



# Economic Load Dispatch and Emission Consideration

Uzodife N. A, Madueme T.C, Onah A. J, Nwosu C.M

**Abstract:** Thermal power plants consume large amounts of fuel and produce toxic gases that pollute the environment. Several generators in a generating plant produce the required energy. The total load demand (MW) for the entire plant is shared among the generating units. Distributing this load equally among the generators is not economical. This paper shows how a thermal plant's electrical power output is shared optimally among generators to minimise generation cost while maintaining supply reliability. This is known as Economic Load Dispatch (ELD). The paper also considers gas emissions from generators as pollutants. It shows that gas emissions from generators greatly increase electrical power generation costs. In other words, reducing pollutant emissions reduces generation costs. This paper considers a load demand of 60 MW. The power plant consists of six generators. The Moth Flame Optimisation technique is used to distribute this load optimally among the generators and obtain the minimum cost of generating 60 MW while considering gas emissions from the generators. Ultimately, the MW outputs of the six generators are 8.8538, 10.8245, 7.8830, 9.8538, 11.8245, and 10.8245. The minimum cost to generate 60 MW of electrical power is \$17,979.00/hr, without considering gas emissions from the generators. When gas emissions are considered, the generation cost increases to \$ 80,843.00. The MFO is implemented in MATLAB. Thus, pollutant emissions from electric generating plants have significant cost implications, as well as greenhouse effects. The paper shows that economic load dispatch (optimal sharing of load among generating units), with or without consideration of gas emissions, minimises power-generation cost.

**Keywords:** Economic Load Dispatch, Fuel Cost, Gas Emission, Moth Flame Optimisation, Power Generation.

## Nomenclature:

SOx: Sulphur oxides

NOx: Nitrogen Oxides

COx: Carbon Oxides

ELD: Economic Load Dispatch

ELDEC: Economic Load Dispatch with Emissions Consideration

MFO: Moth Flame Optimisation

BA: Bat Algorithm

Manuscript received on 05 May 2026 | First Revised Manuscript received on 20 May 2026 | Second Revised Manuscript received on 02 July 2026 | Manuscript Accepted on 15 July 2026 | Manuscript published on 30 July 2026

\*Correspondence Author(s)

**Nichodemus Uzodife**, Department of Electrical Engineering, University of Nigeria, Nsukka, Enugu State, Nigeria. Email ID: [uzodifenichodemus@yahoo.com](mailto:uzodifenichodemus@yahoo.com)

**Theophilus Madueme**, Department of Electrical Engineering, University of Nigeria, Nsukka, Enugu State, Nigeria. Email ID: [theophilus.madueme@gmail.edu.ng](mailto:theophilus.madueme@gmail.edu.ng)

**John Onah\***, Department of Electrical and Electronic Engineering, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. Email ID: [aniagbosoonah@yahoo.com](mailto:aniagbosoonah@yahoo.com)

**Cajethan Nwosu**, Department of Electrical Engineering, University of Nigeria, Nsukka, Enugu, Nigeria. Email ID: [cajethan.nwosu@unn.edu.ng](mailto:cajethan.nwosu@unn.edu.ng)

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC-BY-NC-ND license <http://creativecommons.org/licenses/by-nc-nd/4.0/>

## I. INTRODUCTION

Electric thermal power plants operate by burning fossil fuels such as coal or natural gas. This process generates electricity and toxic gases, such as Sulphur oxides (SO<sub>x</sub>), nitrogen oxides (NO<sub>x</sub>), and carbon oxides (CO<sub>x</sub>), where x designates the number of atoms [1]. These gases are harmful pollutants that pose health risks. Emission of these gases is a major cause of diseases like cancer, breathing problems, neurological damage, and heart attacks. These gases contribute to the greenhouse effect. Beyond their environmental harm, emitting these gases significantly increases electricity generation costs. Therefore, it is essential to account for these emissions. This paper shows how fuel consumption in an electric power plant is optimised and how emissions of these pollutant gases affect the cost of generating electric power from natural gas. The traditional Economic Load Dispatch (ELD) ignores pollutant emissions. It distributes the load optimally among the generating units and achieves the optimum generation cost. However, as public awareness of environmental pollution increased, the Clean Air Act enacted regulatory standards for emissions. Because environmental pollution is a worldwide concern, international standards for emissions from industries and power plants have been established and enforced since 1990 to control pollutants and greenhouse gases, including SO<sub>x</sub>, NO<sub>x</sub>, and CO<sub>x</sub> [2]. Industries and power plants must comply strictly with environmental emission acts. Gas emissions in thermal power plants may be reduced by (i) switching over from high Sulphur fuel content to low Sulphur fuel content using the fuel switching method, (ii) applying post-combustion cleaning systems like electrostatic precipitators, (iii) minimizing air manifold temperature, which results in cooling the air stream, thereby lowering combustion temperatures and reducing NO<sub>x</sub> emissions, and (iv) raising the air/fuel ratio (more air) in order to lower combustion temperature and reduce NO<sub>x</sub> emissions. These problems have made traditional ELD unsatisfactory; hence, the development of economic load dispatch with emissions consideration (ELDEC). Therefore, environmental pollutant emissions dispatch must also be carried out alongside economic load dispatch. Because economic and emission objectives conflict, a combined approach best achieves an optimal solution [3]. Therefore, pollutant emissions are merged with economic load dispatch to form economic load dispatch and emissions consideration (ELDEC) in thermal power plants. This problem considers two objectives: (i) minimising the cost of fuel, Moreover, (ii) minimising the cost of controlling pollutant emissions from the thermal power plant [4]. These costs

