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# Non-Convex Multi Objective Economic Dispatch Using Ramp Rate Biogeography Based Optimization

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***Abstract*****—**Multi objective non-convex economic dispatch problems of a thermal power plant are of grave concern for deciding the cost of generation and reduction of emission level for diminishing the global warming level for improving green-house effect. This paper deals with ramp rate constraints for achieving better inequality constraints so as to incorporate valve point loading for cost of generation in thermal power plant through ramp rate biogeography based optimization involving mutation and migration. Through 50 out of 100 trials, the cost function and emission objective function were found to have outperformed other classical methods such as lambda iteration method, quadratic programming method and many heuristic methods like particle swarm optimization method, weight improved particle swarm optimization method, constriction factor based particle swarm optimization method, moderate random particle swarm optimization method etc. Ramp rate biogeography based optimization applications prove quite advantageous in solving non convex multi objective economic dispatch problems subjected to nonlinear loads that pollute the source giving rise to third harmonic distortions and other such disturbances.

***Keywords*****—**Economic load dispatch, Biogeography based optimization, Ramp rate biogeography based optimization, Valve Point loading, Moderate random particle swarm optimization method, Weight improved particle swarm optimization method.

## I. Introduction

RECENT power quality improvement techniques employ a distributed generation source of solar photovoltaic cells involving capacitors that act as a compensator for polluting the source to counterbalance the nonlinear behaviour of load resulting out of inductive load, rectifier load and other electronic and industrial loads. However, the presence of nonlinearity is not fully eliminated through these techniques. Therefore, the RRBBO technique [13] best fits for non-linear fuel cost characteristic and quadratic emission objective for thermal power plant. Biogeography being a natural species distribution method [12] gets empowered more in dealing with non-convex economic load dispatch method due to inclusion of up ramp limit and down ramp limit in the in-equality constraint. The concept of habitat bearing high suitability index (HSI) giving rise to good solution and habitat bearing low suitability index yielding poor solution was a challenge in BBO. However, in the RRBBO approach, habitat with low HSI gets ample chance to recover by posing a threat to that in the habitat bearing high HSI thereby inducing good qualities from habitat having high suitability index. In this paper, the economic load dispatch posing non-convex cost characteristic and quadratic emission level objective has been attempted through RRBBO technique for IEEE 30 bus test case system involving 6 generating units with and without valve point loading (VPL) as shown in Figs. 3 and 4, respectively. In this paper, the performance of RRBBO has been compared with other heuristic methods like weight improved Particle swarm optimization (WIPSO) and moderate random particle swarm optimization (MRPSO) etcetera. This method is found to outperform all soft computing and classical methods which are shown in Figs. 1 and 2 that illustrate cost versus output power and emission level versus output power.

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## II. Methodology

An ELD [1], [6], [9] problem ascertains a solution for cost of generation and level of emission involving inequality and equality constraints involving classical optimization techniques. However the valve-point effects are taken into consideration in the ELD [1] problem by adding the basic quadratic fuel cost characteristic with rectified sinusoidal component as shown in (1)

$$Fi = \left(a_i \times P_i^2 + b_i \times P_i + c_i\right) + \left|\left(e_i \times \sin\left(f_i \times \left(P_n - P_i\right)\right)\right)\right| \quad (1)$$

where $a_i$, $b_i$, $c_i$, $e_i$, and $f_i$ etc. are fuel cost coefficients.

Equation (1) satisfies the following equality and inequality constraints.

