: Ecolocation behaviour of bats

3.1 Initialization of Bat Population:

Population initialization of bats randomly in between the lower and the upper boundary can be achieved by the equation.

$$x_{ij} = x_{min\ j} + rand(0,1)\left(x_{max\ j} - x_{min\ j}\right) \qquad (6)$$

Where i=1, 2,…n, j=1, 2,….d, x_{minj} and x_{maxj} are lower and upper boundaries for dimension j respectively.

3.2 Update Process of Frequency, Velocity and Solution:

The step size of the solution is controlled with the frequency factor in BA. This frequency factor is generated randomly in between the minimum and maximum frequency [fmin, fmax]. Velocity of a solution is proportional to frequency and new solution depends on its new velocity and it is represented as.

$$f_i = f_{min} + (f_{max} - f_{min})\beta \qquad (7)$$

$$v_i^t = v_i^{t-1} + (x_i^t - x^*)f_i \qquad (8)$$

$$x_i^t = x_i^{t-1} + v_i^t \qquad (9)$$

Where β ϵ[0, 1] indicates randomly generated number, x^*represents current global best solutions. For local search part of algorithm (exploitation) one solution is selected among the selected best solutions and random walk is applied.

$$x_{new} = x_{old} + \varepsilon A^t \qquad (10)$$

Where A^t, is average loudness of all bats, ε∈ [0, 1] is random number and represents direction and intensity of random-walk.

3.3 Update Process of Loudness and Pulse Emission Rate:

As iteration increases, the loudness and pulse emission must be updated because when the bat gets closer to its prey then their loudness Ausually decreases and pulse emission rate also increases, the updating equation for loudness and pulse emission is given by

$$A_i^{t+1} = \alpha A_i^t \quad (11)$$

$$r_i^{t+1} = r_i^0\left[1 - e^{(-\gamma t)}\right] \quad (12)$$

Where α and γ are constants. ri^0 and A_i are factors which consist of random values and Ai^0can typically be [1, 2], while ri^0can typically be[0,1].

3.4 Pseudo Code of Bat Algorithm:

- ✓ Objective function: f(x), $x=(x_1....x_d)^t$
- ✓ Initialize bat population $x_i$and velocity v_i i=1, 2...n
- ✓ Define pulse frequency f_i at x_i
- ✓ Initialize pulse rate $r_i$and loudness A_i
- ✓ While (t<maximum number of iterations)
- ✓ Generate new solutions by adjusting frequency, and updating velocities and location/solutions.
- ✓ If (rand>r_i)
- ✓ Select a solution among the best solutions
- ✓ Generate a local solution around the selected best solution
- ✓ End if
- ✓ If(rand< Ai and f(xi)< f(x*))
- ✓ Accept new solutions
- ✓ Increase r_i, reduce Ai
- ✓ End if
- ✓ Ranks the bats and find current best x*
- ✓ End while
- ✓ Display results.

4. Improved Bat Algorithm (IBA):

Bat Algorithm is an efficient algorithm at exploitation but has some insufficiency at exploration, thus it can easily get trapped in local minimum on most of the multimodal test functions. In order to overcome this problem of standard BA, some modifications are made in the update process of frequency to improve exploration and exploitation capability of BA.

Normally, in bat algorithm the frequency is randomly generated in between the minimum and maximum value, this frequency will have same effect to all dimensions of solution. In order to adopt the effect of change in dimensions on solutions a dynamic frequency varying concept is assigned in this improved bat algorithm.

$$diff_j = \sqrt{(x_{ij} - x_j^*)^2} \quad (13)$$

$$range = \max(diff) - \min(diff) \quad (14)$$

$$f_j = f_{min} + \frac{\sqrt{(\min(diff) - (diff_j))^2}}{range} * (f_{max} - f_{min}) \quad (15)$$

The distances between i_{th} solution and global best solution are calculated first then the frequency updating are assigned according to Eq. (15), so the frequency variation is depend on difference in distances as per the Eq. (13).By varying the Frequency the step size of the solutions also varied. Thus, dimensions which are closer to global optimum point do not steer for irrelevant regions. Instead, they locally search around global optimum point. Velocity formulation Eq. (16) must be updated as follows.

$$v_{ij}^{t} = v_{ij}^{t-1} + \left(x_{ij}^{t} - x_{ij}^{*}\right)f_j \quad (16)$$

