COMBINED ECONOMIC AND EMISSION DISPATCH WITH AND WITHOUT CONSIDERING TRANSMISSION LOSS

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ABSTRACT

This paper gives a complete idea about the Combined Economic and Emission Dispatch (CEED) in different load demand. This paper shows CEED of a six generator system by neglecting the transmission loss first, and after that CEED of the same system considering transmission loss. Here we solve the CEED problem with the help of Mat-Lab software. The results are graphically represented here, like generation cost v/s load demands; load shared by each generator in different load demand and transmission loss v/s load demands.

KEYWORDS

Economic Load Dispatch (ELD), Economic Emission Dispatch (EED), Combined Economic and Emission Dispatch (CEED), B-coefficients.

1. INTRODUCTION

Economic Load Dispatch means finding out the optimal outputs of the generators to meet the total load demand of a system. There are several different algorithms to solve an ELD problem for different loads with or without considering transmission loss [2], [3], [4]. Generally with the help of ELD, we are benefitted financially. But now a day's throughout the world everyone concentrate on reducing the pollutions. At the time of generation many pollutants like carbon di-oxide (CO_2), oxides of nitrogen (NOx), and oxides of sulphur (SOx) are produced from the fossil fuels. These pollutants have, mainly, ill effects to the human body. So, for the environmental point of view the Economic Emission Dispatch (EDD) is introduced, to minimize the emissions for a certain load demand. That means at the time of economic operation, we have to take care of emission constraints along with the financial conditions. For this reason by combining EED and ELD, Combined Economic and Emission Dispatch is introduced (CEED).

Different algorithms are used for solving CEED problems [5], [6], [7]. Here a CEED problem for six generator system without considering transmission loss is performed. Then with the help of B-

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coefficient matrix, the CEED problem is performed with consideration of transmission loss. As a result, technical as well as environmental issues can be taken care of.

In this article, in section two, the problem formulation is discussed. In subsection 2.1, Economic Load Dispatch (ELD) is discussed. In subsection 2.2, Economic Emission Dispatch (EED) is discussed. Subsection 2.3 discusses the Combined Economic and Emission Dispatch (CEED). Section 3 includes the algorithms for CEED with and without considering loss. Section 4 contains a numerical example with discussion on the results. Finally, some concluding remarks are specified in section 5.

2. PROBLEM FORMULATION

The total procedure to solve a CEED problem for a given example is discuss in the following sections.

2.1. Economic Load Dispatch (ELD)

Cost function in an Economic Load Dispatch is given by-

$$F_c = \sum_{i=1}^{NG} (A_i Pg_i^{\ 2} + B_i Pg_i + C_i) Rs/hr \qquad (i)$$

Where,

F_c = total fuel cost (Rs/hr)

NG = total number of generators

A_i, B_i & C_i = cost coefficients of ith generator.

Pg_i= output of ith generator.

There are some constraints, which we have to follow. They are-

2.1.1. Power balance constraint:

$$P_D + P_L = Pg_i \qquad (ii)$$

Where,

P_D= load demand

P_L= transmission loss

Again this P_L can be calculated by following formula

$$P_L = \sum_{i=1}^{NG} \sum_{j=1}^{NG} Pg_i B_{ij} Pg_j MW \qquad (iii)$$

B_{ij} is known as loss coefficient or B-coefficient of B-coefficient matrix. This B-coefficient matrix is very essential for any economic operation considering loss.

2.1.2. Generating Capacity Limits:

$$Pg_i^{\min} \le Pg_i \le Pg_i^{\max}$$

Where,

$Pg_{i_{\min}}$ = Minimum power output limit of ith generator

$Pg_{i_{\max}}$ = Maximum power output limit of ith generator

2.2. Economic Emission Dispatch (EED)

In Economic Emission Dispatch, total emission is given by-

$$E_C = \sum_{i=1}^{NG} (D_i Pg_i 2 + E_i Pg_i + F_i) \qquad (iv)$$

Where,

E_c =total emission

D_i, E_i & F_i= emission coefficients of i^{th} unit

2.3. Combined Economic and Emission Dispatch (CEED)

These ELD and EED are different to each other. The ELD reduces the fuel cost by increasing the pollutants. Whereas the EED reduces the emission of pollutant gasses by increasing the fuel costs. So, we have to find out a operating point to make a balance between operating cost and emission rate and this can be achieved by CEED.