Equality constraints

$$\sum_{i=1}^{n} P_i = P_D + T_L \quad (2)$$

Inequality constraints

$$P_n < P_i < P_x \quad (3)$$

Considering a quadratic behavioral approach for emission objective function for thermal power plant the emission objective is expressed as:

$$J_i = \left(h_i \times P_i^2 + g_i \times P_i + q_i\right) \quad (4)$$

The equality and inequality constraints outlined through (2) and (3) satisfy emission objective in (4) as well. The inequality constraint for generation dispatch is modified using the ramp rate limit constraints as shown in (5)-(7):

$$Max(PG_{i\min}, P_{i0} - DR_i) \le PG_{inew} \le Min(PG_{i\max}, P_{i1} + UR_i) \quad (5)$$

$$P_{gi} - P_{i0} \le UR_i \text{ (Generation increases)} \quad (6)$$

$$P_{i0} - P_{i1} \le DR_i \text{ (Generation decreases)} \quad (7)$$

where $P_{i1}$ = Power generation of $i^{th}$ unit in the current interval $P_{i0}$ = Power generation of $i^{th}$ unit just before the interval. The valve point effect emerging out of the VPL and non-linear loads in electric power system has been emphasized through RRBBO guidelines.

## III. Overview of Non-Convex Multi Objective Economic Dispatch Using Ramp Rate Biogeography Based Optimization

### A. Migration

Ramp rate BBO [7] involves a migration technique for a species for venturing into or out of an island making use of a population of candidate solution required for optimization process. In this optimization process each candidate solution is represented as an array of real numbers. Each real number represents a high suitability index variable (SIV). The SIVs in an array are utilized to compute the habitat suitability index (HSI) of a habitat. The HSI is very similar to objective function i.e. solution with better HIS is regarded as a better solution and solution with poor HIS represents an inferior solution for ramp rate biogeography based optimization. Since BBO [2], [11], [8] involves human population entering a new habitat or moving past an old habitat following immigration and emigration criteria with immigration rate λ and the emigration rate μ for sharing information, so λ and μ are used to decide migration of a particular SIV, from a particular habitat or into a new habitat. Few elite solutions are kept the same in the subsequent iterations for eradicating best solutions undergoing change during Immigration.

Immigration and emigration rates of a habitat comprising species are expressed as

$$\lambda_s = I(1 - \frac{s}{N}) \quad (8)$$

$$\mu_s = E \times s/N \quad (9)$$

*I*, *E*: the maximum immigration and emigration rates respectively; *N*: maximum number of species that a habitat can contain.

### B. Mutation

Due to calamities, the HSI of a habitat undergoes drastic change for obtaining species count that deviates from its equilibrium value. Climatic climaxes can cause momentary change in the HSI of a particular habitat. The Probability of an organism can be computed as

$$P_s = \begin{cases} -(\lambda_s - \mu_s)P_s + \mu_{s+1}P_{s+1} \\ -(\lambda_s - \mu_s)P_s + \mu_s)P_s + \lambda_{s-1}P_{s-1} + \mu_{s+1}P_{s+1} 1 \le s \le N-1 \\ -(\lambda_s - \mu_s)P_s + \lambda_{s-1}P_{s-1} \end{cases} \quad (10)$$

where $P_s$: the probability of the habitat to contain exactly s species.

A candidate of very high probability has remote chance to mutate but for very high HSI solution it becomes impossible to mutate. Mutation rate for an individual solution set is computed involving species count probability as under

$$m(s) = m_x(1 - P_s) / P_{\max}) \quad (11)$$

where m (s): the mutation rate for habitat comprising exactly s species. $m_x$ : User defined parameter. $P_{\max}$: Larger of all the $P_s$ values.

Such a mutation is meant to increase disparity amongst solutions. At this juncture, there is also an elitism to prevent the solutions from getting worst after mutation procedure. In such a situation if a SIV is selected for mutation operation, then one representative random number is substituted.

The RRBBO algorithm as applied to dual objective ELD problem [5], [8], [13] has been summarized below.

