International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 11 | Nov 2018 www.irjet.net p-ISSN: 2395-0072

# Solving Economic Load Dispatch Problem with Valve Point Effect

**Ramesh Kumar Yadav [1], Madhav Singh Kaurav [2]**

*[1]M.Tech (EE), Department of Electrical Engineering, Maharana Pratap College of Technology, India*
*[2]Assistant Professor, Department of Electrical Engineering, Maharana Pratap College of Technology, India*

***

**Abstract -** *Economic load dispatch is a non linear optimization problem which is of great importance in power systems. While analytical methods suffer from slow convergence and curse of dimensionality Jaya optimization can be an efficient alternative to solve large scale non linear optimization problems. This paper presents an overview of basic JO to provide a comprehensive survey on the problem of economic load dispatch as an optimization problem. The study is carried out for thirteen unit generating system for without loss and with loss cases.*

***Key Words*: Jaya Optimization (JO), Economic Load Dispatch(ELD), Valve Point Effect, Shuffled Differential Evolution(SDE), Harmonic Oscillator Quantum-behaved Particle Swarm Optimization(HQPSO),Improved Genetic Algorithm with Multiplier Updating (IGA_MU)**

## 1. INTRODUCTION

Economic load dispatch (ELD) is an constraint based optimization problem in power systems that have the objective of dividing the total power demand among the online participating generators economically while satisfying the essential constraints. The conventional methods include the lambda iteration methods [10, 11], base point and participation factors, etc. Among these methods lambda iteration is the most common method because of ease of implementation. The ELD is a non-convex optimization problem required rigorous efforts to solve by traditional methods.

Moreover, evolutionary and behavioral random search algorithms such as genetic algorithm (GA) [3], particle swarm optimization (PSO) [13] have been implemented on the ELD problem. GAs does possess some weaknesses leading to larger computation time premature convergence [14].

This paper proposes JO as an optimization technique to solve constraints based quadratic cost function with generator constraints and power loss. Algorithm is tested for thirteen generator units. Results are compared with GA and lambda iteration method. The proposed methodology emerges as robust optimization techniques for solving the ELD problem for different size power system.

## 2. PROBLEM FORMULATION

The classic ELD problem minimizes the following incremental fuel cost function associated to dispatch able units [6];

$$C_T = \sum_{i=1}^{N} C_i(P_i)$$

The cost characteristic are shown as

$$C_i = \alpha_i P_i^{\,2} + \beta_i P_i + Y_i \,\$/\text{hr}$$

where $\alpha_i$,$\beta_i$ and $Y_i$ are constants.

### a. Equality Constraints:

The real power balance in the system is given by

$$\sum_{i=1}^{N} P_{Gi} = P_d + P_{loss}$$

where $P_{loss}$ calculated using the B-Matrix loss coefficients and expressed in the quadratic form as given below:

$$P_{loss} = \sum_{i=1}^{n}\sum_{j=1}^{n} P_i B_{ij} P_j$$

where $B_{ij}$ is loss coefficient.

### b. Inequality Constraints:

The generation power 'P' cannot be outside the range stated by the inequality

$P_{i\,min} \leq P \leq P_{imax}$

Where $C_T$ total production cost (Rs/h); $C_i(P_i)$, is incremental fuel cost function (Rs/h); $P_i$, is real power output of the $i^{th}$unit (MW); $N$ is number of generating units; $P_d$ is power demand (MW); $P_{loss}$ is power loss (MW); $B_{ij}$ is transmission loss coefficients;

$P_{i\,min}$is minimum limit of the real power of the $i^{th}$ unit (MW);$P_{imax}$ is maximum limit of the real power of the $i^{th}$ unit (MW).

The problem of economic dispatch generation of real power is to be done to the required load demand by satisfying the above constrains.

