# An enhanced solution for Dynamic Economic Emission scheduling using Biogeography based Optimization Algorithm

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***Abstract***
*Dynamic Economic Emission dispatch being considered chief purpose in power system manipulations, organization and development. Its main purpose reflects about scheduling the allocated generating unit's production in order to congregate the power demand at least operating costs and emission costs while gratifying all units and entity operational constraints. Here it includes the consideration of valve point effects. An approach to curtail the fuel and emission cost using Biogeography based Optimization has been proposed in this paper.*

*The Biogeography based optimization, enthused based on the environmental allotment of natural species, whose characters are recognizable to other schemes like GA &PSO and pursuit for optimal solution by means of immigration and transformation operation. This paper provides an effectual approach in IEEE thirty bus system for obtaining the best global best solution.*

**Keywords:** Dynamic Economic Emission dispatch, Biogeography based optimization, emigration rate, immigration rate, suitability index variable, suitability index.

## Introduction

In current years, ecological effluence has arisen as a wide-reaching menacing crisis and arriving more consideration. Tumbling the emission over the production of power becomes an vital concern due to the channelization of Clean Air Amendments of 1990. The emission dispatching substitute proves an effectual short-range choice where dual expenses being reduced. In such case, the Dynamic Economic Emission dispatch problem becomes a non-discriminatory optimization problem that takes into deliberation of its valve point effects. Dynamic Economic dispatch is defined as the minimization of the mishmash of the power generation, which causes falling up of the total cost while fulfilling the power maintenance relationship, that can be formulated as minimum of the cost function confined to the parity and disparity constraints.

The elementary prerequisite of power system load dispatch is to engender, at the possible lowest cost ample quantity of electricity to meet the demand. Emission dispatch deals with only minimize the emission with violating the economic constraints. To accomplish both these objectives in a single dispatch, we are moving towards fused economic and emission dispatch technique. Emission dispatch deals with the emission of various harmful gases such as oxides of sulphur, nitrogen and carbon. Fuel amalgamation, fuel switching and scrubber are the prime methods for sinking the quantity of $SO_2$ emitted. $NO_X$ emissions are more complex.

The totality $NO_X$ produces throughout incineration is the summation of the sources of $NO_X$ which includes nitrogen in fuel which causes an emission called fuel $NO_X$ and nitrogen in air that yields an emission called thermal $NO_X$. One of the techniques used to decrease emission production in power system is the economic and emission power dispatch. This dispatch determines the power allocation that reduces the system cost considering the level of emission produced.

A scheme is provided for portrait the DLC program flexible to varying system requests. DLC can be incorporated into system operations and utilized for peak splinter and fuel cost reserves, as and when required[3]. The paper takes in hand an assortment of aspects of dispatch for an episode of 1977-88. Papers published in the general region of economic dispatch which are divided into optimal power flow, AGC, dynamic and economic dispatch with non-conventional production sources[5].

In this paper, EC methods are employed to obtain load dispatch solutions for three-, six- and 13-unit systems and prove that EP was enhanced among EC method in solving the problem[13]. The solutions obtained are moderately hopeful and functional in economic emission upbringing.[9] APPFPA based method is proposed for DEED. This paper project a Genetic Algorithm and Ant Colony Search Algorithm to untangle united economic and emission dispatch predicament with transmission fatalities[2]. This cram develops a superior genetic algorithm-based loom for the optimal EED of the hydrothermal power plant utility, taking into reflection non-smooth fuel cost and emission intensity functions[4].

This paper describes about biogeography-based optimization (BBO) figured out over the hypothesis of biogeography, that is the revision of the geological allocation of natural organisms, has been projected to bottleneck situation optimization which is a residents dependent stochastic optimization procedure chipping in sequence flanked by entrant solutions depending on their fitness values with a vision of attaining the worldwide premium result. In this case, it has been implemented to sensor assortment[11]. MSL is used to resolve the dispatch setback for units allowing for valve point effect and the ramp rate limits. The results obtained corroborate the implication of the projected scheme for kinds of dispatch problems with non-flat cost functions been described[7]. A dual economic emission dispatch is offered to get a noteworthy concession between prices and emissions so as to content real power supply-demand symmetry[10].