Pseudo Code for Improved Bat Algorithm:

- ✓ Initialize the population of *n* bats randomly and evaluate the objective function for all bats.
- ✓ Initialize temporary best solution among the solutions.
- ✓ Define frequency as per the Eq. (14-16).
- ✓ Define loudness A_i and the initial velocities v_i (i= 1, 2, . . . , N); Set pulse rate r_i.
- ✓ While (t<maximum number of iterations)
- ✓ Evaluate objective function for generating new solutions by varying the frequency and update velocity Eq.(14-16).
- ✓ If (rand> r_i)
- ✓ Select a solution among the best solutions.
- ✓ Generate a local solution around the selected best solution.
- ✓ End if
- ✓ If (rand< A_i and $f(x_i)$< $f(x^*)$)
- ✓ Accept new solutions
- ✓ Increase r_i, reduce A_i
- ✓ End if
- ✓ Ranks the bats and find current best x*
- ✓ End while
- ✓ Display results.

5. Results:

In this case Bat algorithm is employed to solve the economic dispatch of ten unit system with demand 2700MW consist of valve-point effect and multi-fuel options. the simulation results and the converge of the cost function is shown in Fig-2 for 100 iterations. The random value of frequency change is shown in Fig-3.

Table 1: simulation result of ten unit system with multi fuel option.

Unit Power Output	IBA	Fuel	Unit Power Output	IBA	Fuel
P1 (MW)	231.4150	2	P6 (MW)	236.5850	3
P2 (MW)	226.3850	1	P7 (MW)	292.6550	1
P3 (MW)	297.3150	1	P8 (MW)	241.7650	3
P4 (MW)	237.4850	3	P9 (MW)	407.1550	3
P5 (MW)	280.5950	1	P10 (MW)	248.6450	1
Total Output (MW)	**2700.00**				
Cost (in $/hr)	**621.13**				