- Step1. Select the number of generators i.e. number of SIVs, number of habitats i.e. population size, power demand, loss coefficients, habitat modification probability P modify = 1, mutation probability = 0.01, maximum mutation rate m(max), maximum immigration rate I = 1, maximum emigration rate E = 1, step size of numerical integration dt = 1 and elitism parameter = 36
- Step2. Each SIV of a habitat is initialized randomly while satisfying the constraints of (5)-(7). Each habitat represents a potential solution to the given problem.
- Step3. HSI for each habitat is computed.
- Step4. Based on the HSI values, elite habitats with minimum fuel cost are selected.
- Step5. For each of the non- elite habitats, migration operation is carried out. HSI for each habitat is recomputed. SIVs obtained after migration must satisfy the constraints of (2).
- Step6. Species count probability of each habitat is updated using (10). Mutation operation is carried out on the non-elite habitats. HSI value of each new habitat set is recalculated.
- Step7. Go to step 3 for next iteration. If the predefined number of iterations is reached, stop the process.

## IV. Result Analysis

Using IEEE 30 bus test case system with 6 numbers of generating units with ramp rate constraints the proposed dissertation for BBO was carried out for dual objective economic dispatch problem for thermal power plant bearing cost and emission coefficients (Table I) for cost and emission function (Figs. 1, 2). The ramp rate BBO approach results were tabulated through Table III which compares the results of various heuristic and classical economic load dispatch methods. It is quite clear that RRBBO [10] outperforms all the aforesaid methods.

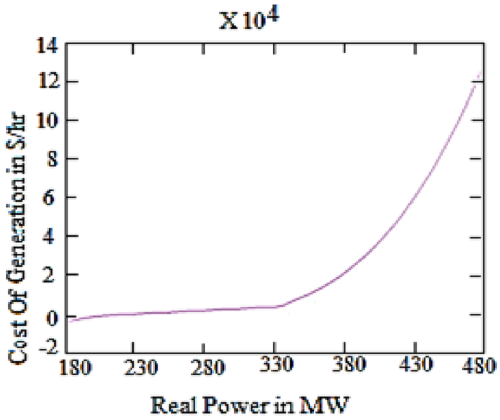


Fig. 1 Cost of generation vs. real power

TABLE I
Cost Coefficients, Unit Capacity and Emission Coefficients for IEEE 30 Bus Test Case System with 6 Units