A study constituting of a three-unit system of different demand is engaged. This paper put forward a new mode for DEED of systems, using a group hunt optimizer with manifold generators that embrace a control management system proposed to deal with multifarious motives[6]. This paper set forth an optimal congestion managing approach in a deregulated energy advertises using Particle swarm optimization under CEED platform[8]. A new BPSO-DE algorithm contemplates to work out dynamic economic emission dispatch crisis[12]. This paper addresses a fusion solution tactic PSO algorithm with the SQP method for the reserve forced dynamic economic dispatch problem of units making an allowance on valve-point effects.[13]

The Endeavour in this article encompasses a way-out stratagem via BBO with a scrutiny of obtaining the optimal solution for DEED problem to investigate its appositeness for promising power systems. Section one demonstrates introduction, Section two explains the problem formulation, Section three outlines the BBO technique, Section four describes the case study, Section five figure out simulation results and Section six concludes the article.

**Problem Formation:** The mathematical formulation of the crisis is discussed as:

**Dynamic Economic Dispatch:** The aim is to originate the best possible planning in view of getting the total functioning costs declined pleasing numerous equality and inequality.

$$F(P_{Gi}) = \sum_{i=1}^{ng} a_i P_{Gi}^2 + b_i P_{Gi} + c_i + |d_i \sin\{e_i(P_{Gi}^{min} - P_{Gi}^{max})\}|$$

**1. Active power maintenance constraints:** The total power production by overall generators has to satisfy the total load demand and system active power loss.

$$\sum_{i=1}^{ng} P_{Gi} - P_D - P_L = 0$$

where $P_L = \sum_{i=1}^{ng}\sum_{j=1}^{ng} P_{Gi}B_{ij}P_{Gj} + \sum_{i=1}^{ng} B_i P_{Gi} + B_{oo}$

**2. Generator limit constraints:** The active power production must be bounded within its relevant minimum and maximum operating limits.

$$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max} \quad i = 1,2,3 \ldots\ldots ng$$

**3. Ramp rate limit constraint:** Owing to generator's ramp rate limits, alteration in active power production limit is observed. Whenever the overall demand is rising the Ramp Up Rate (RUR) is considered and when declined the Ramp Down Rate (RDR) is taken into account.

**UP rate**

$$P_{Gi,t} - P_{Gi,t-1} \leq RUR_i \quad i = 1,2,3 \ldots\ldots ng \quad t = 1,2,\ldots,T$$

**Down rate**

$$P_{Gi,t-1} - P_{Gi,t} \leq RDR_i \, i = 1,2,3 \ldots\ldots ng \; t = 1,2,\ldots,T$$

**Dynamic Emission Dispatch:** Currently the emission reduction is a severe problem in power network. The motive of emission dispatch lies in curtailment of the emission of entire generating units because of combustion of fuels for fabrication of power to convene the power demand and given as:

$$E(P_{Gi}) = \sum_{i=1}^{ng} 10^{-2}(\alpha_i P_{Gi}^2 + \beta_i P_{Gi} + \gamma_i) + \varepsilon_i \exp(\delta_i P_{Gi})$$

**Dynamic Economic Emission Dispatch:** The overall DEED can be mathematically expressed as:

$$\mathrm{Min}\varphi_M = [F(P_{Gi}), E(P_{Gi})]$$

## Method

**1. Summarize of biogeography based optimization technique:** BBO is a contestable optimization tool for construe multimodal convincing effort.

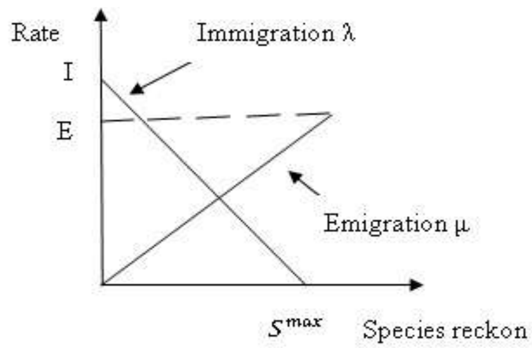


**Figure 1: Species model of the island**

It is depending on the perception of study of species and ecosystem in geographic space, allocation of species based on rain fall, assortment of flora and multiplicity of topographic features. A habitat is defined as the biological vicinity that is occupied by exacting flora and fauna which are purely secluded from another island.

