Comparison of Different Economical Dispatch Algorithms for a Hybrid Power System

Syed Muhammad Faraz Ali, Sheikh Usman Uddin, Umer Hayat, Dr. Sajjad Haider Zaidi

Pakistan Navy Engineering College,
National University of Sciences and Technology, Karachi,
Pakistan
Email: Faraz_EE961@pnec.nust.edu.pk, Usman_EE970@pnec.nust.edu.pk, hayat.umer67@yahoo.com,
sajjadzaidi@pnec.nust.edu.pk

Abstract: With the increase in demand of electrical energy more burden increases on the generating stations. To reduce this burden on generating stations and to provide relief to consumer, Economical Dispatch Algorithms are used that works on principle to find the minimum cost of electrical unit. The paper look in the formulation of economical dispatch problem and how this problem formulation can be modified to include renewable sources. Comparison of two Economical Dispatch Algorithms which include Lambda Search method and Linear Programming are further discussed and their results are also concluded using MATLAB software.

Keywords: Economical Dispatch, Linear Programming, Lambda-Search.

I. INTRODUCTION

Energy play a vital role in the lives of human being. With the increase in electric demand more burden is put on the generation. This inflates the cost in electricity generation. However, people demands of cheap source of energy remains same. To cater all the issues certain method needs to be adopted to minimize the cost of generation. Wind and solar are cheap source of electricity but their reliability is inconsistent. Because these sources highly depend on the weather conditions. Thus, they cannot supply power to load on their own. However, they can be used to form a hybrid power system. In this way, wind and solar will always supply the maximum power that they can and the remaining power demand is fulfill by the conventional generators. The output of solar is DC and therefore it need an inverter before it is synchronized with gird. The output of wind is of variable frequency and it need control mechanism to adjust the frequency to the frequency of grid. The output of each system is connected to common AC bus. This common AC bus is a low voltage bus which supply power to LV load of a house or commercial center. When system is connected in this way, there arises the need to find the optimum point of the generator such that the overall cost of generation is minimum. To find this optimum point two optimization algorithms were test and the result were compared.

II. BACKGROUND

Economical dispatch is a mean by which power is generated by the sources such that the overall cost of generation is minimum while considering the operational limit of the system [1]. Generally, the economic dispatch problem can be solved using Langrange Multiplier. This method finds the value of the λ which is the cost of one more unit of power at the optimal point.

The method requires finding the cost function of the generator which is given by eq. 1. This cost function can be found using the Newton Divided difference quadratic interpolation. To find the cost function at least three mean sample of cost is required at the respective power output of the generator [2]. The unit of the cost function can be $/MW or any other depending which cost unit was considered in the samples.

$$C(P) = \gamma P^2 + \beta P + \alpha \quad (1)$$

where, β, γ are co-efficient of x and x^2 respectively. And a is constant. This a is the cost which incur on running a generator at no load. This means that this cost is unavoidable and will always incur whenever the generator is operating. Eq. 2 gives the operating limit that is associated with the generating source. This is the physical limitation of the generator. P^{min} is the minimum power that a generator can produce and P^{max} is the maximum power that a generator can provide.

$$P^{\min} \leq P \leq P^{\max} \tag{2}$$

Fig. 1 shows the cost curve for a generator. Here P^{min} and P^{max} shows the physical boundaries of generator given by Eq. 2 and the shape of the curve is due to the cost equation, i.e. Eq. 1 related to it. The shape of curve and limit of curve is different for each generator.

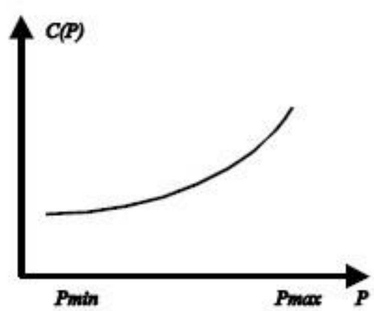


Fig. 1: Cost Curve

III. Problem Formulation

An economical dispatch involve optimizing the set of cost function associated with each generating source to minimize the total cost of production while considering all the constraints.

The problem can be formulated as follow [3]:
Minimize

$$\sum_{i=1}^{N} C(p_i) \tag{3}$$

subjected to,

$$\sum_{i=1}^{N} p_i = p_D \tag{4}$$

$$P_i^{\min} \leq P_i \leq P_i^{\max} \text{ where } i = 1, 2.....n \tag{5}$$

where P_D is the total power demand by the load and N is the number of generating source [4]. Eq. 4 is the equality constraint of the system and eq.5 is the inequality constraints of the system. For simplicity, power loss in transmission is omitted and the cost function is the second order polynomial function given by eq. 1.