The main objective function in CEED can be developed by combining ELD with EED with the help of price penalty factor h_i (Venkatesh et al.,2003) as follows:

$$F_T = \sum_{i=1}^{NG} ((A_i Pg_i^{\ 2} + B_i Pg_i + C_i) + h_i (D_i Pg_i^{\ 2} + E_i Pg_i + F_i)) \qquad (v)$$

The price penalty factor can be calculated by the following formula:

$$h_i = \frac{A_i Pg_i^{\ 2} + B_i Pg_i + C_i}{D_i Pg_i^{\ 2} + EiPg_i + F_i} \qquad (vi)$$

3. ALGORITHMS

3.1 Algorithm for CEED (without considering loss)

1. Read data, namely cost coefficients, A_i, B_i, C_i; D_i, E_i, F_i, B- coefficients, B_{ij}, B_{i0}, B_{00} (i= 1, 2,……, NG); convergence tolerance, ξ; step size α; and maximum iteration allowed, ITMAX, $Pg_i^{\min}$, $Pg_i^{\max}$ etc.
2. Find out hi by equation (vi) and find out modified cost coefficients a_i, b_i & c_i
3. The problem can be stated by formulae

$$F(Pg_i) = \sum_{i=1}^{NG} F_i(Pg_i)$$

and

$$\sum_{i=1}^{NG} Pg_i = P_D$$

The values of λ and Pg_i (i= 1, 2,……, NG) can be obtained directly using the formulae

$$\lambda = \frac{(P_D + \sum_{i=1}^{NG} \frac{b_i}{2 * a_i})}{\sum_{i=1}^{NG} \frac{1}{2 * a_i}}$$

&

$$Pg_i = \frac{\lambda - b_i}{2 * c_i}$$

4. Assume no generator has been fixed at either lower limit or at upper limit
5. Check the limits of generators, if no more violations then go to step 13, else fix as following :

$$\text{If } \; Pg_i < Pg_i^{\min} \; \text{ then } \; Pg_i = Pg_i^{\min}$$

$$\text{If } \; Pg_i = Pg_i^{\max} \; \text{ then } \; Pg_i = Pg_i^{\max}$$

6. Go to step 3
7. Compute optimal total cost from Eq.*(v)* .
8. STOP

3.2. Algorithm for CEED (considering loss)

1. Read data, namely cost coefficients, A_i, B_i, C_i; D_i, E_i, F_i, B- coefficients, B_{ij}, B_{i0}, B_{00} (i= 1, 2,……, NG); convergence tolerance, ξ; step size α; and maximum iteration allowed, ITMAX, $Pg_i^{\min}$, $Pg_i^{\max}$ etc.
2. Find out h_i by equation *(vi)* and find out modified cost coefficients a_i, b_i & c_i
3. Compute the initial values of Pg_i (i= 1, 2,……, NG) and λ by assuming that the transmission losses are zero, i.e. P_L=0. Then the problem can be stated by formulae

$$F(Pg_i) = \sum_{i=1}^{NG} F_i(Pg_i)$$

&

$$\sum_{i=1}^{NG} Pg_i = P_D$$

The values of λ and Pg_i (i= 1, 2,……, NG) can be obtained directly using the formulae

$$\lambda = \frac{(P_D + \sum_{i=1}^{NG} \frac{b_i}{2 * a_i})}{\sum_{i=1}^{NG} \frac{1}{2 * a_i}}$$

&

$$Pg_i = \frac{\lambda - b_i}{2 * c_i}$$

4. Assume no generator has been fixed at either lower limit or at upper limit.
5. Set iteration counter, IT= 1.
6. Compute Pg_i (i= 1, 2,……, R) of generators which are not fixed at either upper or lower limits, using the following equation

$$Pg_i = \frac{\lambda(1 - B_{i0} - \sum_{\substack{j=1 \\ j \neq i}}^{NG} 2 * B_{ij} * Pg_j) - B_i}{2(a_i + \lambda B_{ii})}$$