In evolutionary time, some island may be populated compared to others due to convinced eco-friendly features which are more flattering than for those having least count. Many sorts of flora and fauna in islands of high dwellers emigrate into adjoining island of least quantity of species for their features with those islands of least dwellers to become heir to an elevated species migration rate. The velocity of immigration (λ) and emigration (μ) are the fitness of the quantity of species in islands. The figure indicates various migration rate curves projecting the movements of species across the island.

The above two phenomena assist the species of smaller complimentary region to get hold of enhances characteristics from the species in suitable island and reinforce the fragile rudiments. In BBO, an elucidation is denoted by an island comprising a solution quality called Suitability Index Variables that are expressed in terms of real numbers which is given as predicament along declared variables ($n_d$) as:

$$\text{Island} = \text{SIV}_1, \text{SIV}_2, \text{SIV}_3, \dots\dots.\text{SIV}_{\text{nd}}$$

The appropriateness of nourishing generously proportioned quantity of species could be modelled as a fitness measure indicated by Suitability Index (SI) provided by

$$SI = f(Island) = f(SIV_1, SIV_2, SIV_3, \dots\dots.SIV_{nd})$$

Huge SI indicates a healthier class results and low SI shows a low-grade solution. The intent is to locate ace explication in accordance with SIV which elevates Suitability Index. An individual migration rates say λ, μ were obtained from respective islands that signifies a resolution point. A superior result holds an increased μ and reduced λ and vice-versa. The migration rate say λ and μ are functions of the amount of species in the island and distinct for $K^{th}$ Island as

$$\mu_k = E(k/n)$$
$$\lambda_k = I(1 - (k/n))$$

The flow chart of proposed methodology is given in figure 2.

If I = E, both the rates can linked as:

$$\mu_k + \lambda_k = E$$

The dual objective DEED is given as a mono objective improvisation predicament by allocating unlike weights for every goal.

$$Min\ \varphi = \sum_{i=1}^{ng} \{WF_i(P_{Gi}) + (1 - W)hE_i(P_{Gi})\}$$

A scaling factor h, is integrated with emission fitness to obtain a corresponding price curve in \$/h which is cost penalty factor. The procedure for calculating 'h' is appraise the proportion among the fuel price and emission parallel to $P_{Gi}^{max}$ for each generation.