IV. Renewable Resources

A. Solar

Solar energy the energy drawn from the radiation of the sun. Photo-electric effect is the common way to extract power from these solar irradiation. The output power of the solar cell is given by eq. 6 [5]

$$P_S = P_1 E_C [1 + P_2 (T_j - T_{jref})] \tag{6}$$

where, E_c is solar radiation, T_{jref} is reference temperature of panel, T_j is cell junction temperature, P_1 is characteristic dispersion of panel and P_2 is drift in panels temperature.

B. Wind

Wind energy extract power from the speed of wind and the air density of the surrounding. Wind turbines are commonly used to harness this source of energy. The output power of the wind turbine is given by eq.7 [5]

$$p_w = \frac{1}{2} C_p \rho \pi R_p^2 v_w^3 \tag{7}$$

where, C_p is aerodynamic co-efficient of turbine power, ρ is air density, R_p is turbine radius and V_w is wind speed.
The output power is proportional to the cube of the wind speed. The wind turbines are designed in such a way that the output power reach a steady state in case wind speed increases significantly to prevent mechanical overload. [5]

V. Proposed Procedure

At any time the primary source should be wind and solar since these are available in abundance and environmental friendly. However, these are intermittent sources and cannot independently supply power to the load. Therefore, dependency on the conventional generator becomes necessary. With conventional generators operating in parallel to the renewable sources the reliability of the system increases. The power output of conventional generators should be economically varied to fulfill the power demand by the load. In this way the cost of generation and emission of smoke in the atmosphere will be minimized. The following describe the procedure [3]:

1) Read the power available in all M renewable resources.
2) Read the power demand by the load.
3) Calculate P_D^t such that

$$p_D' = p_D - \sum_{j=1}^{M} p_j$$

where, P_D^t is the remaining power demand that is to be fulfill by conventional generators.

4) Minimize

subjected to

$$\sum_{i=1}^{N} p_i = p_D'$$

and

$$P_i^{\min} \leq P_i \leq P_i^{\max} \text{ where } i = 1, 2.....n$$

5) Find the solution with the minimum total cost.

VI. Optimization Algorithms

Optimization algorithms purpose is to optimize the objective function subjected to the constraints. Two algorithms were implemented. One of which is the lambda-search algorithm and the other is the linear programming algorithm.

A. Lambda-Search Algorithm

In lambda search algorithm, starting value of λ is assumed and the objective function is optimized through iterations. In this approach λ is the langrange multiplier constant. [6]

1) Pick a starting value of λ. This value is found usually by not considering the inequality constraints.

2) Check the value of P_A, P_B, P_C (where P_A, P_B, P_C are the output power of source A, B, C) such that

$$\frac{\partial C_A(P_A)}{\partial P_a} = \frac{\partial C_A(P_A)}{\partial P_a} = \frac{\partial C_A(P_A)}{\partial P_a} = \lambda$$

3) If any of these value exceeds the source limit then fix that value at that limit.

4) Calculate $P_{TOTAL} = P_A + P_B + P_C$

5) If $P_{TOTAL} > Load$ then increase λ

If $P_{TOTAL} < Load$ then decrease λ
If $P_{TOTAL} = Load$ then exit.

6) Go to step 2.

B. Linear Programming

In linear programming the cost curve is converted into piece-wise linear graph using k-breakpoints. The piece-wise linear approximation is the set of straight lines connected together. Fig. 2 shows the linear approximation with four breakpoints. [7]

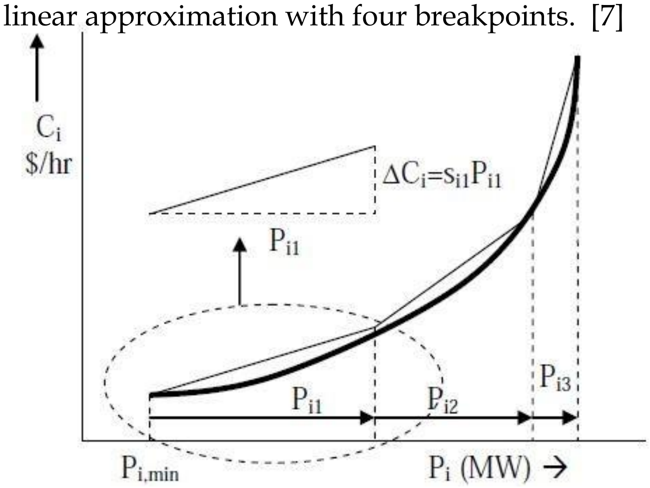


Fig. 2: Piece-wise Approximation of Cost Curve

After linear approximation, incremental cost of each line segment is given by $\Delta C_i = s_{ik}P_{ik}$. The approximation of the cost curve can be improve by using higher number of breakpoints. The approximate cost function is given by eq. 8.

$$K_i(P_{i1} \ldots P_{ik}) = C_i(P_{i.\min}) + s_{i1}P_{i1} + \ldots + s_{ik}P_{ik} \quad (8)$$

where, k is the number of breakpoints.