| Unit | $a_i$ | $b_i$ | $c_i$ | $P_{i\max} = P_i$ | $P_{i\min} = P_i$ | $h_i$ | $g_i$ | $q_i$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.0067 | 6.70 | 94.702 | 181.2 | 30.2 | 0.025 | -1.354 | 22.98 |
| 2 | 0.0067 | 6.70 | 94.701 | 471.6 | 68.6 | 0.0274 | -1.248 | 35.35 |
| 3 | 0.02028 | 7.01 | 309.53 | 367.2 | 61.2 | 0.0151 | 0.805 | 363.30 |
| 4 | 0.0095 | 8.15 | 396.02 | 177.6 | 29.6 | 0.016 | 0.705 | 563.70 |
| 5 | 0.0115 | 5.32 | 147.89 | 360 | 60 | 0.0141 | 0.605 | 763.01 |
| 6 | 0.0015 | 8.01 | 222.32 | 348 | 58 | 0.0142 | 0.604 | 963.01 |
| 7 | 0.00351 | 8.02 | 287.72 | 180 | 30 | 0.023 | -1.213 | 21.99 |
| 8 | 0.00489 | 6.92 | 392.98 | 370.4 | 68.4 | 0.0279 | -1.321 | 34.97 |
| 9 | 0.00573 | 6.58 | 456.76 | 369.6 | 61.6 | 0.017 | 0.901 | 365.34 |
| 10 | 0.00601 | 13 | 723.82 | 172.8 | 28.8 | 0.0142 | 0.721 | 786.96 |
| 11 | 0.001512 | 13 | 723.82 | 364.8 | 60.8 | 0.0143 | 0.603 | 987.89 |
| 12 | 0.00568 | 12.9 | 634.6 | 348 | 58 | 0.028 | 0.609 | 788.56 |
| 13 | 0.004111 | 12.2 | 913.6 | 177.6 | 29.6 | 0.028 | 1.341 | 56 |
| 14 | 0.00760 | 8.81 | 1761.3 | 472.8 | 78.8 | 0.0274 | 1.243 | 56.34 |
| 15 | 0.00705 | 9.05 | 1729 | 367.2 | 61.2 | 0.0151 | 1.345 | 86.96 |
| 16 | 0.00702 | 9.05 | 1728.4 | 175.2 | 29.2 | 0.0162 | 0.675 | 453.87 |
| 17 | 0.00312 | 7.67 | 647.9 | 362.4 | 60.6 | 0.0143 | 0.723 | 578.98 |
| 18 | 0.00312 | 7.92 | 650.7 | 350.4 | 59.4 | 0.0123 | 0.721 | 987.55 |
| 19 | 0.00312 | 8.01 | 647.85 | 182.4 | 30.4 | 0.0155 | 1.234 | 45.67 |
| 20 | 0.00312 | 8.01 | 647.83 | 468 | 78 | 0.016 | 1.238 | 67.78 |
| 21 | 0.00297 | 6.62 | 786.9 | 370.8 | 60.8 | 0.0125 | 0.765 | 87.45 |
| 22 | 0.00296 | 6.62 | 794.55 | 177.6 | 29.2 | 0.0234 | 0.876 | 876.78 |
| 23 | 0.00278 | 6 | 749.56 | 357.6 | 59.6 | 0.213 | 0.543 | 987.67 |
| 24 | 0.00242 | 6.5 | 802.2 | 355.2 | 59.2 | 0.142 | 0.654 | 765.34 |
| 25 | 0.00274 | 7.09 | 802.3 | 302.4 | 50.4 | 0.0123 | -1.654 | 43.45 |
| 26 | 0.00274 | 7.09 | 1056.2 | 348 | 58.0 | 0.023 | -1.734 | 66.78 |
| 27 | 0.52122 | 3.32 | 1056.2 | 388.8 | 64.8 | 0.0234 | 0.876 | 76.34 |
| 28 | 0.52122 | 3.32 | 1055.4 | 153.6 | 25.6 | 0.0213 | 0.987 | 54.89 |
| 29 | 0.52122 | 3.32 | 148.9 | 339.6 | 45.6 | 0.0221 | 0.765 | 897.56 |
| 30 | 0.01138 | 5.31 | 223.5 | 379.2 | 63.2 | 0.0145 | 0.567 | 786.99 |
| 31 | 0.00158 | 6.43 | 223.5 | 242.4 | 40.4 | 0.0123 | 0.765 | 65.34 |
| 32 | 0.00158 | 6.40 | 108.3 | 408 | 68 | 0.231 | 0.654 | 78.45 |
| 33 | 0.00160 | 6.42 | 116.5 | 364.8 | 60.8 | 0.124 | -0.765 | 89.56 |
| 34 | 0.00010 | 8.92 | 117.8 | 177.6 | 29 | 0.213 | -0.897 | 321.99 |
| 35 | 0.00010 | 8.61 | 234.9 | 249.6 | 41.6 | 0.124 | 1.231 | 432.7 |
| 36 | 0.00010 | 8.61 | 1234.1 | 463.2 | 6702 | 0.0231 | 1.453 | 876.9 |