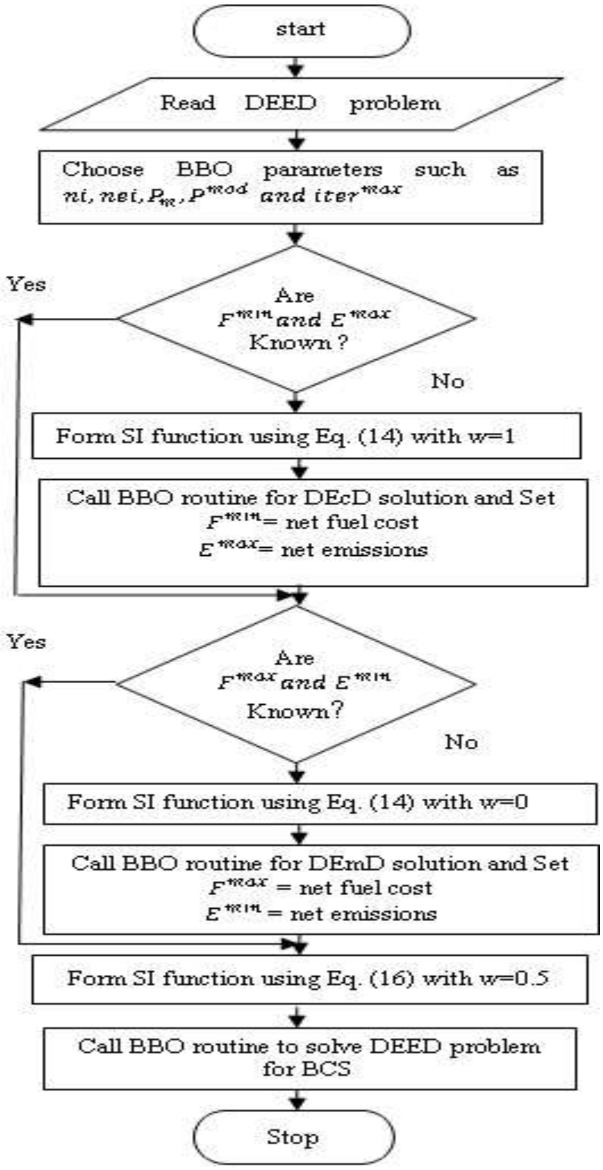


**Figure 2: Flow chart of proposed method**

$$ratio_i = \frac{F_i P_{Gi}^{max}}{E_i P_{Gi}^{max}} \$/ton \qquad i = 1,2, \dots\dots\dots.ng$$

- Coordinate the ratios in mounting series.
- Adjoin the utmost rating of everypower units one at a time.
- At this stage,$ratio_i$, allied with final unit is the required with respective specified power demand $P_D$

The flowchart of BBO routine is shown in figure 3. The amount of w symbolizes relative implication sandwiched among the dual objective. If amount of w is one, the solution inclined to Economic Dispatch which concentrates more the fuel price minimization. The fuel price rises up and the emission rate falls when w is declined insteps from one to zero. The solution becomes Emission dispatch that focus on emissions when w equals zero.

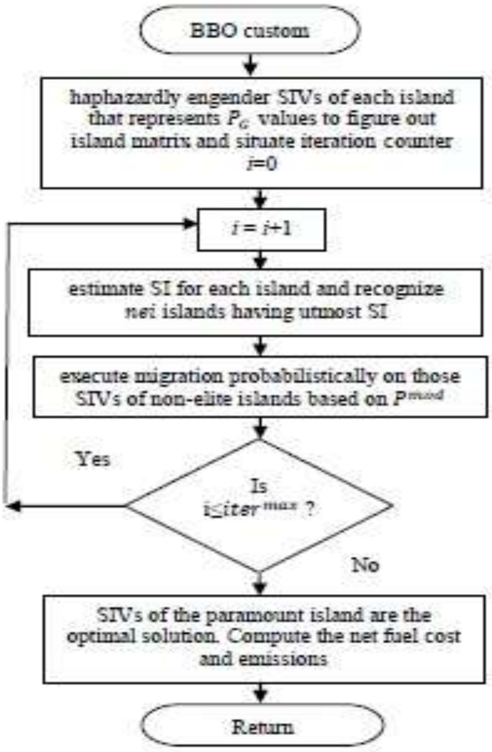


**Figure 3: Flow chart of BBO routine**

The demerits of the active approaches can be triumph over if the multi-objective function of equation is customized through normalizing the fuel price and emission rate as given as:

$$\text{Min}\varphi_M = W\left[\frac{\sum_i^{ng} F_i(P_{Gi}) - F^{min}}{F^{max} - F^{min}}\right] + (1\text{-}W)\left[\frac{\sum_i^{ng} E_i(P_{Gi}) - E^{min}}{E^{max} - E^{min}}\right]$$

Which removes the exploit of h parameter, but needs the value for $F^{max}$,$F^{min}$,$E^{max}$ and $E^{min}$ .The Suitability Indexfitness could be attained by changing the price fitness in Suitability Index function as penalty factor approach as:

$$\text{Max SI} = \frac{1}{1+\Psi}$$

where $\Psi$ is the augmented objective function which is mathematically formulated as:

$$Min\ \Psi = k_1\varphi_M + k_2\{\sum_{i=1}^{ng} P_{Gi} - P_D - P_L\}^2$$

## Case study

One line representation of IEEE thirty bus system is shown in figure 4. The suggested technique had been checked over IEEE thirty bus system comprising of 6 generators for various scheduled horizons.