VII. Findings

A system with three conventional generators and a wind and solar power system is considered with capacity $P_{wind} = 40MW$ and $P_{solar} = 20MW$. The cost function and capacity of each generator is given as follows [8]:

1) $C(1) = 0.00533P_1^2 + 11.669P_1 + 213.1 \quad 50 < P_1 < 200$
2) $C(2) = 0.00889P_2^2 + 10.333P_2 + 200 \quad 37.5 < P_2 < 150$
3) $C(3) = 0.00741P_3^2 + 10.833P_3 + 240 \quad 45 < P_3 < 180$

The economic dispatch of the system is tested at a load of 200MW, 350MW and 500MW. Both algorithms were implemented on this system and the results were compared.

A. Linear Programming

The system stated above was optimized using linear programming with four breakpoints. The results are represented in table 1.

TABLE 1: Results on Linear Programming

Power Demand	P1	P2	P3
200 MW	50	45	45
350 MW	70	130	90
500 MW	150	149.999998	140.000001

Power on each Generator

Power Demand	C1	C2	C3	Total Cost
200 MW	809.875	682.987	742.49	2235.352
350 MW	1056.05	1693.531	1274.99	4024.569
500 MW	2083.375	1949.975	1901.856	5935.206

Cost of Power on each Generator

B. Lambda-Search

The same system was optimized using Lambda-Search algorithm and the results are represented in table 2

TABLE 2: Results on Lambda-search

Power Demand	P1	P2	P3
200 MW	50	45	45
350 MW	68.331	116.11	105.56
500 MW	135.86	150	154.14

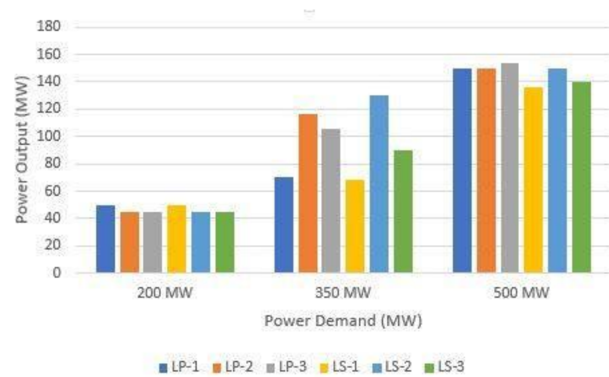
Power on each Generator

Power Demand	Cg1	Cg2	Cg3	Total Cost
200 MW	809.875	682.99	742.49	2235.355
350 MW	1035.3	1519.6	1466.1	4021
500 MW	1896.9	1950	2085.8	5932.7

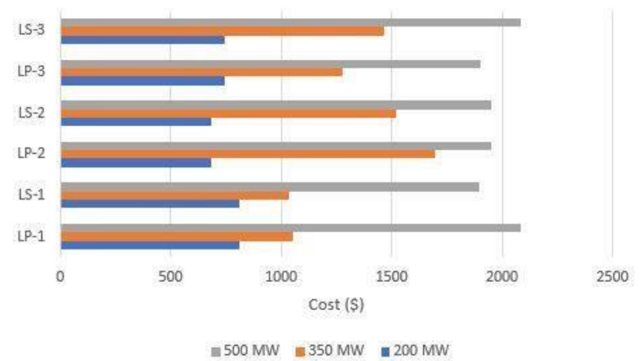
Cost of Power on each Generator

VIII. Results

Fig. 3 shows comparison on power and cost under each algorithm. Fig. 3a shows the comparison of power allocated all three generator under each algorithm. Power output of each generator is same for both algorithm at low power demand. However, as power demand increases, a difference in power output of each generator can be seen. The And fig. 3b gives the cost comparison of the cost of all three generators under each algorithm. As there is a difference in power output of each generator under each algorithm, there is a difference in cost of generation and overall cost of generation.



(a) Power on each algorithm



(b) Cost on each algorithm

Fig. 3: Comparison of each algorithm

IX. Conclusion

By comparing the results presented in the table 1 and 2 it can be concluded that linear programming algorithm rely more on the generator 1 as the power demand of the load increases. For a lesser power demand the output power of all three generators are same and so does the total cost. But as the power demand increases linear programming rely more on generator 1. The result of this is that total cost of generation is slightly more when linear programming was considered for higher power demand.

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