7. Compute transmission loss using Eq.*(iii)*
8. Compute $\Delta P = P_D + P_L - \sum_{i=1}^{NG} Pg_i$
9. Check $\Delta P \leq \xi$, if 'yes then go to step 12
   Check IT≥ ITMAX, if 'yes then go to step 11. (it means program terminated without obtaining the required convergence.)
10. Update $\lambda^{new} = \lambda + \alpha|\Delta P|$, where α is the step size used to increase or decrease the value of λ in order to meet the step 8.
11. IT = IT + 1, $\lambda = \lambda^{new}$ and go to step 6 and repeat
12. Check the limits of generators, if no more violations then go to step 14, else fix as following :

    If $Pg_i < Pg_i^{\min}$ then $Pg_i = Pg_i^{\min}$

    If $Pg_i = Pg_i^{\max}$ then $Pg_i = Pg_i^{\max}$
13. Go to step 5
14. Compute optimal total cost from Eq.*(v)* and transmission loss from Eq. *(iii)*.
15. STOP

4. EXEMPLIFICATION AND DISCUSSION

4.1. Inputs

We are taking here a six generator system. The required generators data for the CEED problem is given in the Table 1. To perform the same problem B-coefficient matrix is also required and it is given in the Table 2.

Table 1. Generators data

Generator	***A_i (Rs/ MW^2hr)***	***B_i (Rs/ MWhr)***	***C_i (Rs/ hr)***	***D_i (Kg/ MW2hr)***	***E_i (Kg/ MWhr)***	***F_i (Kg/ hr)***	***Pgi_{max} (MW)***	***Pgi_{min} (MW)***
1	*0.00375*	*2*	*0*	*0.0126*	*-1.1*	*22.983*	*300*	*5*
2	*0.01750*	*1.75*	*0*	*0.0200*	*-0.1*	*25.313*	*80*	*4*
3	*0.06250*	*1*	*0*	*0.0270*	*-0.01*	*25.505*	*85*	*8*
4	*0.00834*	*3.25*	*0*	*0.0291*	*-0.005*	*24.9*	*75*	*3*
5	*0.02500*	*3*	*0*	*0.0290*	*-0.004*	*24.7*	*90*	*5*
6	*0.02500*	*3*	*0*	*0.0271*	*-0.0055*	*25.3*	*90*	*5*

Table 2. B-coefficient matrix for six generator system

0.0003	0.0001	0	-0.0001	0	-0.0001
0.0001	0.0001	0.0001	-0.0001	0	-0.0001
0	0.0001	0.0006	-0.0001	0	-0.0002
-0.0001	-0.0001	-0.0001	0.0023	0.0006	-0.0002
0	0	0	0.0006	0.0007	-0.0002
-0.0001	-0.0001	-0.0002	-0.0002	-0.0002	0.0006

4.2. Figures and Tables of Outputs (without Loss)

In this section, with the help of the input data (Table 1), we find out the following results (Table 3.) using Mat-Lab software [10]. Here we increase the load demand from 100 MW to 400 MW with an interval of 50 MW and find out the load sharing between the six generators for the corresponding load demands. Sharing of the loads between the all generators for different load is shown in the Table 3.

Table 3.Generator outputs & costs in different loads

Load (MW)	*Pg_1 (MW)*	*Pg_2 (MW)*	*Pg_3 (MW)*	*Pg_4 (MW)*	*Pg_5 (MW)*	*Pg_6 (MW)*	*Cost (Rs/h)*
100	*52.3783*	*20.6419*	*11.8654*	*4.8586*	*5.1066*	*5.1493*	*227.4*
150	*80.5859*	*27.4091*	*14.5679*	*9.7275*	*8.8099*	*8.8998*	*363.9*
200	*108.7935*	*34.1763*	*17.2704*	*14.5964*	*12.5132*	*12.6503*	*510.8*
250	*137.0010*	*40.9435*	*19.9730*	*19.4652*	*16.2165*	*16.4008*	*667.9*
300	*165.2086*	*47.7107*	*22.6755*	*24.3341*	*19.9198*	*20.1513*	*835.2*
350	*193.4162*	*54.4779*	*25.3780*	*29.2030*	*23.6231*	*23.9018*	*1012.9*
400	*221.6238*	*61.2451*	*28.0805*	*34.0718*	*27.3264*	*27.6524*	*1200.8*

Figure 1. shows total generation costs for different load demands graphically and the load shared by the each generator for different loads is graphically shown in the Figure 2.