The loss coefficients in per unit on a 100 MVA base are given as shown below.

$$B_{ij} = \begin{bmatrix} 218 & 107 & -3.6 & -11 & 5.5 & 33 \\ 107 & 170.4 & -1.9 & -17.9 & 2.6 & -1 \\ -4 & -1.9 & 245.9 & -132.8 & -118 & -79 \\ -11 & -17.9 & -132.8 & 265 & 98 & 45 \\ 55 & 26 & -118 & 98 & 216 & -1 \\ 33 & 28 & -79 & 45 & -1 & 297.8 \end{bmatrix}$$

$B_o$=[0.10731 17.704 -40.645 38.453 13.832 55.503]
$B_{oo}$=[1.4]

Data comprising of various coefficients of costs, ramp limits and others are given in table 3. The prospective method is enforced to this system for selected parameters and the best is considered to be the enhanced solution.

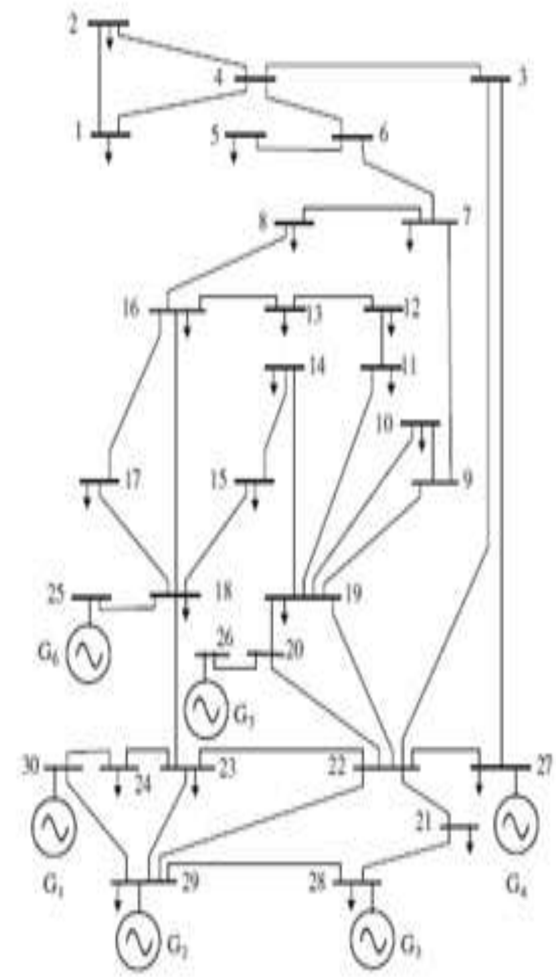

**Figure 4: One line representation of IEEE thirty bus system**

## Simulation and Results

**Economic Emission Dispatch:** In this case, the stimulated output for economic emission dispatch using Biogeography Optimization technique for IEEE 30 bus system whose demand is 2.834 MW is shown in table 1. It gives fuel cost of 681.357352 $/h and emission cost of 0.194833 Kg/h.

**Table 1**
**Output of BBO for IEEE 30 bus for demand 2.834 MW**

| Generation | Obtained values with losses |
|---|---|
| Pg1(MW) | 0.46010 |
| Pg2 (MW) | 0.42242 |
| Pg3 (MW) | 0.55544 |
| Pg4 (MW) | 0.31044 |
| Pg5 (MW) | 0.56521 |
| Pg6 (MW) | 0.55123 |
| Fuel cost ($/h) | 681.357352 |
| Emission cost (kg/h) | 0.194833 |
| Losses (MW) | 0.033288 |

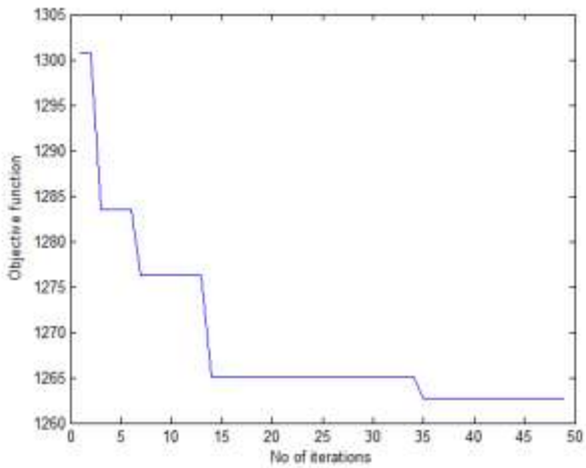


**Figure 5: Convergence characteristics corresponding to IEEE 30 bus system for demand 2.834 MW**

The simulated stimulated output for economic emission dispatch using Biogeography Optimization technique for IEEE thirty bus systems whose demand is 4.50 MW is shown in table 2. It gives fuel cost of 1059.702 $/h and emission cost of 0.231850 Kg/h.