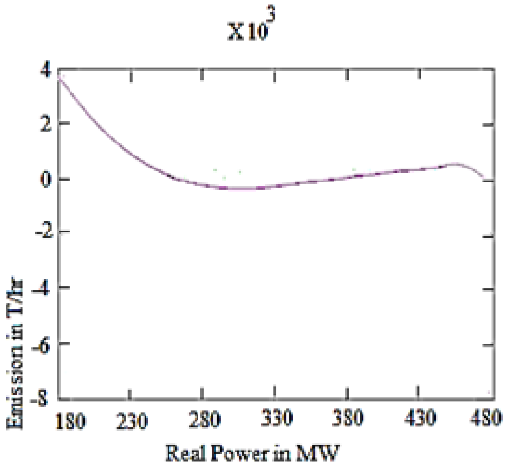


Fig. 2 Emission level vs. Real power

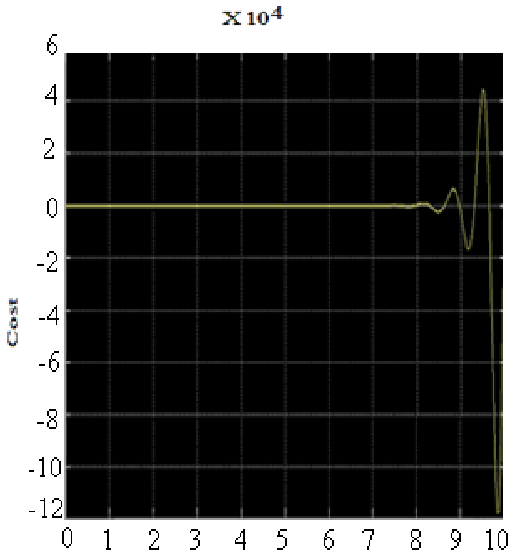


Fig. 3 Unit with VPL for population size of 36 trials

## V. Conclusion

ACWRRPSO presented advanced PSO technique involving VPL [4], [5], [9], [13], ramp rate. RRBBO presented advanced BBO technique involving VPL, ramp rate constraints and price penalty factor for optimization of cost objective and emission objective function. The nonlinear behaviour of cost curve and emission objective is well taken care of by the presented method. The results obtained by this method outperform all the classical and heuristic methods like evolutionary programming [3] and swarm optimization techniques as described through Tables I-III and Figs. 1-4.

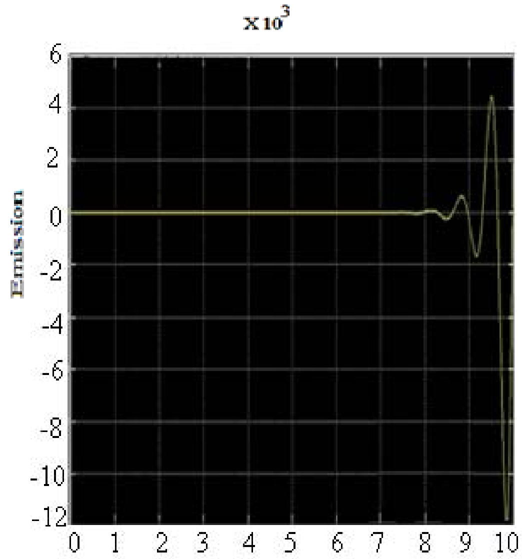


Fig. 4 Unit without VPL for population size of 36 trials

TABLE II
TRANSMISSION LOSS COEFFICIENTS FOR 6 UNIT 30 BUS IEEE TEST CASE SYSTEM FOR THERMAL SYSTEM

| Unit | B coefficients ($B_{ij}$) | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 0.0015 | 0.0010 | 0.0006 | -0.0001 | -0.0002 | -0.0001 |
| 2 | 0.0010 | 0.0012 | 0.0008 | 0.0001 | -0.0003 | -0.0001 |
| 3 | 0.0007 | 0.0008 | 0.0030 | 0,0000 | -0.0009 | -0,0006 |
| 4 | -0.0001 | 0.0001 | 0.0000 | 0.0020 | -0.0004 | -0.0008 |
| 5 | -0.0005 | -0.0005 | -0.0009 | -0.0004 | 0.0120 | -0.0001 |
| 6 | -0.0002 | -0,0001 | -0,0006 | -0.0006 | -0.0002 | 0.0148 |