### C. Valve-Point Loading Effect

For more rational and precise modeling of fuel cost function, the above expression of cost function is to be modified suitably. The generating units with multi-valve steam turbines exhibit a greater variation in the fuel-cost functions

[3]. The valve opening process of multi-valve steam turbines produces a ripple-like effect in the heat rate curve of the generators. These "valve-point effect" are illustrated in Figure-1 [6].

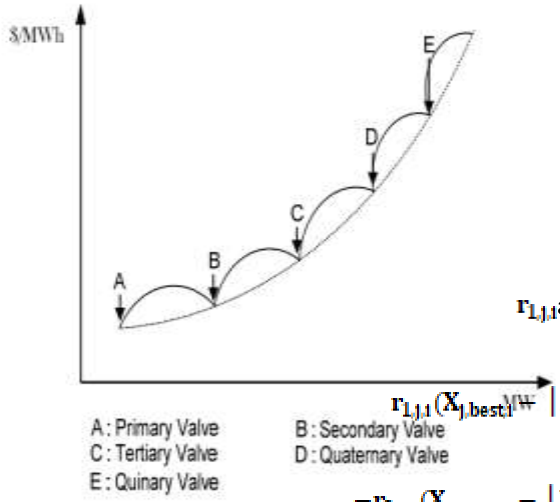


**Figure 1-Valve Point loading effect**

The significance of this effect is that the actual cost curve function of a large steam plant is not continuous but more important it is non-linear. In reality, the generating units with multi-valve steam turbine have very different input–output curve compared with the smooth cost function. Therefore, the inclusion of the valve-point loading effects makes the representation of the incremental fuel cost function of the generating units more practical. The incremental fuel cost function of a generating unit with valve-point loadings is represented as follows:

$$C_i = \alpha_i P_i^{\,2} + \beta_i P_i + \Upsilon_i + |e_i * \sin(f_i * (P^{min} - Pi)| \ \ \$/\text{hr}$$

Where $e_i$ and $f_i$ are the coefficients of generator reflecting the valve-point effects.

## 3. JAYA OPTIMIZATION

JO is a simple yet powerful optimization algorithm developed by Dr. R. Venkata Rao in 2015 for solving the constrained and unconstrained optimization problems [1]. This algorithm is based on the concept that the solution obtained for a given problem should move towards the best solution and should avoid the worst solution. This algorithm requires only the common control parameters and does not require any algorithm-specific control parameters.

Let $f(x)$ is the objective function to be minimized (or maximized). At any iteration $i$, assume that there are 'm' number of design variables (i.e. $j$=1, 2… m), 'n' number of candidate solutions (i.e. population size, $k$=1,2,…,n). Let the best candidate *best* obtains the best value of $f(x)$ (i.e. $f(x)$ best) in the entire candidate solutions and the worst candidate *worst* obtains the worst value of $f(x)$ (i.e. $f(x)$ worst) in the entire candidate solutions. If $X_{j,k,i}$ is the value of the $j^{th}$ variable for the $k^{th}$ candidate during the $i^{th}$ iteration, then this value is modified as per the following Eq. (1).

$$X'_{j,k,i} = X_{j,k,i} + r_{1,j,i}(X_{j,best,i} - |X_{j,k,i}|) - r_{2,j,i}(X_{j,worst,i} - |X_{j,k,i}|)$$

where,

$X_{j,best,i}$ - the value of the variable j for the best candidate

$X_{j,worst,i}$ - is the value of the variable j for the worst candidate.

$X'_{j,k,i}$ - is the updated value of $X_{j,k,i}$

$r_{1,j,i}$ and $r_{2,j,i}$ - are the two random numbersfor the $j^{th}$ variable during the $i^{th}$ iteration in the range [0, 1].

$r_{1,j,i}(X_{j,best,i} - |X_{j,k,i}|)$ - indicates the tendency of the solution to move closer to the best solution

$-r_{2,j,i}(X_{j,worst,i} - |X_{j,k,i}|)$ - indicates the tendency of the solution to avoid the worst solution. $X'_{j,k,i}$ is accepted if it gives better function value.