**Dynamic Economic Emission Dispatch:** The Net fuel cost and emission cost corresponding to Dynamic Economic Dispatch by setting 'w' as 1 are 4845.071$/h and 1.36 kg/h which are indicated in table 4. The Net fuel cost and emission cost with respect to Dynamic Emission Dispatch by setting 'w' as 0 are 5008.653 $/h and 1.24 kg/h that are given in table 5.The Net fuel price and emission cost analogous to Dynamic Economic Emission Dispatch by setting 'w' as 0.5 are 4890.11$/h and 1.261 kg/h offered in table 6.

The comparisons of the net fuel cost and emission cost obtained for various Dynamic Economic (DEcD), Dynamic Emission (DEmD) and Dynamic Economic Emission dispatches (DEED) are presented as given below in figure 7. The obtained optimal results are given in p.u. From the above discussions, the proposed method offers the minimum fuel cost in a DEcd, the lowered emission cost in DEmD and conciliation between fuel and emission in DEED.

**Table 2**
**Output of BBO for IEEE 30 bus for demand 4.50 MW**

| Generation | Obtained values with losses |
|---|---|
| Pg1(MW) | 0.49281 |
| Pg2 (MW) | 0.58396 |
| Pg3 (MW) | 0.94671 |
| Pg4 (MW) | 1.03115 |
| Pg5 (MW) | 0.92034 |
| Pg6 (MW) | 0.59737 |
| Fuel cost ($/h) | 1059.702 |
| Emission cost (kg/h) | 0.231850 |
| Losses (MW) | 0.073091 |

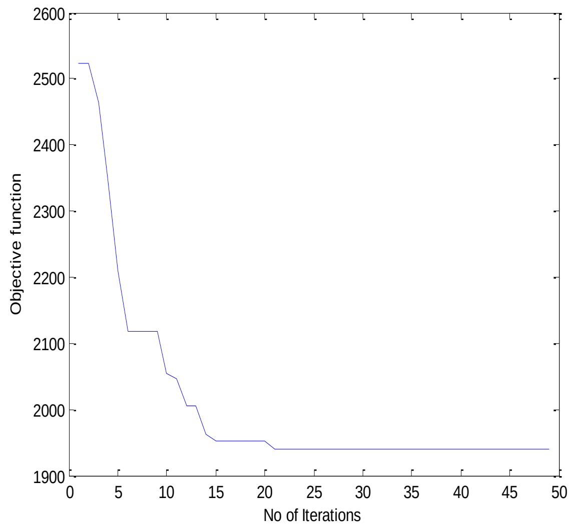


**Figure 6: Convergence characteristics corresponding to IEEE 30 bus system for demand 4.50 MW**

## Conclusion

Electric utilities faces new challenging tasks every day which it requires configuration of ultimate objectives. In this work, the BBO technique was accessible as an effectual method for disentangle the embarrassed multi objective optimization problem. Here the customized objective function gives implication for optimal scheduling of units to gratify the load demand. The intended technique had been veteran for thirty bus test system of six generating units and the results with consideration of valve-point effects and ramp rate limits are obtained.

The solution obtained reveals the performance of the technique in pronouncement optimal or in the vicinity of best possible solution for a non-linear function.