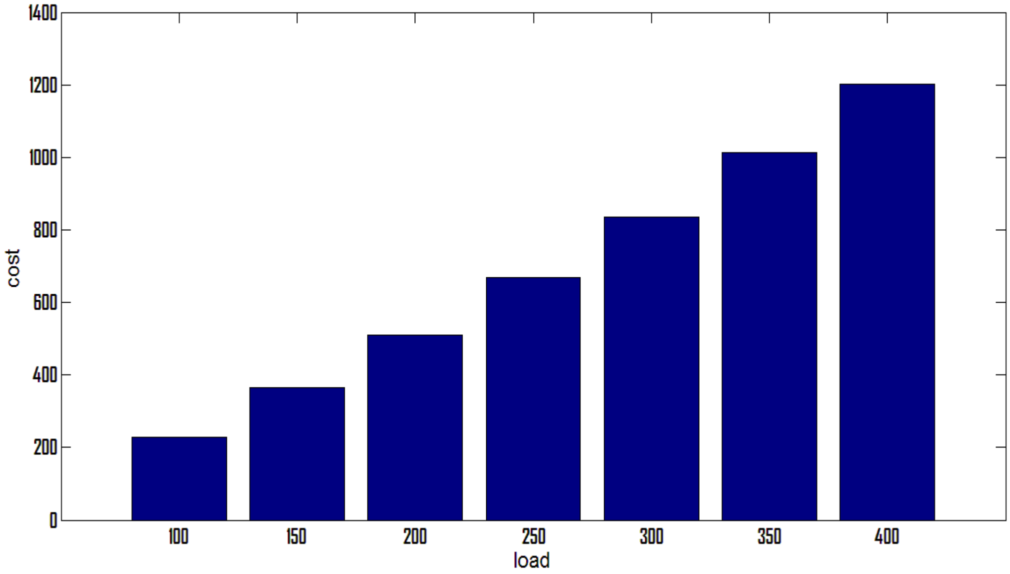

Figure 1. Load Demand v/s total cost

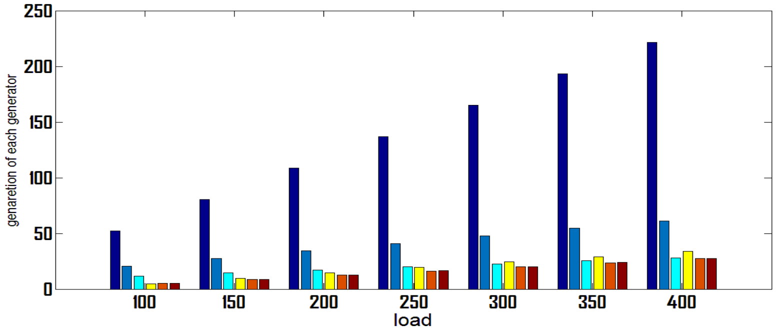

Figure 2. Load Demand v/s generation of each generator

4.3. Figures and Tables of Outputs (considering Loss)

In this section we find out the load sharing of generator s, but here we consider the transmission loss. For this time we have take B-coefficient matrix as an input from the Table 2. Here we also vary our load demand from 100 MW to 400 MW with an interval of 50 MW and get the generation values of each generator for the different load demands. These results are shown in the Table 4.

Table 4.Generator outputs, loss & costs in different loads

Load (MW)	***Pg_1 (MW)***	***Pg_2 (MW)***	***Pg_3 (MW)***	***Pg_4 (MW)***	***Pg_5 (MW)***	***Pg_6 (MW)***	***Loss (MW)***	***Cost (Rs/h)***
100	*16.7575*	*16.5460*	*16.7640*	*17.1010*	*16.8088*	*17.1724*	*1.1497*	*277*
150	*25.2728*	*24.8663*	*25.3083*	*25.8276*	*25.1521*	*26.1789*	*2.6060*	*449.1*
200	*33.8820*	*33.2199*	*33.9642*	*34.6749*	*33.4550*	*35.4720*	*4.6680*	*644.5*
250	*42.5875*	*41.6082*	*42.7340*	*43.6456*	*41.7182*	*45.0567*	*7.3503*	*864.3*
300	*51.3917*	*50.0329*	*51.6206*	*52.7428*	*49.9422*	*54.9382*	*10.6685*	*1109.3*
350	*60.2974*	*58.4957*	*60.6268*	*61.9694*	*58.1276*	*65.1222*	*14.6392*	*1380.5*
400	*69.3072*	*66.9985*	*69.7559*	*71.3287*	*66.2752*	*75.6144*	*19.2801*	*1679*

The variation of total generation costs for different load demands is shown in the Figure 3 and Figure 4 shows the load shared by the generators at different load demands. The variation of transmission loss at different load demands is also shown graphically in the Figure 5.