All the accepted function values at the end of iteration are maintained and these values become the input to the next iteration. The algorithm always tries to get closer to success (i.e. reaching the best solution) and tries to avoid failure (i.e. moving away from the worst solution). The algorithm strives to become victorious by reaching the best solution and hence it is named as Jaya.

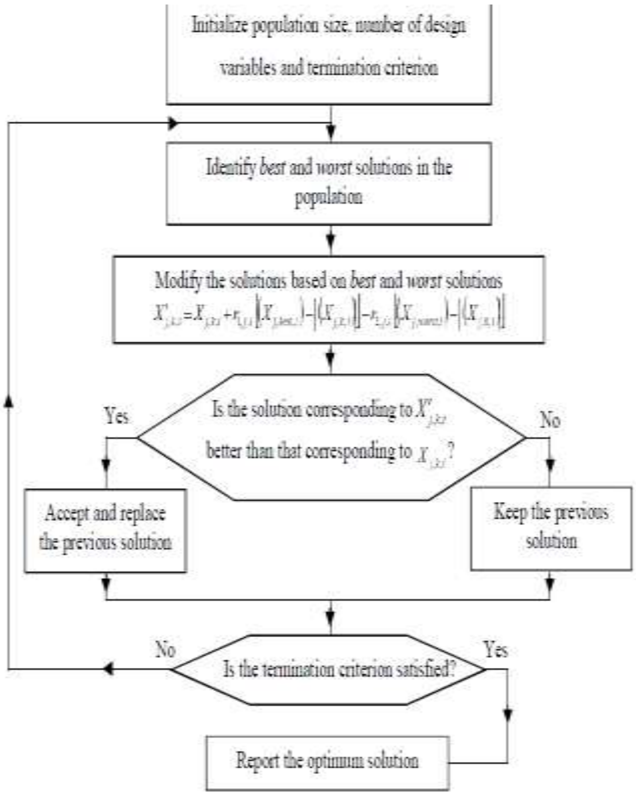


**Figure 2: JO Flow Chart**

## 4. RESULT AND DISCCUSION

To verify the feasibility of the proposed JO method thirteen unit test system is taken for without transmission loss an

### a. Case Study of Thirteen Generating Units:

The thirteen generating units considered are having different characteristic. Their cost function characteristics with valve point effects are given by table below [2].

**Table 1: Data for 13 generating units**

| $G$ | $P_i^{min}$ | $P_i^{max}$ | $\alpha_i$ | $\beta_i$ | $\gamma_i$ | $e_i$ | $f_i$ |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 680 | 0.00028 | 8.10 | 550 | 300 | 0.035 |
| 2 | 0 | 360 | 0.00056 | 8.10 | 309 | 200 | 0.042 |
| 3 | 0 | 360 | 0.00056 | 8.10 | 307 | 150 | 0.042 |
| 4 | 60 | 180 | 0.00324 | 7.74 | 240 | 150 | 0.063 |
| 5 | 60 | 180 | 0.00324 | 7.74 | 240 | 150 | 0.063 |
| 6 | 60 | 180 | 0.00324 | 7.74 | 240 | 150 | 0.063 |
| 7 | 60 | 180 | 0.00324 | 7.74 | 240 | 150 | 0.063 |
| 8 | 60 | 180 | 0.00324 | 7.74 | 240 | 150 | 0.063 |
| 9 | 60 | 180 | 0.00324 | 7.74 | 240 | 150 | 0.063 |
| 10 | 40 | 120 | 0.00284 | 8.60 | 126 | 100 | 0.084 |
| 11 | 40 | 120 | 0.00284 | 8.60 | 126 | 100 | 0.084 |
| 12 | 55 | 120 | 0.00284 | 8.60 | 126 | 100 | 0.084 |
| 13 | 55 | 120 | 0.00284 | 8.60 | 126 | 100 | 0.084 |

According to the constraints considered in this work among inequality constraints only activepower constraints are constraints are considered. There operating limit of maximum and minimum power are also different. The unit operating ranges given in the table 4.5 [2]i.e.$P_i^{min} \le P_i \le P_i^{max}$.