**Table 3**
**Data of IEEE 30 bus system**

| UNIT | a | B | c | e | f | α | B | γ | ξ | δ | $P^{min}$ $(p.u)$ | $P^{min}$ $(p.u)$ | RDR | RUR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 100 | 200 | 10 | 15 | 6.2383 | 6.49 | -5.554 | 4.091 | 2e-4 | 2.857 | 0.05 | 0.5 | 0.18 | 0.10 |
| 2 | 120 | 150 | 10 | 10 | 8.976 | 5.638 | -6.047 | 2.543 | 5e-4 | 3.333 | 0.05 | 0.6 | 0.40 | 0.30 |
| 3 | 40 | 180 | 20 | 10 | 14.784 | 4.586 | -5.094 | 4.258 | 1e-4 | 8.000 | 0.05 | 1.0 | 0.25 | 0.27 |
| 4 | 60 | 100 | 10 | 5 | 20.944 | 3.38 | -3.55 | 5.326 | 2e-3 | 2.00 | 0.05 | 1.2 | 0.45 | 0.48 |
| 5 | 40 | 180 | 5 | 5 | 25.133 | 4.586 | -5.094 | 4.258 | 1e-6 | 8.00 | 0.05 | 1.0 | 0.35 | 0.30 |
| 6 | 150 | 100 | 5 | 5 | 18.48 | 5.151 | -5.555 | 6.131 | 1e-5 | 6.667 | 0.05 | 0.6 | 0.20 | 0.15 |

**Table 4**
**Optimal solution for Dynamic Economic Dispatch**

| Hour | Power Demand | Optimal generation | | | | | | losses | Fuel cost | Emission Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Pg1 | Pg2 | Pg3 | Pg4 | Pg5 | Pg6 | | | |
| 1 | 2.834 | 0.38 | 0.40 | 0.48 | 0.80 | 0.43 | 0.39 | 0.04 | 633.895 | 0.204 |
| 2 | 3.40 | 0.44 | 0.40 | 0.69 | 0.80 | 0.70 | 0.42 | 0.04 | 768.041 | 0.205 |
| 3 | 4.65 | 0.50 | 0.58 | 0.90 | 1.20 | 1.00 | 0.56 | 0.09 | 1091.607 | 0.247 |
| 4 | 4.10 | 0.45 | 0.40 | 0.90 | 1.10 | 0.92 | 0.39 | 0.06 | 929.820 | 0.234 |
| 5 | 3.00 | 0.27 | 0.39 | 0.69 | 0.80 | 0.67 | 0.22 | 0.03 | 671.750 | 0.210 |
| 6 | 3.40 | 0.10 | 0.40 | 0.69 | 1.60 | 0.80 | 0.37 | 0.06 | 750.839 | 0.231 |
| Net fuel cost in $/hr: 4845.701 | | | | | | | | | | |
| Net Emission Cost in kg/hr: 1.331 | | | | | | | | | | |

**Table 5**
**Optimal solution for Dynamic Emission Dispatch**

| Hour | Power Demand | Optimal generation | | | | | | losses | Fuel cost | Emission Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Pg1 | Pg2 | Pg3 | Pg4 | Pg5 | Pg6 | | | |
| 1 | 2.834 | 0.40 | 0.43 | 0.54 | 0.44 | 0.64 | 0.42 | 0.03 | 672.303 | 0.195 |
| 2 | 3.40 | 0.48 | 0.45 | 0.69 | 0.68 | 0.69 | 0.46 | 0.08 | 781.871 | 0.200 |
| 3 | 4.65 | 0.49 | 0.56 | 0.95 | 1.15 | 0.98 | 0.60 | 0.08 | 1100.857 | 0.244 |
| 4 | 4.10 | 0.50 | 0.60 | 0.90 | 0.80 | 0.80 | 0.56 | 0.06 | 949.918 | 0.213 |
| 5 | 3.00 | 0.38 | 0.39 | 0.66 | 0.15 | 0.67 | 0.48 | 0.03 | 702.282 | 0.196 |
| 6 | 3.40 | 0.47 | 0.57 | 0.73 | 0.63 | 0.53 | 0.52 | 0.04 | 801.422 | 0.199 |
| Net total fuel cost ii $/hr: 5008.653 | | | | | | | | | | |
| Net total Emission Cost in kg/hr: 1.24 | | | | | | | | | | |