are minimised simultaneously. The cost of fuel (natural gas) and the cost of controlling/reducing greenhouse gas emissions are combined into the total generation cost. Thus, this paper optimises the total cost of generating electric power using natural gas as fuel.

Thus, the objective function of the ELDEC is to minimise generation cost while satisfying load demand and equality and inequality constraints. Techniques used to determine the lowest possible generation cost include Newton's method, Lambda Iteration Method, Lagrange Relaxation method, Simulated Annealing, Equal Incremental Cost Criteria, etc. [5] More recent techniques include: Particle Swarm Optimisation and Ant Colony Algorithm, Hybrid of Particle Swarm Optimisation and Gravitational Search Algorithm (hybrid PSO-GSA), Moth Flame Optimisation (MFO), Bat Algorithm (BA) [6]-[8]. This paper uses MFO to optimise the generators' output powers (MW) and the generation cost for 60 MW.

## II. MATERIAL AND METHODS

### A. Distribution of Load among Units within a Plant

The relationship between fuel cost and generated power in a power plant is known as the cost function. It is either a quadratic function or a quadratic function with ripples [9]. Thus, the fuel cost ( $f_i$ ) of  $i^{th}$  generating unit is given in terms of the power output of the unit as follows [10].

$$f_i = \frac{a_i}{2} P_{gi}^2 + b_i P_{gi} + c_i \quad (1)$$

$P_{gi}$  is the output power in MW of unit  $i$ .

$a_i$ ,  $b_i$ , and  $c_i$  are constants.

The incremental fuel cost of the unit is given as:

$$\lambda_i = \frac{df_i}{dP_{gi}} = a_i P_{gi} + b_i \quad (2)$$

The approximate incremental fuel cost at any particular output is the additional cost in dollars per hour to increase the output by 1 MW. All generating units within a plant must operate at the same incremental fuel cost to achieve economic load dispatch (ELD) [16]. Thus, for a plant having two units operating under ELD:

$$\begin{aligned} \lambda &= \frac{df_1}{dP_{g1}} = a_1 P_{g1} + b_1 \\ \lambda &= \frac{df_2}{dP_{g2}} = a_2 P_{g2} + b_2 \end{aligned} \quad (3)$$

Where  $\lambda$  = incremental fuel cost of plant

From Equation (3):

$$P_{g1} = \frac{\lambda - b_1}{a_1} \quad (4)$$

$$P_{g2} = \frac{\lambda - b_2}{a_2} \quad (5)$$

It can be shown from the foregoing that:

$$\lambda = a_T P_{gT} + b_T \quad (6)$$

Where:

$$a_T = \left( \sum_{i=1}^2 \frac{1}{a_i} \right)^{-1} \quad (7)$$

$$b_T = a_T \left( \sum_{i=1}^2 \frac{b_i}{a_i} \right) \quad (8)$$

$$P_{gT} = P_{g1} + P_{g2} \quad (9)$$

### B. The ELD Objection Function

For a system consisting of  $n$  generating units, the total power generated is:

$$P_{gT} = \sum_{i=1}^n P_{gi} \quad (10)$$

The total fuel cost for the entire plant is the sum of the fuel costs of individual generators. Thus, the cost function is given by Equation (11), while the ELD objective function is given by Equation (12) [11]:

$$f = \sum_{i=1}^n f_i = \sum_{i=1}^n \frac{a_i}{2} P_{gi}^2 + b_i P_{gi} + c_i \quad (11)$$

$$\text{Minimize } f = \sum_{i=1}^n \frac{a_i}{2} P_{gi}^2 + b_i P_{gi} + c_i \quad (12)$$

The quadratic relation between the number of pollutants released and the generated power is:

$$E_i = \alpha_i P_i^2 + \beta_i P_i + \gamma_i \quad (13)$$

where:

$\alpha_i$ ,  $\beta_i$ ,  $\gamma_i$  are the emission coefficients

$P_i$  does the unit generate the power?  $i$

$E_i$  is the emission function of the unit  $i$

In this case, the objective is to minimise total cost by minimising both fuel cost and emission cost. This is also known as total-cost minimisation. Therefore, the objective function for optimal economic dispatch considering emissions is:

$$\text{Minimize } F_T = \sum_{i=1}^N \{ (a_i P_i^2 + b_i P_i + c_i) + h_i (\alpha_i P_i^2 + \beta_i P_i + \gamma_i) \} \quad (14)$$

$$h_i = \frac{a_i P_i^{2i_i(\max())}}{i(\max())^{2i_i(\max())}} \quad (15)$$

### C. Moth Flame Optimisation (MFO) Algorithm

The moth flame optimisation algorithm solves the ELD problem by achieving optimal generation cost while maintaining system load and constraints. The MFO algorithm was proposed in 2015 [12]. It is population-based and is acclaimed as the best algorithm for searching the search space compared with other algorithms. This is because each moth is subjected to the corresponding solution (flame), while avoiding local stagnation or premature convergence [13]. The MFO coding for ELD is as follows [14].