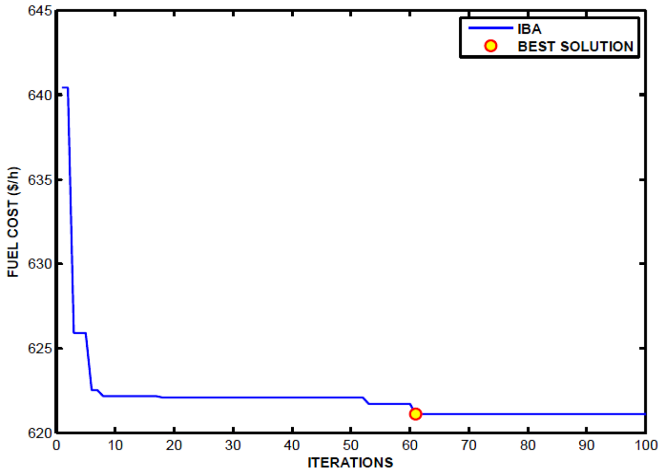

Figure 2: Convergence Characteristics of IBA

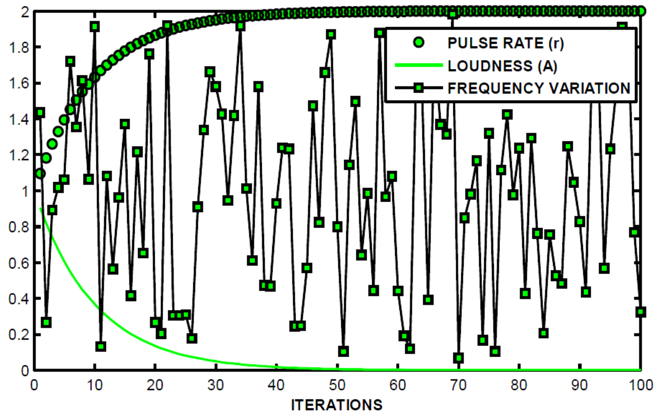

Figure 3: Parameter Variation of IBA

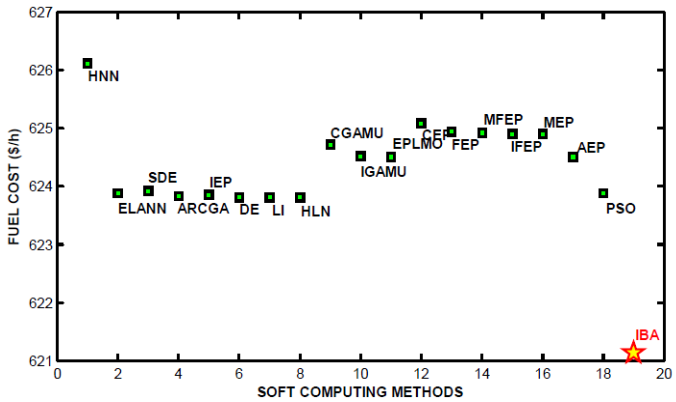

Figure 4: Result Comparison of IBA with Other Techniques

Table 2: Result Comparison of IBA with Other Techniques

S.No	Methods	Fuel Costs ($/H)
1	HNN - Hopfield neural network[9]	626.12
2	ELANN - Enhanced Lagrangian Neural Network [9]	623.88
3	SDE - Self-Adaptive Differential Evolution [9]	623.9225
4	ARCGA - Adaptive Real Coded Genetic Algorithm [9]	623.828
5	IEP- Improved Evolutionary Programming [9]	623.851
6	DE-Differential Evolution [9]	623.809
7	LI - Lamda Iteration[9]	623.8089
8	HLN-Hopfield Lagrange network[9]	623.8092
9	CGAMU - Conventional Genetic Algorithm with multiplier updating [11]	624.7193
10	IGAMU - Improved Genetic Algorithm with Multiplier Updating [11]	624.5178
11	EPLMO - Evolutionary Programming Levenberg Marquardt Optimization[11]	624.5074
12	CEP - Classical Evolutionary Programming [10]	625.0874
13	FEP-Fast Evolutionary Programming [10]	624.9370
14	MFEP - Mean Fast Evolutionary Programming [10]	624.9218
15	IFEP - Improved Fast Evolutionary Programming [10]	624.9064
16	MEP - Modified Evolutionary Programming [10]	624.9035
17	AEP-Accelerated Evolutionary Programming [10]	624.5074
18	PSO - Particle Swarm Optimization [12]	623.88
19	**IBA - Improved Bat Algorithm**	**621.13**

6. Conclusion:

In this paper, Improved Bat algorithm is applied to economic load dispatch problems with ten unit system with multi-fuel option as a test case. The results obtained by this method are compared with other soft computing techniques. The comparison shows that Improved Bat algorithm performs better and got good convergence characteristics. The Bat algorithm has superior features, including quality of solution, stable convergence characteristics and good computational efficiency. Therefore, this results shows that Improved Bat algorithm is a promising technique for solving complicated problems in power system.

7. References:

1. B. H. Chowdhury and S. Rahman, "A Review of Recent Advances in Economic Dispatch", IEEE Trans. Power Syst 5(4), 1990, pp. 1248-1259.
2. F. N. Lee and A. M. Breipohl, "Reserve Constrained Economic Dispatch with Prohibited Operating Zones", IEEE Trans Power Syst 8(1), 1993, pp. 246-254.
3. S.K. Dash," An Artificial Neural Network Method for Optimal Generation Dispatch with Multiple Fuel Options", International Journal of Advanced Electrical and Electronics Engineering, ISSN (Print): 2278-8948, Volume-2, Issue-1, 2013.
4. Dr G. Sreenivasan, B. Dheeraj Merin Babu, K. Srikanth,and B. Rajesh Kiran," solution of eld problem with valve point effects and multi-fuels using IPSO algorithm", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, ISSN (Print) : 2320 – 3765, Vol. 2, Issue 11, November 2013.
5. Radhakrishnan Anandhakumar, and Srikrishna Subramanian," Economic Dispatch with Multiple Fuel Options Using CCF", Scientific Research Journal, doi:10.4236/epe.2011.32015 Published Online May 2011.
6. Umamaheswari Krishnasamy and Devarajan Nanjundappan, "A Refined Teaching-Learning Based Optimization Algorithm for Dynamic Economic Dispatch of Integrated Multiple Fuel and Wind Power Plants", Hindawi Publishing Corporation, Volume 2014, Article ID 956405, http://dx.doi.org/ 10.1155/2014/956405.
7. R. Balamurugan and S. Subramanian, "Self-Adaptive Differential Evolution Based Power Economic Dispatch of Generators with Valve-Point Effects and Multiple Fuel Options", World Academy of Science, Engineering and Technology, International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering Vol: 1, No: 3, 2007.
8. Xin-She Yang, Bat algorithm: literature review and applications, Int. J. Bio-Inspired Computation, Vol. 5, No. 3, pp. 141–149 (2013). DOI: 10.1504/IJBIC.2013.055093.
9. Nguyen Trung Thang," Economic Emission Load Dispatch with Multiple Fuel Options Using Hopfield Lagrange Network", International Journal of Advanced Science and Technology, Vol. 57, pp.9-24 August, 2013.
10. P. S. Manoharan and P. S .Kannan, "A Novel EP Approach For Power Economic Dispatch With Valve-Point Effects And Multiple Fuel Options" , Journal Of Electrical Systems, 4-2(2008): 1-12.
11. V. Srinivasan and T. Saravanan," Application of EP to Multiple Fuel Options Economic Dispatch", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 3, Issue 11, November 2014.
12. Rashida Hasan and Farhana Haque, "Self Adaptive Differential Evolution for Handling Economic Load Dispatch with Valve-point Effect, Multiple Fuel & Transmission Losses" International Research Journal of Computer Science Engineering and Applications Vol 2 Issue 8 August 2013
13. Pranjal pragya verma, Praveen Ganesh, G. Avinash and K. Chandrasekaran," Solving economic load dispatch problem using clustered gravitational search