### i. Result For 13 Generating Units

Total Number of Inequality Constraint Violation = 0

Number of Iterations Required for Convergence = 99

The Total Simulation Time (in Seconds) = 6.9503

**Table 2: ELD with valve point effect neglecting loss using JO method**

| Power | Generation in MW |
|---|---|
| $P_1$ | 523.089141 |
| $P_2$ | 262.366503 |
| $P_3$ | 261.701258 |
| $P_4$ | 100.293455 |
| $P_5$ | 60.000000 |
| $P_6$ | 100.666764 |
| $P_7$ | 100.692048 |
| P8 | 100.562728 |
| $P_9$ | 100.628103 |
| $P_{10}$ | 40.000000 |
| $P_{11}$ | 40.000000 |
| $P_{12}$ | 55.000000 |
| $P_{13}$ | 55.000000 |
| **Total Generation** | **1800** |

**The Optimal Fuel Cost (in $/hr.)= 17937.6739**

In the table 4.6 the optimum value of power generation with the effect of valve point is achieved using JO within the operating limit as given in table 4.5 .Hence, with the help of these optimized value of power generations which meets **1800 MW** demand we able to obtain the optimum minimum cost of total generation. The convergence profile of the cost function is depicted in Fig. 4.7, optimal generation scheduling of 13 units shown in the Fig. 4.8 and inequality constraints violation is depicted in Fig. 4.9.