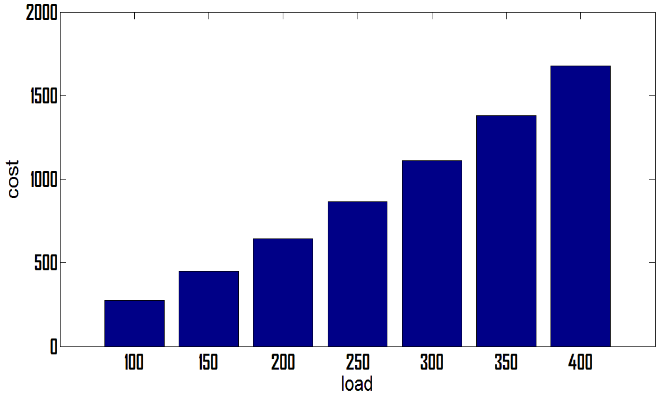

Figure 3. Load Demand v/s total cost

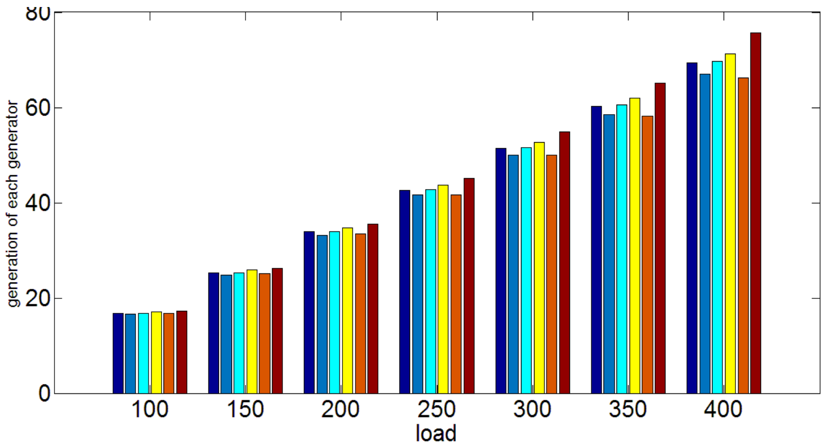

Figure 4. Load Demand v/s generation of each generator

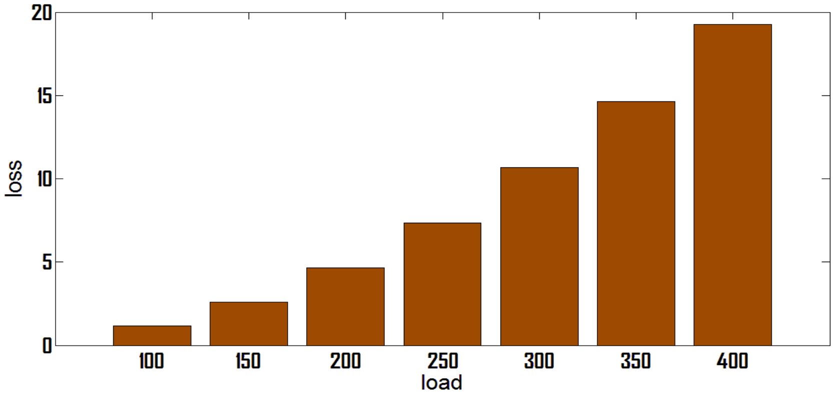

Figure 5. Load Demand v/s Loss

5. CONCLUSIONS

The demand of power in the world increases day by day. Due to this increase in power demand the emission rate of pollutant increases also. But we have to control this pollution problem and also meet the load demand economically. From this discussion we can conclude that, the balance between economy and emission can be achieved by the Combined Economic and Emission Dispatch, very efficiently.

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