Step 1: Define load demand and the maximum and minimum power limits of generators.

Step 2: Define the economic load-dispatch objective function and equality constraints using power-balance violation.

Step 3: The mapping of moth position to the generator's power is defined

Step 4: Specify the dimension of the moth position based on the number of generators.

Step 5: Initialise moth positions based on the



generators' maximum and minimum limits.

Step 6: Set iteration to 1.

Step 7: Use equation (16) to update the flame number

$$Flame(number) = round\left(N - lx \frac{N-l}{T}\right) \quad (16)$$

Where:

$l$  = current number of iterations

$N$  = maximum number of flames

$T$  = maximum number of iterations

Step 8: Bring back moths outside the search space based on generator power limits.

Step 9: At iteration count of one, sort the moths' fitness and positions. Select the best moth and assign it to the flame ( $F_j$ ) with respect to the fitness sorted.

Step 10: Sort the moths' fitness and positions at iteration counts greater than one, in accordance with the previous and current iterations. The best moth's fitness and position are selected based on the fitness sorted and assigned to the flame ( $F_j$ ).

Step 11: Use equation (17) to calculate " $a$ "

$$a = (-1 + \text{current iteration})x\left(\frac{-1}{\text{Maximum iteration}}\right) \quad (17)$$

Step 12: Use equation (18) to determine " $t$ "

$$t = (a - 1)x \text{rand} + 1 \quad (18)$$

$t$  is a random number in  $[-1, 1]$

Step 13: Use Equation (19) to compute the moth's distance to the corresponding flame.

$$D_i = |F_j - M_i| \quad (19)$$

Where:

$F_j$  is the position of the  $j^{\text{th}}$  flame

$M_i$  is the position of the  $i^{\text{th}}$  moth

Step 14: Moth position is updated by equation (20)

$$Moth\_Position = D_i e^{bt} \cos(2\pi t) + F_j \quad (20)$$

Where:

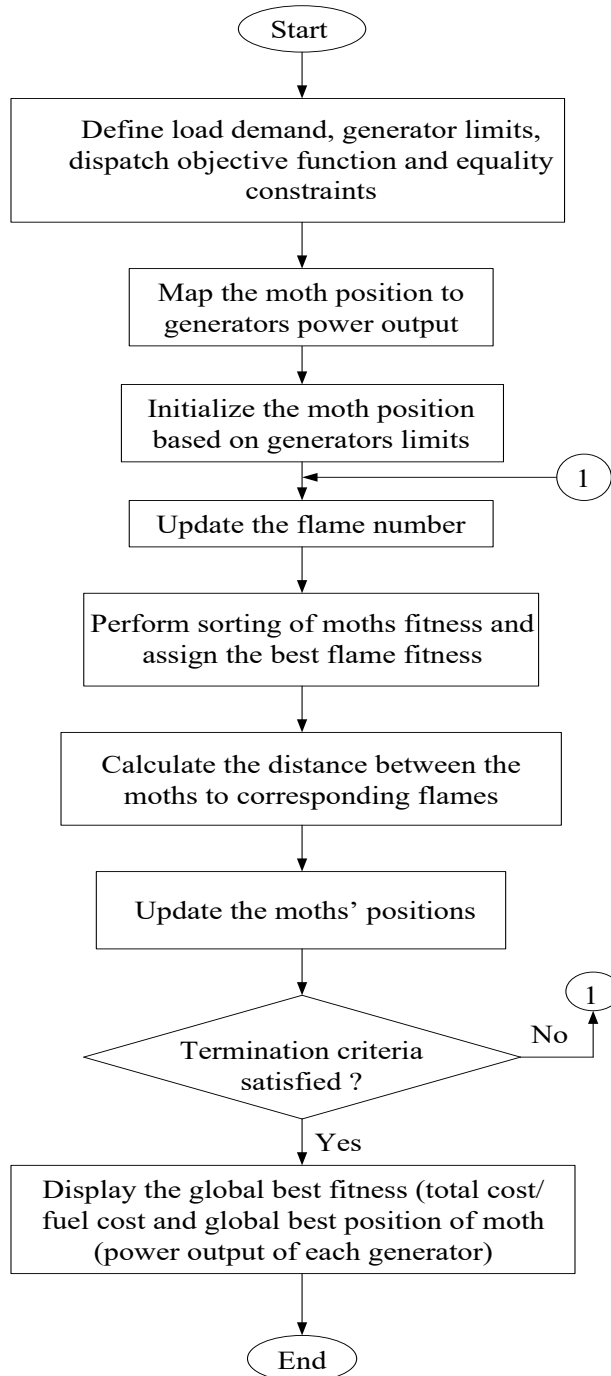
$b$  is a constant that defines the shape of a logarithmic spiral

Step 15: Iteration is increased.

Step 16: Repeat Steps 7-14 until the maximum number of iterations is reached.

Step 17: Display the best flame fitness, which gives the objective-function value. This is the total generation/fuel cost; the corresponding moth position and the power generated in each unit are also displayed.

Fig. 1 shows the flow chart of the Moth Flame Optimisation algorithm.



[Fig.1: Moth Flame Optimisation Algorithm Flow Chart]

Table I shows the Moth Flame Optimisation implementation for economic load dispatch.

Table I: Moth Flame Optimisation Implementation in Economic Load Dispatch

| Moth Flame Optimization       | Economic Dispatch                      |
|-------------------------------|----------------------------------------|
| Decision variable (dimension) | Number of generating units in a system |
| Moths' position               | Power dispatched                       |
| Fitness                       | Cost of generation                     |
| Lower and upper boundaries    | Generator limits                       |

In this paper,  $N$  = maximum number of flames = 40,  $T$  = maximum number of iterations = 100

**Table II: Fuel Cost Coefficients and Generator Limits of a Six-Unit Test System with COX, NOx, and SOX Emissions**

| Unit | P <sub>min</sub><br>(MW) | P <sub>max</sub><br>(MW) | a <sub>i</sub> (\$<br>\$/MW <sup>2</sup> ) | b <sub>i</sub><br>(\$/MW) | c <sub>i</sub><br>(\$) |
|------|--------------------------|--------------------------|--------------------------------------------|---------------------------|------------------------|
| 1    | 4                        | 18                       | 0.002035                                   | 8.43205                   | 85.6348                |
| 2    | 5                        | 17.5                     | 0.003866                                   | 6.41031                   | 303.7780               |
| 3    | 4                        | 18.2                     | 0.002182                                   | 7.42890                   | 847.1484               |
| 4    | 5                        | 18                       | 0.001345                                   | 8.30154                   | 274.2241               |
| 5    | 6                        | 18.4                     | 0.002182                                   | 7.42890                   | 847.1484               |
| 6    | 5                        | 18                       | 0.005963                                   | 6.91559                   | 202.0258               |

**Table III: NOX Emission Coefficients of Six-Unit Test System [12]**

| Unit | $\alpha_{i(N)}$ (Kg/MW <sup>2</sup> hr) | $\beta_{i(N)}$ (Kg/MW <sup>2</sup> hr) | $\gamma_{i(N)}$ (Kg/hr) |
|------|-----------------------------------------|----------------------------------------|-------------------------|
| 1    | 0.006323                                | -0.38128                               | 80.9019                 |
| 2    | 0.006483                                | -0.79027                               | 28.8249                 |
| 3    | 0.003174                                | -1.36061                               | 324.1775                |
| 4    | 0.006732                                | -2.39928                               | 610.2535                |
| 5    | 0.003174                                | -1.36061                               | 324.1775                |
| 6    | 0.006181                                | -0.39077                               | 50.3808                 |

**Table IV: SOX Emission Coefficients [12]**

| Unit | $\alpha_{i(N)}$ (Kg/MW <sup>2</sup> hr) | $\beta_{i(N)}$ (Kg/MW <sup>2</sup> hr) | $\gamma_{i(N)}$ (Kg/hr) |
|------|-----------------------------------------|----------------------------------------|-------------------------|
| 1    | 0.001206                                | 5.05928                                | 51.3778                 |
| 2    | 0.002320                                | 3.84624                                | 182.2605                |
| 3    | 0.001284                                | 4.45647                                | 508.5207                |
| 4    | 0.110813                                | 4.97641                                | 165.3433                |
| 5    | 0.001284                                | 4.45647                                | 508.5207                |
| 6    | 0.003578                                | 4.14938                                | 121.2133                |

**Table V: COX Emission Coefficients [12]**

| Unit | $\alpha_{i(N)}$ (Kg/MW <sup>2</sup> hr) | $\beta_{i(N)}$ (Kg/MW <sup>2</sup> hr) | $\gamma_{i(N)}$ (Kg/hr) |
|------|-----------------------------------------|----------------------------------------|-------------------------|
| 1    | 0.001206                                | 5.05928                                | 51.3778                 |
| 2    | 0.002320                                | 3.84624                                | 182.2605                |
| 3    | 0.001284                                | 4.45647                                | 508.5207                |
| 4    | 0.110813                                | 4.97641                                | 165.3433                |
| 5    | 0.001284                                | 4.45647                                | 508.5207                |
| 6    | 0.003578                                | 4.14938                                | 121.2133                |

### III. RESULTS AND DISCUSSION

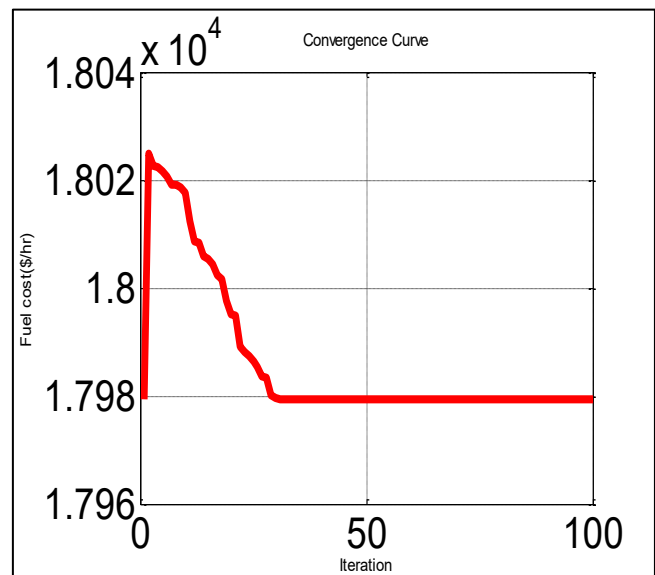
We generated 40 sets of power outputs, corresponding to the maximum number of flames (population = 40). Each set has six outputs for the six generators in the power plant, as shown in Table VI, where number 20 satisfies the optimisation and power-balance requirements. The search space, or solution space, contains these results. The optimisation algorithm has to locate the optimal solution - number 20 in Table VI, where the generated power is 60.0640 MW.

**Table VI: Generator Outputs in MW**

| GT1    | GT2     | GT3    | GT4    | GT5     | GT6     | Total   |
|--------|---------|--------|--------|---------|---------|---------|
| 4.3183 | 5.3820  | 4.2547 | 5.3183 | 6.3820  | 5.3820  | 31.0373 |
| 4.3445 | 5.4134  | 4.2756 | 5.3445 | 6.4134  | 5.4134  | 31.2045 |
| 4.3571 | 5.4285  | 4.2857 | 5.3571 | 6.4285  | 5.4285  | 31.2855 |
| 4.4617 | 5.5541  | 4.3694 | 5.4617 | 6.5541  | 5.5541  | 31.9550 |
| 4.9713 | 6.1656  | 4.7771 | 5.9713 | 7.1656  | 6.1656  | 35.2164 |
| 4.9754 | 6.1705  | 4.7803 | 5.9754 | 7.1705  | 6.1705  | 35.2426 |
| 5.2699 | 6.5238  | 5.0159 | 6.2699 | 7.5238  | 6.5238  | 37.1272 |
| 5.4189 | 6.7026  | 5.1351 | 6.4189 | 7.7026  | 6.7026  | 38.0807 |
| 5.5761 | 6.8914  | 5.2609 | 6.5761 | 7.8914  | 6.8914  | 39.0872 |
| 5.7119 | 7.0542  | 5.3695 | 6.7119 | 8.0542  | 7.0542  | 39.9559 |
| 5.8687 | 7.2425  | 5.4950 | 6.8687 | 8.2425  | 7.2425  | 40.9598 |
| 6.7692 | 8.3231  | 6.2154 | 7.7692 | 9.3231  | 8.3231  | 46.7231 |
| 6.7850 | 8.3420  | 6.2280 | 7.7850 | 9.3420  | 8.3420  | 46.8239 |
| 7.1710 | 8.8052  | 6.5368 | 8.1710 | 9.8052  | 8.8052  | 49.2944 |
| 7.8156 | 9.5787  | 7.0525 | 8.8156 | 10.5787 | 9.5787  | 53.4197 |
| 7.9223 | 9.7067  | 7.1378 | 8.9223 | 10.7067 | 9.7067  | 54.1025 |
| 8.2176 | 10.0611 | 7.3741 | 9.2176 | 11.0611 | 10.0611 | 55.9927 |
| 8.3874 | 10.2649 | 7.5100 | 9.3874 | 11.2649 | 10.2649 | 57.0796 |

|               |                |               |               |                |                |                |
|---------------|----------------|---------------|---------------|----------------|----------------|----------------|
| 8.4559        | 10.3470        | 7.5647        | 9.4559        | 11.3470        | 10.3470        | 57.5175        |
| <b>8.8538</b> | <b>10.8245</b> | <b>7.8830</b> | <b>9.8538</b> | <b>11.8245</b> | <b>10.8245</b> | <b>60.0640</b> |
| 8.8976        | 10.8772        | 7.9181        | 9.8976        | 11.8772        | 10.8772        | 60.3449        |
| 9.4688        | 11.5626        | 8.3751        | 10.4688       | 12.5626        | 11.5626        | 64.0004        |
| 10.3236       | 12.5883        | 9.0589        | 11.3236       | 13.5883        | 12.5883        | 69.4710        |
| 10.4631       | 12.7558        | 9.1705        | 11.4631       | 13.7558        | 12.7558        | 70.3640        |
| 10.5548       | 12.8657        | 9.2438        | 11.5548       | 13.8657        | 12.8657        | 70.9506        |
| 10.5574       | 12.8689        | 9.2459        | 11.5574       | 13.8689        | 12.8689        | 70.9674        |
| 10.7874       | 13.1448        | 9.4299        | 11.7874       | 14.1448        | 13.1448        | 72.4390        |
| 10.948        | 13.3379        | 9.5586        | 11.9483       | 14.3379        | 13.3379        | 73.4690        |
| 11.0605       | 3.4726         | 9.6484        | 12.0605       | 14.4726        | 13.4726        | 74.1869        |
| 11.0936       | 13.5124        | 9.6749        | 12.0936       | 14.5124        | 13.5124        | 74.3993        |
| 11.4313       | 13.9176        | 9.9451        | 12.4313       | 14.9176        | 13.9176        | 76.5605        |
| 11.5469       | 14.0562        | 10.0375       | 12.5469       | 15.0562        | 14.0562        | 77.2999        |
| 11.5774       | 14.0929        | 10.0619       | 12.5774       | 15.0929        | 14.0929        | 77.4954        |
| 11.6552       | 14.1862        | 10.1241       | 12.6552       | 15.1862        | 14.1862        | 77.9931        |
| 11.9221       | 14.5065        | 10.3377       | 12.9221       | 15.5065        | 14.5065        | 79.7013        |
| 11.9520       | 14.5424        | 10.3616       | 12.9520       | 15.5424        | 14.5424        | 79.8928        |
| 12.0028       | 14.6034        | 10.4022       | 13.0028       | 15.6034        | 14.6034        | 80.2180        |
| 12.1472       | 14.7767        | 10.5178       | 13.1472       | 15.7767        | 14.7767        | 81.1423        |
| 12.2346       | 14.8815        | 10.5877       | 13.2346       | 15.8815        | 14.8815        | 81.7013        |
| 12.4913       | 15.1896        | 10.7930       | 13.4913       | 16.1896        | 15.1896        | 83.3443        |

Figure 2 shows the ELD graph without emissions using the MFO algorithm. Here, we apply the ELD objective function without considering gas emissions (Equation (12)). The algorithm located the optimal power outputs of the generators and then computed the cost of generation iteratively. The algorithm ran 100 iterations and obtained \$17,979.00/hr as the optimal generation cost. Figure 2 shows the plot of iteration versus generation cost. The horizontal part of the curve corresponds to \$17, 979.00/hr.



**[Fig.2: Convergence Curve of ELD by MFO Algorithm Without Considering Gas Emissions]**

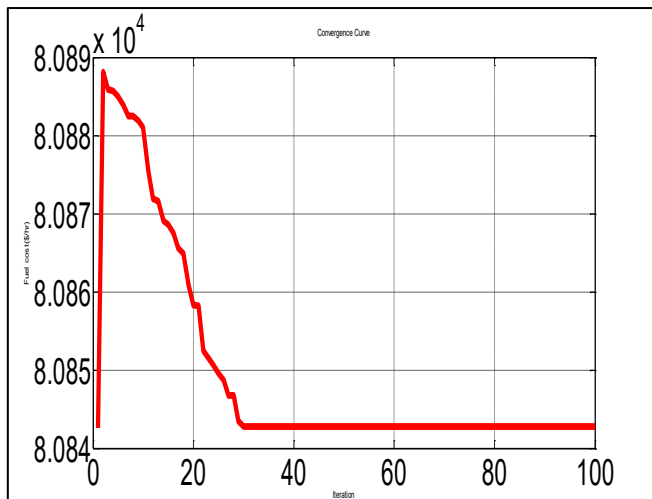
Standard hydrocarbon gases like natural gas or LPG contain carbon and naturally produce CO<sub>2</sub> upon combustion. According to the International Energy Agency (IEA), emissions factors of greenhouse gases (GHGs) - carbon oxides (CO<sub>x</sub>), nitrogen oxides (NO<sub>x</sub>), and Sulphur oxides (SO<sub>x</sub>), as by-products- are CO<sub>2</sub>: 450 kg/MWh; CO: 0.4 kg/MWh; NO<sub>x</sub>: 2.8 kg/MWh; SO<sub>x</sub>: 0.4 kg/MWh [15]-[19]. Table VII shows the emission amounts corresponding to the generation of 60 MWh.



Table VII: Quantities of Emissions

| Fuel type   | Quantity of Electricity Generated (MWh) | Emission Quantities (Kg/hr) |     |                 |                 |
|-------------|-----------------------------------------|-----------------------------|-----|-----------------|-----------------|
|             |                                         | CO <sub>2</sub>             | CO  | NO <sub>x</sub> | SO <sub>x</sub> |
| Natural Gas | 1.0                                     | 450                         | 0.4 | 2.8             | 0.4             |
|             | 60                                      | 27,000                      | 24  | 168             | 24              |

Figure 3 shows the Economic Load Dispatch and Emission Consideration (ELDEC) graph. Here, gas emissions are considered. This case applies the objective function for optimal economic dispatch considering emissions (Equation (14)).



[Fig.3: Convergence Curve of ELDEC by MFO Algorithm, Considering Gas Emissions]

Figure 3 shows that the fuel cost of generating 60MW, considering emissions, is \$80,843.00/hr, corresponding to the horizontal part of the curve. Thus, Combustion of natural gas generates greenhouse gases (GHGs) as by-products, thereby directly increasing fuel consumption. The costs due to the emission of carbon oxides (NO<sub>x</sub>), nitrogen oxides (NO<sub>x</sub>), and Sulphur oxides (SO<sub>x</sub>) from a gas-powered electric power plant are classified as: (i) Capital Costs: these include the cost of installation and maintenance of the equipment for controlling/minimizing emissions, (ii) Operational Costs: these involve payment of emission taxes/penalties. A carbon tax directly assigns a market price to emissions. Thus, carbon pricing, regulatory compliance, and equipment costs generally increase gas power plant emissions (especially CO<sub>2</sub>) and raise electricity generation costs. Ultimately, as production capacity increases, emissions rise, and market prices go up. However, using hydrogen as fuel or a specialised zero-emission turbine can achieve zero emissions. Table 8 shows the MFO results.

#### IV. CONCLUSION

In this paper, we performed economic load dispatch considering greenhouse gas emissions using MFO. The results obtained are more comprehensive than those in existing works. The results include the optimum fuel cost, emissions per gas, the total cost of generating 60 MW, and a graphical display of the results. The MFO shows that the optimum cost of generating 60 MWh of electrical energy in a gas-powered plant is \$80,843.00/hr. This cost was obtained by optimally sharing the load among six generators in the

plant, as shown in Table VI. Thus, gas emissions from electrical power generation have an adverse financial effect, in addition to environmental pollution. Moreover, economic load dispatch (optimal sharing of load among generating units), with or without gas emission consideration, minimises power generation costs. To reduce electricity generation costs, it is crucial to reduce toxic gas emissions.

#### DECLARATION STATEMENT

Some cited references are older and are noted explicitly as [3], [6], [8], [10], [11], [14], and [16]. However, these works remain significant for the current study, as they are pioneering in their fields. As the article's author, I must verify the accuracy of the following information.

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

- **Funding Support:** This article has not been funded by any organisations or agencies. This independence ensures the research is conducted objectively and without external influence.
- **Conflicts of Interest/ Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Ethical Approval and Consent to Participate:** The content of this article does not necessitate ethical approval or consent to participate, with supporting documentation.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Authors' Contributions:** The authorship of this article is contributed equally by all participating individuals.

#### REFERENCES

1. N. Chopra, G. Kumar, and S. Mehta, "Multi-objective Economic Emission Load Dispatch using Grey Wolf Optimisation," International Journal of Advanced Engineering Research and Science (IJAERS), vol. 3, issue 11, pp. 26-33, 2016. DOI: [10.22161/ijaers/3.11.5](https://doi.org/10.22161/ijaers/3.11.5)
2. B. Taheri, G. Aghajani and M. Sedaghat "Economic Dispatch in a power system considering environmental pollution using a Multiobjective Particle Swarm Optimisation based on the Pareto Criterion and Fuzzy Logic," International Journal of Energy and Environmental Engineering, vol. 8, no. 2, pp. 99-107, 2017. DOI: [10.1007/s40095-017-0233-9](https://doi.org/10.1007/s40095-017-0233-9)
3. W.S.Wang, Y.M.Chen, "A particle Swarm approach to solve environmental/economic dispatch problem," International Journal of Engineering Computations, vol. 1, pp. 157-172, 2010. <https://growing-science.com/beta/ijec/868-a-particle-swarm-approach-to-solve-environmental-economic-dispatch-problem.html>, works remain significant; see the [declaration](#)
4. J. Radosavljevic, "A solution to the Combined Economic and Emission Dispatch using Hybrid PSOGSA Algorithm," Applied Artificial Intelligence, vol. 30, No. 5, pp. 445-474, 2016. DOI: [10.1080/08839514.2016.1185860](https://doi.org/10.1080/08839514.2016.1185860)
5. M. Ahmad, W. Ali and H. Farooq, "Solving the Problem of Economic Load Dispatch for a small-scale power system using a Novel Hybrid PSOGSA Algorithm," International Symposium on Recent Advances in Electrical Engineering (RAEE), pp.1-6, 2018. <https://www.semanticscholar.org/paper/94773ff7cc5f0a4054a08bcf605882e4ce4177dd>
6. H. Hardiansyah and R. Rusman, "Combined Economic Emission Disptch Solution using Modified Artificial Bee Colony Algorithm," International Journal of Advanced Research in Electrical, Electronic and Instrumentation Engineering, vol. 4, issue 11, pp.



- 910 – 917, 2015. DOI: [10.15662/IJAREEIE.2015.0411001](https://doi.org/10.15662/IJAREEIE.2015.0411001). Works remain significant; see the [declaration](#)
7. G. R. Kumar and B. Sasikala, "Multi-Objective Economic Emission Dispatch using BAT Algorithm with Multiple Loads," International Research Journal of Engineering and Technology (IRJET), vol. 04, issue 10, pp. 131 – 135, 2017. <https://www.irjet.net/archives/V4/i10/IRJET-V4I1026.pdf>
  8. S. K. Dewangan, A. Jain, and A. P. Huddar, "A traditional Approach to solve the economic load dispatch problem considering the Generator Constraints," IOSR Journal of Electrical and Electronic Engineering (IOSR-JEEE), vol. 10, issue 2, pp. 27 – 32, 2015. [https://www.academia.edu/120401347/Energy\\_management\\_of\\_micro\\_grid\\_using\\_cooperative\\_game\\_theory](https://www.academia.edu/120401347/Energy_management_of_micro_grid_using_cooperative_game_theory), works remain significant; see the [declaration](#)
  9. V. Kuma, J. Singh, Y. Singh, and S. Sood, "Optimal Economic Load Dispatch using Genetic Algorithms," International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering, vol. 9, no. 4, pp. 463-470. <https://dokumen.pub/>
  10. J. J. Grainger and W. D. Stevenson, Power System Analysis. McGraw-Hill, pp. 531- 541, 1994. <https://www.scirp.org/reference/referencespapers?referenceid=1580338>, works remain significant; see the [declaration](#)
  11. U. K. Gupta, G. Gangil, and S. Agarwal "Performance Analysis of Economic Load Dispatch using Genetic Algorithm," International Journal of Research in Advent Technology, vol. 2, no. 9, pp. 60-64, 2014. <https://ejtas.com/index.php/journal/article/view/664>, works remain significant; see the [declaration](#)
  12. A. T. Mohamad, R. Hegazy, T. Vladimir, A. Z. K. Ahmed, Y. Almoataz, & V. Artem (2018). "Impact of optimum Allocation of Renewable Distributed Generation on Distribution Networks Based on Different Optimisation Algorithms," Energies, vol. 6, no. 7, pp. 11-33, 2018. DOI: [10.3390/en11010245](https://doi.org/10.3390/en11010245)
  13. H. Buch, I. Trivedi, and P. Jangir, "Moth Flame Optimisation to Solve Optimal Power Flow with Non-parametric Statistical Evaluation Validation," International Journal of Engineering, vol. 80, pp. 1-22, 2017. DOI: [10.1007/s00521-018-3382-8](https://doi.org/10.1007/s00521-018-3382-8)
  14. S. Mirjalili, "Moth-Flame Optimization Algorithm, A Novel Nature-inspired Heuristic Paradigm," Knowledge-Based Systems, vol. 10, no. 2, pp. 32-40, 2015. DOI: [10.4018/978-1-5225-5643-5.ch031](https://doi.org/10.4018/978-1-5225-5643-5.ch031). Works remain significant; see the [declaration](#)
  15. [www.google.com/search](https://www.google.com/search).
  16. A. Bhattacharya and Chattopadhyay, "Solving Economic Emission Load Dispatch Problems using Hybrid Differential Evolution," Applied Soft Computing Journal, vol. 11, no. 2, pp. 2526-2537, 2011. DOI: [10.1016/j.asoc.2010.09.008](https://doi.org/10.1016/j.asoc.2010.09.008); works remain significant, see the [declaration](#)
  17. S. Manickam and L. Lakshminar, "Water Wave Optimization Algorithm for Solving Combined Economic and Emission Dispatch Problems," International Journal of Applied Science and Engineering, April, 2017. <https://www.researchgate.net/publication/316595942>
  18. C. Faseela, "Combined Economic and Emission Dispatch with Valve Point Effect using Moth Flame Optimization (MFO)," International Journal of Mechanical Engineering Technology, vol. 8, no. 8, pp. 26-37, 2017. [https://iaeme.com/MasterAdmin/Journal\\_uploads/IJMET/VOLUME\\_8\\_ISSUE\\_8/IJMET\\_08\\_08\\_004.pdf](https://iaeme.com/MasterAdmin/Journal_uploads/IJMET/VOLUME_8_ISSUE_8/IJMET_08_08_004.pdf)
  19. A. J. Adesanmi, S. A. Badmus, O. A. Gbadebo, and J. A. Onibare, "Emission Inventory of Electricity Generation from Thermal Power Plants in Nigeria," Global Scientific Journals, vol. 7, no. 2, pp. 140 – 149, 2019. DOI: [10.1016/j.heliyon.2021.e06398](https://doi.org/10.1016/j.heliyon.2021.e06398)

**Disclaimer/Publisher's Note:** The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the Publisher /Journal and/or the editor(s). The Publisher /Journal and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.