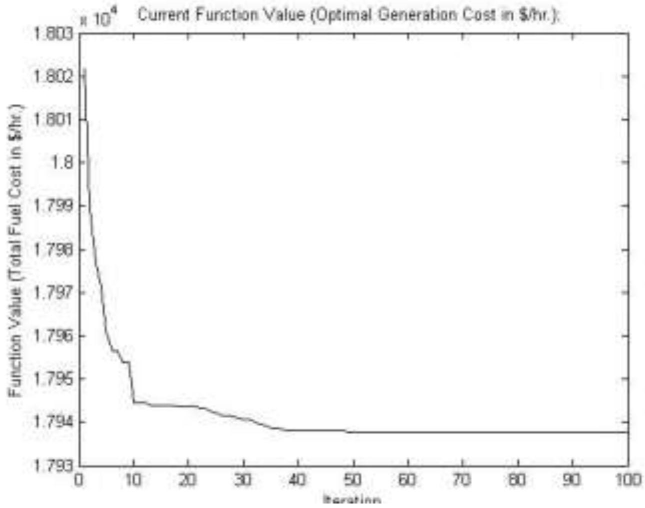


**Figure 3- Cost curve of 1800 MW demand by JO method with valve point effect without loss**

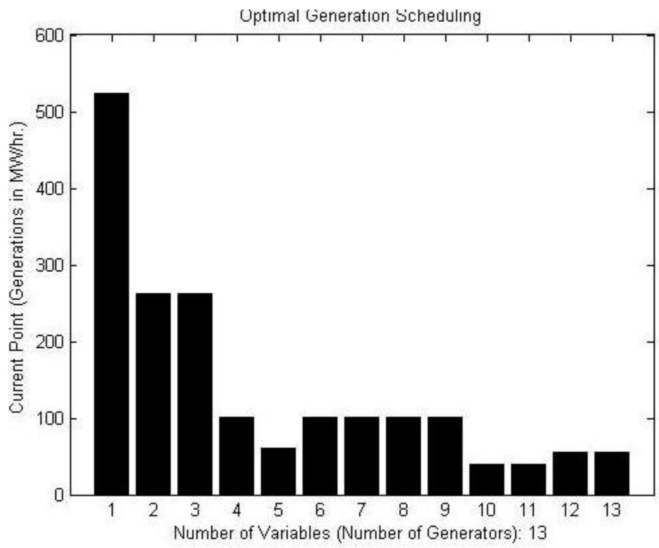


**Figure 4: Optimal Generation Scheduling of 1800 MW demand by JO method with valve point effect without loss**

**a. Comparison of JO With Different Methods Applied On Solving ELDwith Valve Point Effect without Considering losses**

The problem is solved with power demands of 1800 MW met by 13 generating units in order to show the effectiveness of the proposed method in producing quality solutions. In this case valve point effect is considered but the transmission line losses are not considered. Comparison of proposed algorithm is done with Shuffled Differential Evolution (SDE) optimization, Improved Genetic Algorithm with Multiplier Updating (IGA_MU) and Harmonic Oscillator Quantum-behaved Particle Swarm optimization (HQPSO). The simulation result of ELDfor 13 generating units which fulfill the power demand of 1800 MW obtained by SDE, IGA_MU and HQPSO is taken from the existing published paper [6].

**Table 3: Comparisons of simulation results of different methods for 13-unit case study system with PD = 1800 MW**

| Units | SDE | IGA_MU | HQPSO | JO |
|---|---|---|---|---|
| 1 | 628.3185 | 628.3151 | 628.3180 | 523.089141 |
| 2 | 222.7493 | 148.1027 | 149.1094 | 262.366503 |
| 3 | 149.5995 | 224.2713 | 223.3236 | 261.701258 |
| 4 | 60.0000 | 109.8617 | 109.8650 | 100.293455 |
| 5 | 109.8665 | 109.8637 | 109.8618 | 60.000000 |
| 6 | 109.8665 | 109.8643 | 109.8656 | 100.666764 |
| 7 | 109.8665 | 109.8550 | 109.7912 | 100.692048 |
| 8 | 109.8665 | 109.8662 | 60.0000 | 100.562728 |
| 9 | 109.8665 | 60.0000 | 109.8664 | 100.628103 |
| 10 | 40.0000 | 40.0000 | 40.0000 | 40.000000 |
| 11 | 40.0000 | 40.0000 | 40.0000 | 40.000000 |
| 12 | 55.0000 | 55.0000 | 55.0000 | 55.000000 |
| 13 | 55.0000 | 55.0000 | 55.0000 | 55.000000 |
| Total Power in MW | 1800 | 1800 | 1800 | 1800 |
| Total Cost in $/hr | 17963.8293 | 17963.9848 | 17963.9571 | 17937.6739 |

Table 3 shows the best dispatch solutions obtained by the proposed method for the load demand of 1800 MW. The convergence profile for JO method is presented in Figure 3. The results obtained by the proposed methods are compared with those available in the literature as given in Table 3. Though the obtained best solution is not guaranteed to be the global solution, the JO has shown the superiority to the existing methods. The minimum cost obtained by JO method is 17937.6739$/h, which is the best cost found so far and also compared the JO method with the SDA, IGA_MU and HQPSO methods. The minimum cost for SDE, IGA_MU and HQPSO is 17963.8293$/hr, 17963.9848$/hr and 17963.9571 $/hr. respectively. The results demonstrate that the proposed algorithm outperforms the other methods in terms of better optimal solution.

## 5. CONCLUSION

The optimum cost for thirteen generating units with valve point effect is achieved by JO and after comparing with the existing algorithm it is found that the proposed algorithm outperforms the other methods in terms of better optimal solution and the best ELD solutions obtained by the proposed method for the load demand of 1800 MW. Though the obtained best solution is not guaranteed to be the global solution, the JO has shown the superiority to the existing methods. The results demonstrate that the proposed algorithm outperforms the other methods in terms of better optimal solution.

## REFERENCES

1. R. VenkataRao, "A simple and new optimization algorithm for solving constrained and unconstrained optimization problems", International Journal of Industrial Engineering Computations, Aug. 2016, 7(1):19-P34.

2. Leandro dos Santos Coelho, Viviana Cocco Mariani,"Combining of Chaotic Differential Evolution and Quadratic Programming for Economic Dispatch Optimization With Valve-Point Effect" , IEEE Trans. On Power Syst.2005, 21(2):989-995.