TABLE III
RESULT OF 6 UNIT SYSTEM FOR A LOAD DEMAND OF 1588 MW INCORPORATING TRANSMISSION LOSS

| Unit Power Output | PSO | WIPSO | MRPSO | RRBBO |
|---|---|---|---|---|
| $PG_1$ (MW) | 14922 | 15002 | 19102 | 19480 |
| $PG_2$ (MW) | 14884 | 15588 | 16012 | 16020 |
| $PG_3$ (MW) | 16585 | 17109 | 17408 | 17556 |
| $PG_4$ (MW) | 15888 | 16034 | 19047 | 0070 |
| $PG_5$ (MW) | 35981 | 36162 | 36398 | 36400 |
| $PG_6$ (MW) | 7082 | 8087 | 8153 | 8170 |
| Loss (MW) | 56.78 | 59.87 | 63.59 | 48.57 |
| Total Power output(MW) | 1388 | 1409 | 1545 | 1588 |
| Fuel cost($/hr) | 61119.076 | 62120.09 | 63629.22 | 61115.696 |
| Emission level(T/hr) | 1026.23 | 1033.477 | 1043.458 | 1021. 32 |

## References

[1] Nagendra Singh, Yogendra Kumar, "Constrained Economic Load Dispatch Using Evolutionary Technique", Asian Journal of Technology & Management Research (ISSN: 2249 –0892) Vol. 03 – Issue: 02 (Jul - Dec 2013).

[2] Aniruddha Bhattacharya, *Member, IEEE*, and Pranab Kumar Chattopadhyay, "Biogeography-Based Optimization for Different Economic Load Dispatch Problems", IEEE Transactions On Power Systems, Vol. 25, No. 2, May 2010. .

[3] N. Sinha, R. Chakrabarti and P. K. Chattopadhyay, "Evolutionary Programming Techniques for Economic Load Dispatch", IEEE Trans. Evolutionary Computation, 2003, 7(1): 83-94.

[4] J. B. Park, K. S. Lee, J. R. Shin and K. Y. Lee, "A Particle Swarm Optimization for Economic Dispatch with Non-Smooth Cost Functions",

IEEE Trans. Power Systems, 2005, 20(1): 34-42.
[5] C. L. Chiang, "Improved Genetic Algorithm for Power Economic Dispatch of Units with Valve-Point Effects and Multiple Fuels", IEEE Trans. Power Systems, 2005, 20(4): 1690-1699.
[6] W. M. Lin, F. S. Cheng and M. T. Tsay. An Improved Tabu Search for Economic Dispatch with Multiple Minima, IEEE Trans. Power Systems, 2002, 17(1): 108-112.
[7] Ali Nazari, Amin Hadidi, "Biogeography Based Optimization Algorithm for Economic Load Dispatch of Power System" American Journal of Advanced Scientific Research, Vol. 1, Issue. 3, pp. 99-105, 2012.
[8] Bhuvnesh Khokhar, K. P. Singh Parmar, Surender Dahiya, "Application of Biogeography-based Optimization for Economic Dispatch Problems", International Journal of Computer Applications (0975 – 888), Volume 47– No.13, June 2012.
[9] Hardiansyah, "A Modified Particle Swarm Optimization Technique for Economic Load Dispatch with Valve-Point Effect", I.J. Intelligent Systems and Applications, 2013, 07, 32-41 Published Online June 2013 in MECS DOI:10.5815/ijisa.2013.07.05.
[10] Jyoti Jain, Rameshwar Singh, "Biogeography-Based Optimization Algorithm for Load Dispatch in Power System", International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 7, July 2013)
[11] Bhuvnesh Khokhar, K. P. Singh Parmer, Surrender Dahiya, "Application of Biogeography-based Optimization for Economic Dispatch Problems", International Journal of Computer Applications (0975 – 888) Volume 47– No.13, June 2012.
[12] Hardiansyah, "Solving Economic Dispatch Problem with Valve-Point Effect using a Modified ABC Algorithm", International Journal of Electrical and Computer Engineering, Vol 3(3), pp.377-385, June 2013.
[13] G. Sreenivasan, Dr. C. H. Saibabu, Dr.S. Sivanagaraju, "Solution of Dynamic Economic Load Dispatch (DELD) Problem with Valve Point Loading Effects and Ramp Rate Limits Using PSO" International Journal of Electrical and Computer Engineering (IJECE) Vol.1, No.1, pp. 59-70, September 2011.

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