**Table 6**
**Optimal solution for Dynamic Economic Emission Dispatch**

| Hour | Power Demand | Optimal generation | | | | | | losses | Fuel cost | Emission cost |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Pg1 | Pg2 | Pg3 | Pg4 | Pg5 | Pg6 | | | |
| 1 | 2.834 | 0.38 | 0.40 | 0.47 | 0.65 | 0.55 | 0.41 | 0.04 | 640.0331 | 0.198 |
| 2 | 3.40 | 0.46 | 0.40 | 0.70 | 0.65 | 0.67 | 0.56 | 0.04 | 773.148 | 0.200 |
| 3 | 4.65 | 0.50 | 0.60 | 0.97 | 1.10 | 0.96 | 0.60 | 0.08 | 1098.661 | 0.240 |
| 4 | 4.10 | 0.50 | 0.45 | 0.90 | 0.95 | 0.80 | 0.56 | 0.006 | 934.566 | 0.219 |
| 5 | 3.00 | 0.35 | 0.40 | 0.69 | 0.65 | 0.55 | 0.39 | 0.03 | 674.848 | 0.199 |
| 6 | 3.40 | 0.45 | 0.41 | 0.69 | 0.81 | 0.55 | 0.53 | 0.05 | 768.558 | 0.203 |
| Net total fuel cost in$/hr:  4890.111 | | | | | | | | | | |
| Net total Emission Cost in kg/hr:1.261 | | | | | | | | | | |

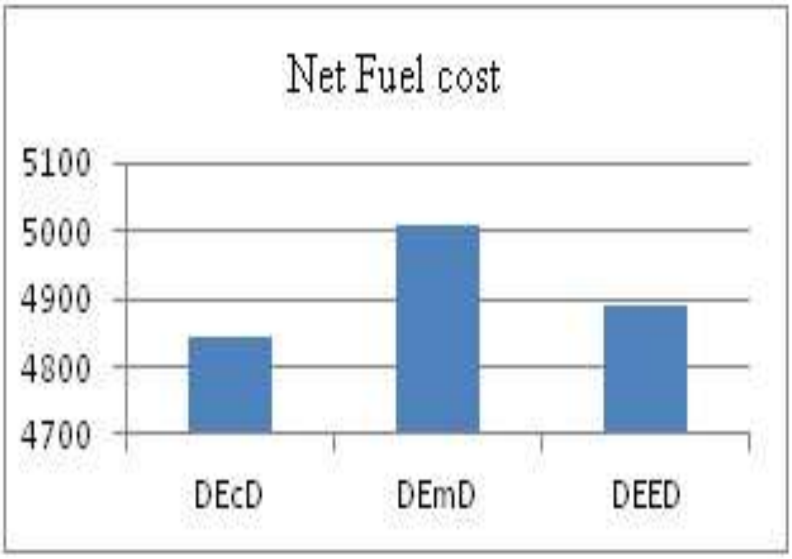


**Figure 7: Representation of Net fuel cost obtained from DEcD, DEmD, DEED**

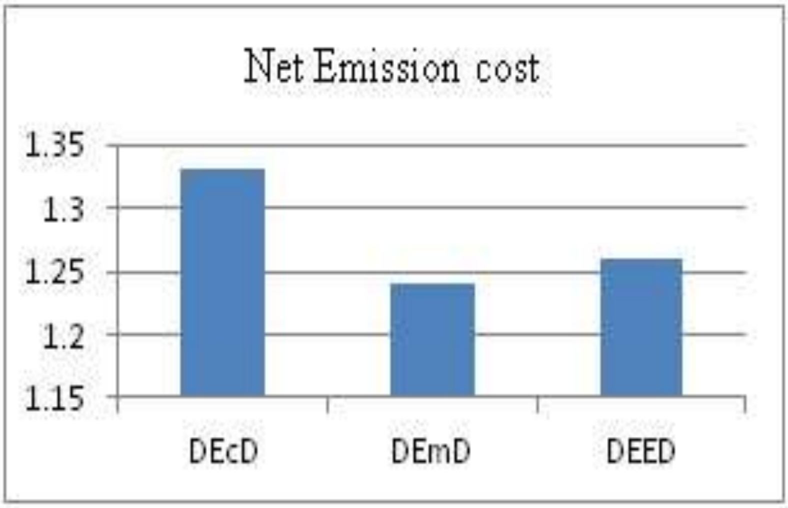


**Figure 8: Representation of Net Emission cost obtained from DEcD, DEmD, DEE**

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