3. A.J.Wood and B.F.Wollenberg, "Power Generation, OperationAnd Control", Wiley-Blackwell: New York; 3rd Edition, 2013.

4. B.R Gupta and VandanaSinghal. "Power System Operation and Control",S Chand:New Delhi; 1st Edition2010

5. S. Sivanagaraju& G. Sreenivasan, "Power System Operational and Control", Pearson,1st Edition2009

6. G. Chandrakala, V. Ramakrishna & Jan BhashaShaik, "Solving economic dispatch with valve point loading effects by using optimization techniques",International Journal of Engineering Science Invention 2014, 3(9):.01-011

7. D. P. Kothari, Yadwinder Singh Brar, Harinder Pal Singh"Multiobjective Load Dispatch Using Particle Swarm Optimization" Published 2013IEEE.

8. SaiH.Ling,Herbert H.C.Iu,KitY.Chan and ShuK.Ki "Economic Load Dispatch: A New Hybrid Particle Swarm Optimization Approach".

9. N.A.Rahmat, and I.Musirin"Differential Evolution Ant Colony Optimization (DEACO) Technique in Solving Economic Load Dispatch Problem", Published in Power Engineering and Optimization Conference (PEDCO) Melaka,Malaysia,2012 IEEE International 6-7 June2012.

10. Sunny Orike and David W. Corne "Improved Evolutionary Algorithms for Economic Load Dispatch Optimization Problems", Published in Computational Intelligence (UKCI), 2012 12th UK Workshop on 5-7 Sep 2012.

11. Gaurav Prasad Dixit, Hari Mohan Dubey, Manjaree Pandit,B.K.Panigrahi"Artificial Bee Colony Optimization for Combined Economic Load and Emission Dispatch", Sustainable Energy and Intelligent Systems (SEISCON 2011), International Conference on 20-22 July2011.

12. I.A. Farhan, and M. E. El-Hawary "Multi-Objective Economic-Emission Optimal Load Dispatch Using Bacterial Foraging Algorithm"2012 25th IEEE Canadian Conference on Electrical and Computer Engineering.

13. Luis Bayón,José M.Grau,María M.Ruiz,andPedro M.Suárez "The Exact Solution of the Environmental/Economic Dispatch Problem" IEEE TransactionsOnPowerSystems,Vol.27,No.2,May2012.

14. AmitaMahor, Vishnu Prasad and Saroj Rangnekar "Economic dispatch using particle swarm optimization:A review"IEEE Transactionson Power Systems,Vol.27,No. 2, June2009.

15. R Prathiba, S Sakthivel and M Balasingh Moses "Flower pollination algorithm applied for different economic load dispatchproblems",International Journal of Engineering and Technology (IJET), ISSN: 0975-4024, Volume 6, No. -2, Apr-May 2014 1009.

16. Economic/Emission Load Dispatch IEEE-International Conference on Advances in Engineering, Science and Management (ICAESM -2012) March 30- 31, 2012.

17. Rayapudi, S. Rao. "An intelligent water drop algorithm for solving economic load dispatch problem." International Journal of Electrical and Electronics Engineering 5, no. 2 (2011):43-49.

18. Pandi, V. Ravikumar, and Bijaya Ketan Panigrahi. "Dynamic economic load dispatch using hybrid swarm intelligence based harmony search algorithm." Expert Systems with Applications 38, no. 7 (2011): 8509-8514.

19. Swain, R. K., N. C. Sahu, and P. K. Hota. "Gravitational search algorithm for optimal economic dispatch." Procedia Technology 6 (2012):411-419.

20. Yang, Xin-She, Seyyed Soheil Sadat Hosseini, and Amir Hossein Gandomi. "Firefly algorithm for solving non-convex economic dispatch problems with valve loading effect." Applied Soft Computing 12, no. 3 (2012):1180-118