algorithm" International Journal of Industrial Electronics and Electrical Engineering, Volume-2, Issue-8, Aug.-2014.
14. Jinho Kim, Chang Seob Kim, and Zong Woo Geem" A Memetic Approach for Improving Minimum Cost of Economic Load Dispatch Problems" Hindawi Publishing Corporation, Volume 2014,PP 1-11.
15. A. Rabii, S. Mobaieen, B. Mohamady and A. Suroody," A New Heuristic Algorithm for solving non-convex economic power dispatch" journal of applied sciences",2011(23),pp.3791-3796.
16. Kamlesh Kumar Vishwakarma, Hari Mohan Dubey, Manjaree Pandit and B.K. Panigrahi," Simulated annealing approach for solving economic load dispatch problems with valve point loading effects", International Journal of Engineering, Science and Technology ,Vol. 4, No. 4, 2012, pp. 60-72.
17. B. Shaw, S. Ghoshal, V. Mukherjee, and S. P. Ghoshal, "Solution of Economic Load Dispatch Problems by a Novel Seeker Optimization Algorithm", International Journal on Electrical Engineering and Informatics - Volume 3, Number 1, 2011.
18. Sinha N., Chakrabarti R., Chattopadhyay P.K.: 'Evolutionary programming techniques for economic load dispatch', IEEE Trans. Evol. Comput., 2003, 7, (1), pp. 83–94.
19. P. K. Hota, A. K. Barisal, R. Chakrabarti, "Economic emission load dispatch through fuzzy based bacterial foraging algorithm", Electrical Power and Energy Systems, 2010, 32, pp. 794–803.
20. S. Hemamalini and S.P. Simon, "Maclaurin series-based Lagrangian method for economic dispatch with valve-point effect", IET Gener. Transm. Distrib., 2009, 3, (9), pp. 859– 871.
21. S. Vijayaraj and Dr. R. K. Santhi ,Multi-Area Economic Dispatch with Multi Fuel Option Using Improved Bat Algorithm, International Journal of Innovative Research in Science, Engineering and Technology ,Vol. 5, Issue 10, October 2016.
22. S. Vijayaraj and Dr. R. K. Santhi ,Multi-Area Economic Dispatch with Valve Point Effect Using Improved Bat Algorithm, International Journal for Research in Applied Science & Engineering Technology, Volume 4 Issue 10, October 2016.
23. S. Vijayaraj and Dr. R. K. Santhi ,Multi-Area Economic Dispatch with Prohibited Operating Zones Using Improved Bat Algorithm, International Journal of Multidisciplinary Research and Modern Education, Volume II, Issue II, 2016.
24. S. Vijayaraj, and Dr. R. K. Santhi, "Multi-area economic dispatch using Improved Bat Algorithm", International Journal of Applied Engineering Research, Vol. 10, pp 40139-40146, 2015.
25. S. Vijayaraj., and Dr. R. K. Santhi.," Economic Dispatch with Valve Point Effect Using Improved Bat Algorithm" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering