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# Computational Solution to Economic Operation of Power Plants

**Temitope Adefarati[1,*], Ayodele Sunday Oluwole[1], Mufutau Adewolu Sanusi[2]**

[1]Department of Electrical/Electronic Engineering, Federal University, Oye Ekiti, 370282, Nigeria
[2]Department of Electrical/Electronic Engineering, Federal ploytechnic Ede Osun State Nigeria

**Abstract** The production cost of electricity is a very important index in national development. Electricity tariff depends on the fuel cost which carries the highest percentage of the total operation cost in any power plant. In order to keep electricity tariff as low as possible, fuel cost which carries the highest percentage of the total operating cost has to be minimized. Economic operation of the power plants can be achieved through economic load dispatch and unit commitment. Lagrange relaxation is one of the best solutions in solving economic load dispatch problem because it is more efficient and easier than other methods. This approach has been implemented to minimize the fuel cost of generating electricity while taking into account some technical constraints.

**Keywords** Economic Efficiency, Economic Load Dispatch, Incremental Cost

## 1. Introduction

The optimum economic operation of electric power syste m has occupied an important position in the electric power industry. With recent power deregulation all over the world, it has become necessary for power generating utilities to run their power plants with minimum cost while satisfying their customers load demand (Peak and Base load). In order to achieve this, all the generating units in any power plant must be loaded in such a way that optimum economic efficiency can be achieved[2]. The purpose of economic operation of any power plant is to reduce the fuel cost which carries the highest percentage of the operating cost while running the plant[1][2]. The minimum fuel cost can only be achieved by applying economic load dispatch and unit commitment in any interconnected power system. Hence, Economic load dispatch is a powerful and useful tool to assess optimum operation as well as the financial and electrical performance of a power plant.

## 2. Economic Operation of Power Systems

Economical production of electricity is the most important factor in the power system. In any combined power plants, all the generating units should be loaded in such a way that optimum efficiency can be achieved. The purpose of economic operation is to reduce the fuel cost of the operation of the power system. The optimum operation of a power plant can only be achieved by economic load scheduling of different units in the power plants or different power plants in the power system. Economic load scheduling is the determination of the generating output of different units in a power plant in such way to minimize the total fuel cost and at the same time meet the total power demand[2],[7]. The economic load division between different generating units can only be computed if the operating cost expressed in terms of power output

$$\text{Efficiency of generating unit} = \frac{\text{Output in MW} \times 1000 \times 100\%}{\text{Input in KJ per second}} = \frac{\text{Output in MW} \times 1000 \times 3600 \times 100\%}{\text{Input in KJ per hour}}$$

If P stands for the power output in megawatts (MW) and C be the fuel cost, then Fig.1 shows a typical input and output characteristic curve of a power plant.

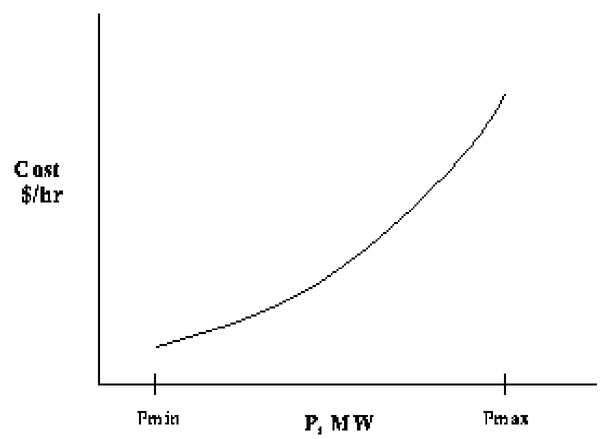


**Figure 1.** Typical input/output Characteristic curve for a single unit in a power plant

* Corresponding author:
temitope.adefarati@yahoo.com (Temitope Adefarati)
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The Pmax is limited by thermal consideration and a given power unit cannot produce more power than it is designed for. The Pmin is limited because of the stability limit of the machine. If the power output of any generating unit for optimum operation of the system is less than a specified value Pmin, the unit is not put on the bus bar because it is not possible to generate that low value of power from that unit[7],[8]. Hence the generating Power Pi cannot be outside the range stated by the inequality, i.e.

$$P_{\min} \le P_i \le P\max$$

### 2.1. Operational Cost in a Power Plant

The main economic factor in the power system operation is the cost of generating real power. In any power system this cost has two components[1].

1. The fixed cost being determined by the capital investment, interest charged on the money borrowed, tax paid, labour charge, salary given to staff and other expenses that continue irrespective of the load on the power[1].

2. The variable cost is a function of loading on generating units, losses, daily load requirement and purchase or sale of power[1].

The economic operation of an electrical power can be achieved by minimizing the variable factor only while the personnel in charge of the plant operation have little control over the fixed costs[1].

### 2.2. The Objectives of the Research

The objectives of the research are as follows:

1. To formulate a mathematical model to minimize the total fuel cost of producing electrical power in a power plant within a stipulated time interval. The cost of each generating unit in a power plant is represented by the quadratic equation of the second order. The objective function of a power plant is the algebraic sum of the quadratic fuel cost of each gener ating unit in a power plant.[6],[12]. The objective function of each generating unit can be expressed as

$$F(P^i) = a^i + b^i P^i + c^i P^{i\,2},$$

Where *ai*, *bi* and *ci* are the cost coefficients of generating unit at bus *i*[6][12].

2. To develop the best approach that will help all the power utility companies to solve the problem of economic load dispatch in an interconnected power system.

3. To estimate the output power and fuel consumption of each generating unit in a power plant while meeting the load demands at a minimum fuel cost.

4. To design a computer application program to solve the problem of economic dispatch problem in any interconnecte d power system.

5. To deploy all the available resources for power generation such as natural gas, water, diesel, uranium, coal and petrol more efficiently and thus handle peak and base loads more efficiently and reliably with economic load dispatch.

### 2.3. Economic Load Dispatch

The Economic Load Dispatch is a process of allocating demand loads to different generating units in a power plant at a minimum fuel cost while meeting the technical constraints. It is formulated as an optimization process of minimizing the total fuel cost of all the committed generating units in a power plant while meeting the load demands and technical constraints[3],[7].

$$F^i = a^i + b^i P^i + c^i P^{i\,2} \tag{1}$$

The fuel cost function of a generating unit is represented by a quadratic equation of the second order as shown in equation.1 Where $a_i$, $b_i$ and $c_i$ are constants of $i^{th}$ generating unit.

### 2.4. Incremental Cost

Incremental cost can be determined by taking the derivative of the equation 1.0

$$\frac{\partial F_i}{\partial P_i} = b + 2c \quad P_i \tag{2}$$

$$\lambda = b + 2c \quad P_i \tag{3}$$

$$\text{Pi} = \frac{\lambda - b_i}{2c_i} \tag{4}$$

Subject to

$$P_{\min} \le P_i \le P\max \tag{5}$$

Sum up the entire Pi of the power system

$$\text{I.e. } \sum_i^N P_i \quad \text{i=1 to N} \tag{6}$$

$$P_D = \sum_i^N P_i \tag{7}$$

$$\text{Or} \quad P_D - \sum_i^N P_i \le \varepsilon \tag{8}$$

Where $\varepsilon = 10^{-5}$. If conditions in equation (5.0) are met, Then Sum up all the Pi(s)

$$\text{i.e.} \quad \sum_i^N P_i \tag{9}$$

$$\text{Error} = \text{ABS}\left(\sum_i^N P_i - P_D\right) \tag{10}$$

$$\text{Error} = \le \varepsilon \tag{11}$$

If convergence is not achieved then modifies λ and recompute $P_i$, the process is continued until

$P_D - \sum_i^N P_i$ is less than a specified accuracy or

$$P^D = \sum_i^N P_i$$

If convergence is achieved, then compute the following,

1. $F_i$ = a + b $P_i$ + c $P_i^2$
2. $P_i$ for each unit

### 2.5. Computational Algorithms

Step1. Total power demand would be given.
Step2. Assign initial estimated value of λ (0).
Step3. Let $\varepsilon$ be equal to $10^{-5}$.
Step4. $F_i$ For all the units would be given.

Step5. Differentiate $F_i$ with respect to Pi ( $\frac{\partial F_i}{\partial P_i}$ = bi + 2ci $P_i$=λ)

Step6. Rearrange $\frac{\partial F_i}{\partial P_i}$ (so that Pi = $\frac{\lambda - b_i}{2c_i}$)

Step7. Compute the individual Units P1, P2-------Pn Corresponding to λ (0).

Step8. Compute $\sum_i^N P_i$

Step9. Check if the relationship ∑Pi (0) =PD is satisfied or

$$P_D - \sum_i^N P_i = \leq \varepsilon$$

Step10. If the sum is less than total power demand, then assigns a new value λ (1) repeat steps 8 and 9.

Step11. If the sum is less than the demand, then assigns a new value λ (2) and repeat steps 8 and 9. Continue the iteration until when it will converge.

$$P_D = \sum_i^N P_i \text{ or } P_D - \sum_i^N P_i \leq \varepsilon$$

Step12. Calculate fuel cost and $P_i$ for each generating unit.

## 3. Modelling of Polynomial Equation for Each Generating Unit

Polynomial model for the generating units can be achieved through the least square method.

### 3.1. Least Square Equations

$$\sum F_i = aN + b\sum p + c\sum p^2 \quad \text{(i)}$$

$$\sum F_i\, p = a\sum p^2 + b\sum p^2 + c\sum p^3 \quad \text{(ii)}$$

$$\sum F_i\, p^2 = a\sum p^2 + b\sum p^3 + c\sum p^4 \quad \text{(iii)}$$

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} N+ & \sum p + & \sum p^2 \\ \sum p^2 + & \sum p^2 + & \sum p^3 \\ \sum P^2 + & \sum p^3 + & \sum p^4 \end{bmatrix}^{-1} \begin{bmatrix} \sum F_i \\ \sum F_i p \\ \sum F_i P^2 \end{bmatrix}$$

### 3.2. MAT LAB Simulation

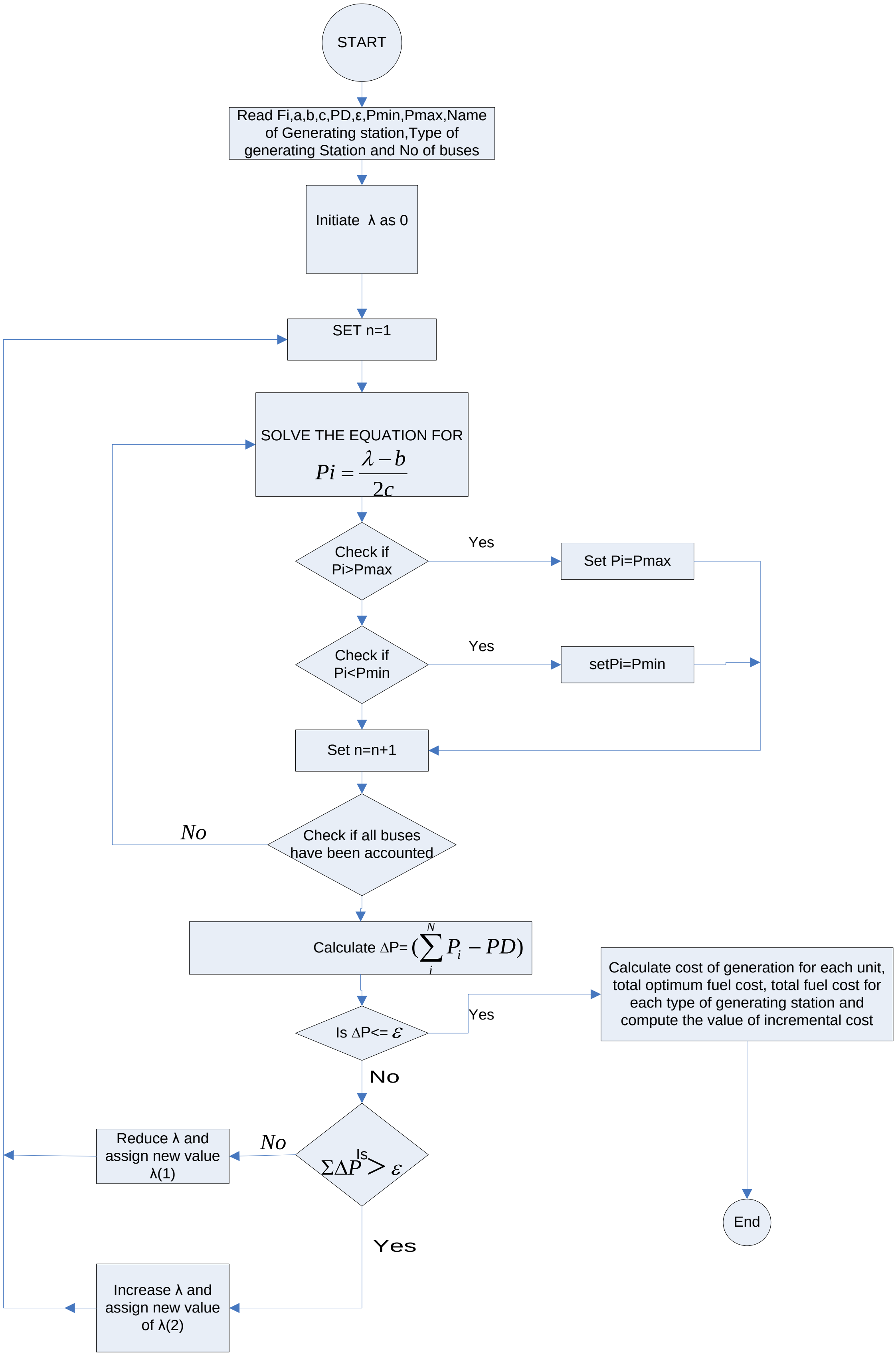
With MAT LAB simulation coefficients a, b and c can be achieved, therefore the polynomial equation for each generating unit is expressed as

$$F = a + bP + c\,P^2$$

**Table 1.** The 1st generating unit

| Power ( Mw) | Fuel Cost ( $/Hr ) | $P^2$ ( Mw) $^2$ | $P^3$ ( Mw) $^3$ | $P^4$ ( Mw) $^4$ | PxF ( $Mw/Hr) | $P^2$ XF ( Mw) $^2$ ($/Hr) |
|---|---|---|---|---|---|---|
| 100 | 710 | 10000 | 1000000 | 100000000 | 71000 | 7100000 |
| 150 | 997.5 | 22500 | 3375000 | 506,250,000 | 149625 | 22443750 |
| 200 | 1320 | 40000 | 8000000 | 1600000000 | 264000 | 52800000 |
| 250 | 1677.5 | 62500 | 15625000 | 3906250000 | 419375 | 104843750 |
| 300 | 2070 | 90000 | 27000000 | 8100000000 | 621000 | 186300000 |
| 350 | 2497.5 | 122500 | 42875000 | 15006250000 | 874125 | 305943750 |
| 400 | 2960 | 160000 | 64000000 | 25600000000 | 1184000 | 473600000 |
| 450 | 3457.5 | 202500 | 91125000 | 41006250000 | 1555875 | 700143750 |
| 500 | 3990 | 250000 | 125000000 | 62500000000 | 1995000 | 997500000 |
| 2700 | 19680 | 960000 | 378000000 | 1.58325E+11 | 7134000 | 2850675000 |

Table 1 shows the power and fuel characteristic of the first generating unit




Flow chart for economic load dispatch problems

**Figure 2.** Flow chart for economic load dispatch

By applying the least square equations

$$19680 = 9a + 2700b + 960000c \quad \text{(i)}$$
$$7134000 = 2700a + 960000b + 378000000c \quad \text{(ii)}$$
$$2850675000 = 960000a + 378000000b + 1.58325 \times 10^{11} c \quad \text{(iii)}$$

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} 9 & 2700 & 960000 \\ 2700 & 960000 & 378000000 \\ 9660000 & 378000000 & 1.58325\times10^{11} \end{bmatrix}^{-1} \begin{bmatrix} 19680 \\ 7134000 \\ 2850675000 \end{bmatrix}$$

Where a = 240, b = 4 and c= 0.007

Therefore, the polynomial equation for the first generating unit can be expressed as

$$F = 240 + 4P + 0.007\,P^2$$

**Table 2.** The 2nd generating unit

| Power ( Mw) | Fuel Cost ( \$/Hr ) | $P^2$ ( Mw) $^2$ | $P^3$ ( Mw) $^3$ | $P^4$ ( Mw) $^4$ | PxF ( \$Mw/Hr) | $P^2$ XF ( Mw) $^2$ (\$/Hr) |
|---|---|---|---|---|---|---|
| 50 | 673.75 | 2500 | 125000 | 6250000 | 33687.5 | 1684375 |
| 75 | 928.4375 | 5625 | 421875 | 31,640,625 | 69632.812 | 5625928.437 |
| 100 | 1195 | 10000 | 1000000 | 100000000 | 119500 | 11950000 |
| 125 | 1473.4375 | 15625 | 1953125 | 244140625 | 184179.6875 | 23022460.94 |
| 150 | 1763.75 | 22500 | 3375000 | 506250000 | 264562.5 | 39684375 |
| 175 | 2065.9375 | 30625 | 5359375 | 937890625 | 361539.0625 | 63269335.94 |
| 200 | 2380 | 40000 | 8000000 | 1600000000 | 476000 | 95200000 |
| **875** | **10480.3125** | **126875** | **20234375** | **3426171875** | **1509101.562** | **240436475.3** |

Table 2 shows the power and fuel characteristic of the second generating unit

By applying the least square method

$$10480.3125 = 7a + 875b + 126875c \quad \text{(i)}$$
$$1509101.562 = 875a + 126875b + 20234375c \quad \text{(ii)}$$
$$240436475.3 = 126875a + 20234375b + 3426171875c \quad \text{(iii)}$$

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} 7 & 875 & 126875 \\ 875 & 126875 & 20234375 \\ 126875 & 20234375 & 3426171875 \end{bmatrix}^{-1} \begin{bmatrix} 10480.3125 \\ 1509101.562 \\ 240436475.3 \end{bmatrix}$$

Where a = 200, b=9 and c=0.0095

Therefore, the polynomial equation for the second generating unit can be expressed as

$$F = 200 + 9P + 0.0095\,P^2$$

**Table 3.** The 3rd generating unit

| Power ( Mw) | Fuel Cost (\$/Hr) | $P^2$ ( Mw) $^2$ | $P^3$ ( Mw) $^3$ | $P^4$ ( Mw) $^4$ | PxF ( \$Mw/Hr.) | $P^2$ XF ( Mw) $^2$ (\$/Hr.) |
|---|---|---|---|---|---|---|
| 80 | 733.6 | 6400 | 512000 | 40960000 | 58688 | 4695040 |
| 100 | 880 | 10000 | 1000000 | 100,000,000 | 88000 | 8800000 |
| 150 | 1277.5 | 22500 | 3375000 | 506250000 | 191625 | 28743750 |
| 200 | 1720 | 40000 | 8000000 | 1600000000 | 344000 | 68800000 |
| 250 | 2207.5 | 62500 | 15625000 | 3906250000 | 551875 | 137968750 |
| 300 | 2740 | 90000 | 27000000 | 8100000000 | 822000 | 246600000 |
| 350 | 3317.5 | 122500 | 42875000 | 15006250000 | 1161125 | 406393750 |
| **1430** | **12876.1** | **353900** | **98387000** | **29259710000** | **3217313** | **902001290** |

Table 3 shows the power and fuel characteristic of the third generating unit

By applying the least square equations

$$12876.1 = 7a + 1430b + 353900c \quad \text{(i)}$$
$$3217313 = 1430a + 353900b + 98387000c \quad \text{(ii)}$$
$$902001290 = 353900a + 98387000b + 29259710000c \quad \text{(iii)}$$

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} 7 & 1430 & 353900 \\ 1430 & 353900 & 98387000 \\ 353900 & 98387000 & 29259710000 \end{bmatrix}^{-1} \begin{bmatrix} 12876.1 \\ 3217313 \\ 902001290 \end{bmatrix}$$

Where a = 220,b = 5.7 and c= 0.009

Therefore, the polynomial equation for the 3rd generating unit can be expressed as

$$F = 220 + 5.7P + 0.009\,P^2$$

**Table 4.** The 4th generating unit

| Power ( Mw) | Fuel Cost ( $/Hr. ) | $P^2$ ( Mw) $^2$ | $P^3$ ( Mw) $^3$ | $P^4$ ( Mw) $^4$ | PxF ( $Mw/Hr.) | $P^2$ XF ( Mw) $^2$ ($/Hr.) |
|---|---|---|---|---|---|---|
| 50 | 772.5 | 2500 | 125000 | 6250000 | 38625 | 1931250 |
| 75 | 1075.65 | 5625 | 421875 | 31,640,625 | 80673.75 | 6050531.25 |
| 100 | 1390 | 10000 | 1000000 | 100000000 | 139000 | 13900000 |
| 125 | 1715.625 | 15625 | 1953125 | 244140625 | 214453.125 | 26806640.63 |
| 150 | 2052.5 | 22500 | 3375000 | 506250000 | 307875 | 46181250 |
| 500 | 7006.275 | 56250 | 6875000 | 888281250 | 780626.875 | 94869671.88 |

Table 4 shows the power and fuel characteristic of the fourth generating unit

By applying the least square equations

$$7006.275 = 5a + 500b + 56250c \quad \text{(i)}$$
$$780626.875 = 500a + 56250b + 6875000c \quad \text{(ii)}$$
$$94869671.88 = 56250a + 6875000b + 888281250c \quad \text{(iii)}$$

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} 5 & 500 & 56250 \\ 500 & 56250 & 6875000 \\ 56250 & 6875000 & 888281250 \end{bmatrix}^{-1} \begin{bmatrix} 12876.1 \\ 3217313 \\ 902001290 \end{bmatrix}$$

Where a = 200, b = 11 and c= 0.009

Therefore, the polynomial equation for the fourth generating unit can be expressed as

$$F = 200 + 11P + 0.009\,P^2$$

**Table 5.** The 5th generating unit

| Power ( Mw) | Fuel Cost ($/Hr. ) | $P^2$ ( Mw) $^2$ | $P^3$ ( Mw) $^3$ | $P^4$ ( Mw) $^4$ | PxF ($Mw/Hr.) | $P^2$ XF ( Mw) $^2$ ($/Hr.) |
|---|---|---|---|---|---|---|
| 50 | 730 | 2500 | 125000 | 6250000 | 36500 | 1825000 |
| 75 | 1000 | 5625 | 421875 | 31,640,625 | 75000 | 5625000 |
| 100 | 1280 | 10000 | 1000000 | 100000000 | 128000 | 12800000 |
| 125 | 1570 | 15625 | 1953125 | 244140625 | 196250 | 24531250 |
| 150 | 1870 | 22500 | 3375000 | 506250000 | 280500 | 42075000 |
| 175 | 2180 | 30625 | 5359375 | 937890625 | 381500 | 66762500 |
| 200 | 2500 | 40000 | 8000000 | 1600000000 | 500000 | 11200000 |
| **875** | **11130** | **126875** | **20234375** | **3426171875** | **1597750** | **164818750** |

Table 5 shows the power and fuel characteristic of the fifth generating unit

By applying the least square equations

$$11130 = 7a + 875b + 126875c \quad \text{(i)}$$
$$1597750 = 875a + 126875b + 20234375c \quad \text{(ii)}$$
$$164818750 = 126875a + 20234375b + 3426171875c \quad \text{(iii)}$$

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} 7 & 875 & 126875 \\ 875 & 126875 & 20234375 \\ 126875 & 20234375 & 3426171875 \end{bmatrix}^{-1} \begin{bmatrix} 12876.1 \\ 3217313 \\ \end{bmatrix}$$

Where a = 220,b = 9.8 and c= 0.008

Therefore, the polynomial equation for the fifth generating unit can be expressed as

$$F = 220 + 9.8P + 0.008\, P^2$$

**Table 6.** The 6th generating unit

| Power (Mw) | Fuel Cost ($/Hr.) | $P^2$ (Mw)$^2$ | $P^3$ (Mw)$^3$ | $P^4$ (Mw)$^4$ | PxF ($Mw/Hr.) | $P^2$ XF (Mw)$^2$ ($/Hr.) |
|---|---|---|---|---|---|---|
| 50 | 858.75 | 2500 | 125000 | 6250000 | 42937.5 | 2146875 |
| 60 | 997 | 3600 | 216000 | 12,960,000 | 59820 | 3589200 |
| 70 | 1136.75 | 4900 | 343000 | 24010000 | 79572.5 | 5570075 |
| 80 | 1278 | 6400 | 512000 | 40960000 | 102240 | 8179200 |
| 90 | 1420.75 | 8100 | 729000 | 65610000 | 127867.5 | 11508075 |
| 100 | 1565 | 10000 | 1000000 | 100000000 | 156500 | 15650000 |
| 110 | 1710.75 | 12100 | 1331000 | 146410000 | 188182.5 | 20700075 |
| 120 | 1858 | 14400 | 1728000 | 207360000 | 222960 | 2675520 |
| **680** | **10825** | **62000** | **5984000** | **603560000** | **980080** | **94098700** |

Table 6 shows the power and fuel characteristic of the sixth generating unit

By applying the least square equations

$$10825 = 5a + 875b + 126875c \quad \text{(i)}$$
$$980080 = 875a + 126875b + 20234375c \quad \text{(ii)}$$
$$94098700 = 126875a + 20234375b + 3426171875c \quad \text{(iii)}$$

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} 8 & 680 & 62000 \\ 680 & 62000 & 5984000 \\ 62000 & 5984000 & 603560000 \end{bmatrix}^{-1} \begin{bmatrix} 10825 \\ 980080 \\ 94098700 \end{bmatrix}$$

Where a = 190, b = 13 and c= 0.0075

Therefore, the polynomial equation for the sixth generating unit can be expressed as

$$F = 190 + 13P + 0.0075\, P^2$$

## 4. Test System

This system has 6 units while the Units Cost data and system load demand are given respectively in Table 7.

F1= 240 + 4P + 0.007 $P^2$ ($/Hr)

F2= 200 + 9P + 0.0095($/Hr)

F3= 220 + 5.7P + 0.009($/Hr)

F4= 200 + 11P + 0.009($/Hr)

F5= 220 + 9.8P + 0.008($/Hr)

F6= 190 + 13P + 0.0075 $P^2$ ($/Hr)

**Table 7.** Test System Data

| Unit | Pmin MW | Pmax MW | A $/Hr | B $/MWHr | C $/MW$^2$Hr |
|---|---|---|---|---|---|
| 1 | 100 | 600 | 240 | 4 | 0.007 |
| 2 | 50 | 600 | 200 | 9 | 0.0095 |
| 3 | 80 | 800 | 220 | 5.7 | 0.009 |
| 4 | 50 | 500 | 200 | 11 | 0.009 |
| 5 | 50 | 650 | 220 | 9.8 | 0.008 |
| 6 | 5 | 300 | 190 | 13 | 0.0075 |

Table 7 shows the quadratic fuel cost for the six generating units

**Table 8.** The results of the simulation

| Time (Hr) | Load (MW) | Fuel Cost ($/Hr) | Incremental Cost($/MWHr) |
|---|---|---|---|
| 0100HRS | 1600 | 16845.93 | 13.0822 |
| 0200HRS | 1800 | 19517.26 | 13.63114 |
| 0300HRS | 2000 | 22298.39 | 14.18009 |
| 0400HRS | 2100 | 23750.12 | 14.45456 |
| 0500HRS | *2200* | 25189.3 | 14.72903 |
| 0600HRS | *2250* | 25949.18 | 14.86626 |
| 0700HRS | *2300* | 26675.93 | 15.0035 |
| 0800HRS | *2350* | 27449.53 | 15.14073 |
| 0900HRS | *2400* | 28190 | 15.27797 |
| 1000HRS | *2450* | 28977.33 | 15.4152 |
| 1100HRS | *2500* | 29731.52 | 15.55244 |
| 1200HRS | *2550* | 30532.57 | 15.68967 |
| 1300HRS | *2600* | 31300.49 | 15.82691 |
| 1400HRS | *2650* | 32115.27 | 15.96414 |
| 1500HRS | *2750* | 33725.4 | 16.23861 |
| 1600HRS | *2800* | 34520.77 | 16.37585 |
| 1700HRS | *2900* | 36192.07 | 16.65032 |
| 1800HRS | *2950* | 37028.02 | 16.78755 |
| 1900HRS | *3000* | 37850.83 | 16.92479 |
| 2000HRS | *3100* | 39557.03 | 17.19926 |
| 2100HRS | *3200* | 41290.68 | 17.47373 |
| 2200HRS | *3100* | 39557.03 | 17.19926 |
| 2300HRS | *2900* | 36192.07 | 16.65032 |
| 2400HRS | *2750* | 33725.4 | 16.23861 |

The simulation results are analysed in Table 8, the table shows the load emand, fuel cost and incremental cost for the six generating unit

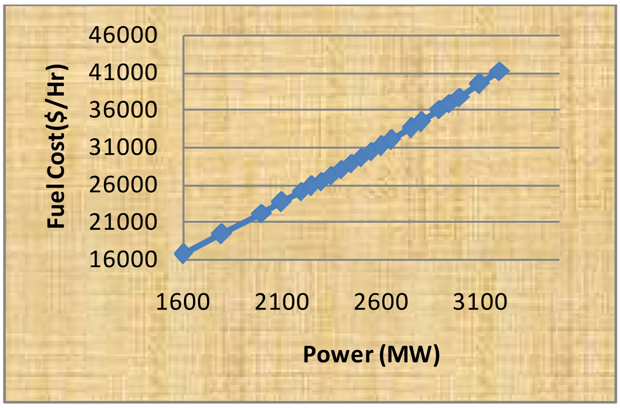
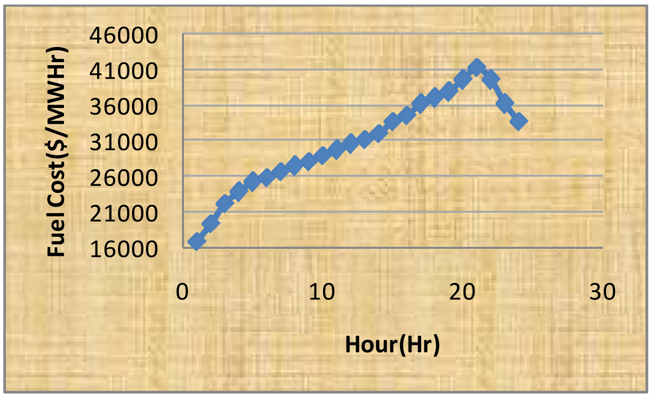



Figure 3. shows the relationship between the load demand and fuel cost in a power system. There is a linear relationship between fuel cost and load demand

**Figure 3.** Power generated vs. Fuel cost




Based on the simulated results, figure 4 shows the hourly fuel cost in the power system

**Figure 4.** Fuel Cost per hour

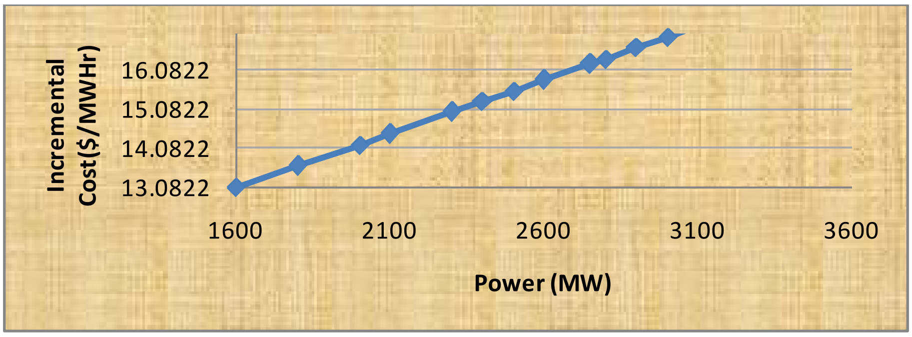



Figure 5 shows that the system incremental cost λ is directly proportional to the demand load

**Figure 5.** Power generated vs. Incremental Cost

**Table 9.** The effect of unit commitment in a power plant

| Units | Type of Generating unit | Output Power MW | Fuel Cost $/Hr | Economic Efficiency $/MWHr |
|---|---|---|---|---|
| 1 | Base load generating unit | 648.7288 | 5780.859 | 8.91106 |
| 2 | Base load generating unit | 4.8528 | 2572.212 | 12.010122 |
| 3 | Base load generating unit | 410.1224 | 4072 | 9.92874 |
| 4 | Peak load generating unit | 115.68 | 1592.89 | 13.7698 |
| 5 | Base load generating unit | 205.1377 | 2567.001 | 12.51355 |
| 6 | Peak load generating unit | 5.480223 | 261.4681 | 47.7112 |
| | Total | 16000 | 16846.4301 | 104.844472 |

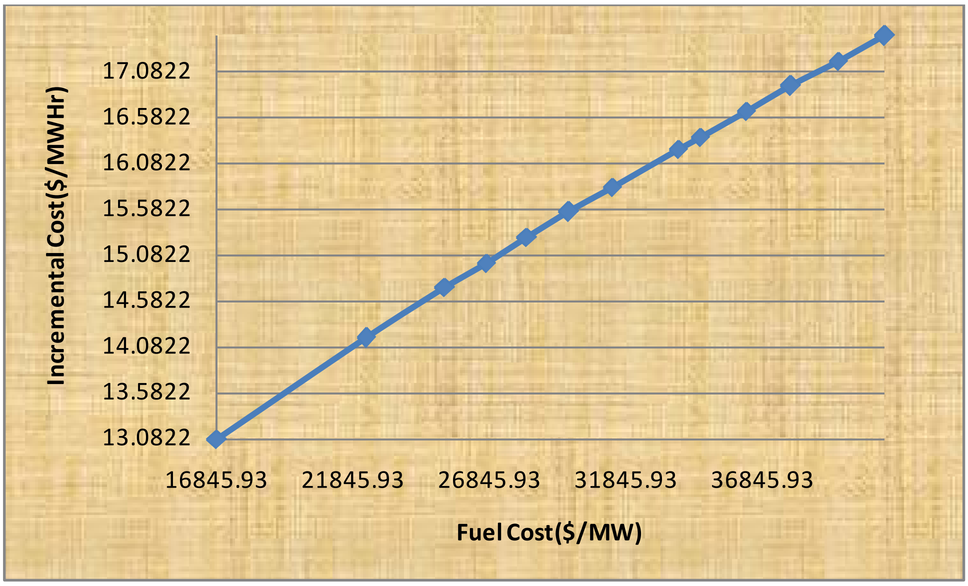



Figure 6 shows that fuel cost is directly proportional to the system incremental cost λ

**Figure 6.** Fuel cost vs. Incremental Cost

## 5. Effect of Unit Commitmen

The first aspect of the Economic Load Dispatch is the unit commitment problem where it is required to select optimally out of the available generating sources to operate, to meet the expected load and provide a specified margin of operating reserve over a specified period of time[10]. From the analys is as shown in Table 9, the base load generating units are 1, 2, 3 and 5 due to their low fuel consumption and optimum economic operation while peak load generating units are 4 and 6.

**Table 10.** Power plant fuel Consumption by considering unit commitment

| Power Generated (MW) | FCWO($/Hr) | FCW($/Hr) | Fuel Cost($/Hr) |
|---|---|---|---|
| 1600 | 16845.93 | 16606.9 | 239.03 |
| 1800 | 19517.26 | 19406 | 111.23 |
| 2000 | 22298.39 | 22165.2 | 133.19 |
| 2200 | 25189.3 | 25121.3 | 68.03 |
| 2300 | 26675.93 | 26649.7 | 26.24 |
| 9900 | 110526.8 | 109949.1 | 577.72 |

FCWO=Fuel Cost without considering unit Commitment
FCW=Fuel Cost by considering unit commitment

## 6. Results and Discussion

The results for the system incremental cost and operating cost were plotted for the various load levels. From figure 5 and figure 6, it shows that operating cost and incremental cost rise linearly with load values. Therefore, it can be concluded that fuel cost and the system incremental cost λ are directly proportional to the demand load. They follow an approximately linear trend in relation to the load demand. Table 8.0 shows that fuel cost and incremental costs are directly proportional to the demand load in any integrated power system. Table 10 also shows the effect of unit commi tment on units 1, 2, 3, 4, 5 and 6. From the table 9, the base load generating units are 1, 2, 3 and 5 due to their efficiency and optimum economic operation while peak load generating units are 4 and 6. In any power plant, the generating unit with the cheapest Fuel Cost, efficiency and the best optimum economic operation will be selected to dispatch first. As shown in Table 3.0, Generating Unit No. 1 is the cheapest while Generating Unit No. 6 is the most expensive in terms of fuel cost and economic efficiency N/MWHr. Hence, Generating Unit No. 1 would be dispatched first and Generat ing Unit No.6 last. Generating unit 1 is the cheapest and it has the best generating capability of the system.

## 7. Conclusions

It can be seen that any increase in load demand brings about the same rise in the system fuel cost; a cost that would be passed on to the customers since fuel cost carries the highest percentage of the operating cost of power plants. Hence, it shows that the relationship between fuel prices and Load demands is approximately linear. With the current po wer deregulation in the world , it is essential to optimise the running cost of power plants by reducing the fuel consumpti on for meeting a particular load demand. This can only be achieved through the economic load dispatch.

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