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Economic Load Dispatch of a Three Unit Thermal System : Using Both Analytical Method and Fuzzy Logic

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***Abstract*— This paper gives a theoretical analysis of the economic load dispatch problem by taking a three unit thermal system as the reference. Load allocation to each unit is determined using analytical method keeping in mind that it serves the total system load and satisfies the generation constraints. A MATLAB program is developed which gives the load allocation as output when the system load is varied step by step. Results are shown with the help of both tables and graphs. In the second phase system is again analyzed using a fuzzy controller and a comparative analysis is done in terms of the fuel costs obtained from conventional method and the fuzzy controller. The whole analysis is done without considering the transmission losses.**

Keywords—Load, Demad, Lambda, Fuzzy Controller, Membership Function, Fuel Cost

I. INTRODUCTION

Economic Load Dispatch (ELD) problem is one of the major concerns for power engineers as it is directly related to the reliability, stability and economy of the system. The prime concern of ELD scheme is to allocate the total system load among all the generators of the system in such a way that the fuel cost is minimized and at the same time the generation constraints are also satisfied.

The total cost of generation can be divided into two parts i.e. fixed cost and variable cost. The *fixed cost* comprises largely of the capital investment and some other miscellaneous expenses which do not have any relation with the load demand or the generator loadings. The variable cost mainly comprises of the generator loadings, system losses and purchase or sale of power.

The cost minimization using ELD scheme is thereby refers only to the variable cost. The fixed cost is indifferent of the system generation or load demand.

II. THE INCREMENTAL FUEL COST

The incremental fuel cost, mostly referred to as lambda(λ) is one of the key terms in economic load dispatch. It is the minimum value of the operating cost that is obtained after equalizing all the partial derivatives of the cost functions of all the plants and also satisfying the load demand.

$$\lambda = dCi/dPi, \qquad i=1,2,\ldots\ldots n$$

Where Ci is the cost function of the ith unit, Pi is the generation of the ith unit and n is the total number of units.

III CONSTRAINTS OF ECONOMIC DISPATCH

The first constraint is the equality constraint i.e. the total generation must be equal to the total system load provided losses are neglected.

$$\sum Pi = Pload, \quad i=1,2,\ldots\ldots n$$

The second constraint is the inequality constraint. It ensures that the load allocated to each generator lies between the minimum and maximum limits of generation of that particular unit.

$$Pimin \leq Pi \leq Pimax$$

IV SYSTEM UNDER INVESTIGATION

The system considered here is a three unit thermal system whose cost functions and constraints are as given below:

Unit1:

$$C1 = 300 + 1.6P1 + 0.005P1^2 \quad Rs/MW$$
$$80 \leq P1 \leq 250$$

Unit2:

$$C2 = 250 + 2.02P2 + 0.001P2^2 \quad Rs/MW$$
$$300 \leq P1 \leq 700$$

Unit3:

$$C3 = 160 + 2.03P3 + 0.025P3^2 \quad Rs/MW$$
$$60 \leq P1 \leq 550$$

The system is solved using analytical method with the help of a MATLAB program which takes load demand as the input and gives out power generation as the output for all the three units while satisfying all the constraints mentioned earlier.

The algorithm for analytical solution is mentioned below:

step1: Start
step2: Input the system load demand
step3: Calculate P1, P2, P3, λ
step4: Check if any of the generation constraints are violated. If they are within limit then go to step6
step5: If limit is violated for the ith unit then fix it at the margin value i.e. Pi=Pmax and Pload=Pload-Pi
step6: Again reschedule the remaining units with the new load demand.
step6: Display P1, P2, P3, λ
step7: Stop

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V ANALYTICAL SOLUTION METHOD

Using the analytical method load allocations to the units have, incremental fuel cost and total fuel cost been found for different values of load demand(Pd) as input which can be observed from the following table. It is observed that on increasing the load, both incremental cost and fuel cost rises and the pattern has been shown with graphs. All the graphs show an increasing pattern.

TABLE I: RESULTS OF ANALYTICAL METHOD

Pd	P1	P2	P3	λ	FC(total)
450	100	290	60	2.6	1801.7
480	105	315	60	2.65	1880.45
500	108.3	331.67	60	2.68	1933.78
550	116.67	373.33	60	2.76	2070.03
600	125	415	60	2.85	2210.45
650	133	456	60	2.93	2355.03
700	141	498	60	3.01	2503.78
720	145	515	60	3.05	2564.45
750	150	540	60	3.10	2656.7
780	155	565	60	3.15	2750.45
800	158	581	60	3.18	2813.78
850	166.67	623	60	3.26	2975

The different responses obtained are as shown below:

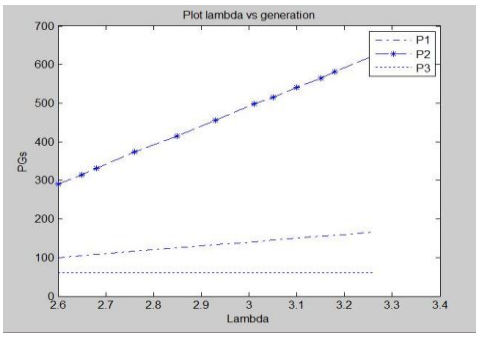

Fig1: Generation vs. incremental cost curve for 3 units

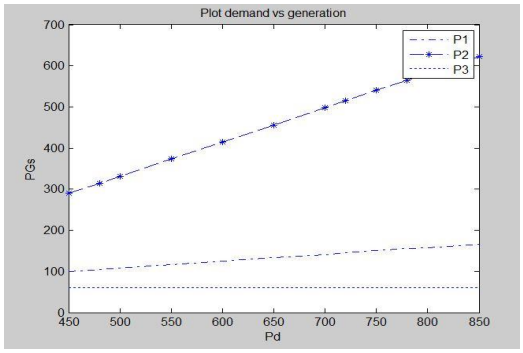

Fig2: Generation vs. load demand curve for 3 units

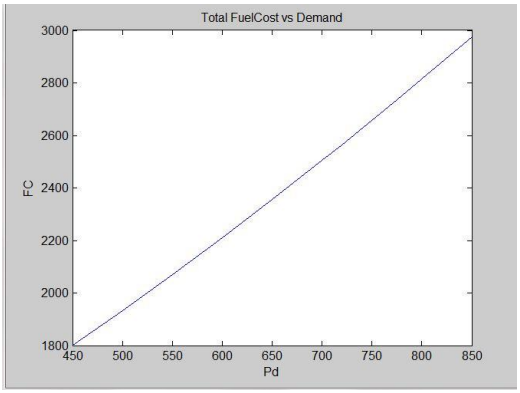

Fig3: Total fuel cost vs. load demand curve for 3 units

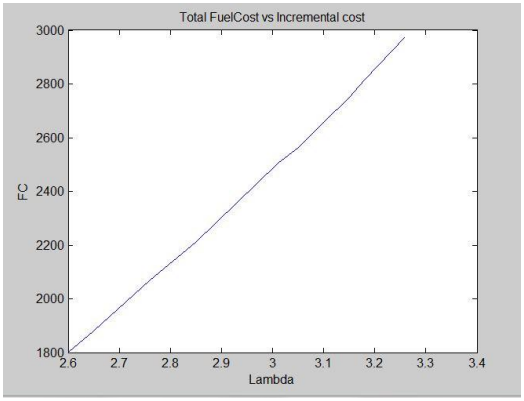

Fig4: Total fuel cost vs. incremental cost curve for 3 units

V IMPLEMENTATION OF FUZZY LOGIC CONTROLLER

The fuzzy logic controller provides an alternate way to solve the economic dispatch problem. The fuzzy controller implemented here is a two input one output system. The designing and tuning of the controller is done manually on the basis of understanding the behavior of the output in response to the change of input quantities. The input quantities are demand Pd and incremental cost λ. The output quantity is power generation of respective units. Three separate but similar type of controllers are used for the three units. The input output relation is given by the following rule table:

TABLE II: RULE TABLE FOR P1, P2, P3

Pd /λ	L	M	H
L	L	L	L
M	L	L	L
H	M	M	M

The terms L, M, H stands for Low, Medium and High respectively. Hence the rules will be depicted as: 'If Pd is Low and λ is Low then P is Low". The Membership functions for the Pd, λ and P1 are shown below. Triangular membership functions are used. For defuzzification, Centroid method has been used.

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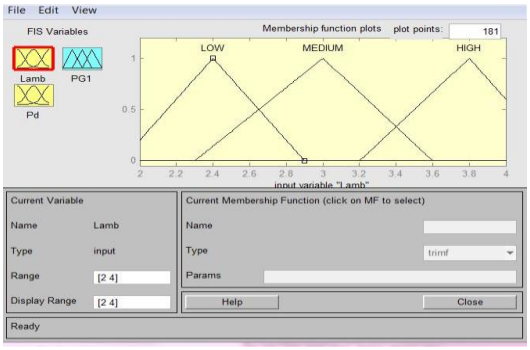

Fig 5: Membership function for λ

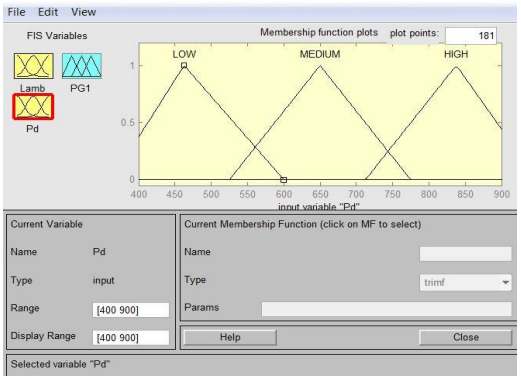

Fig 6: Membership function for Pd

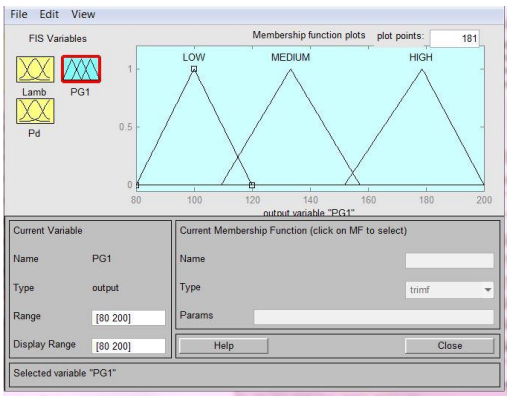

Fig 7: Membership function for P1

VI RESPONSES OF FUZZY LOGIC CONTROLLER

The following table lists out the generation scheduling given by the fuzzy logic controller in response to a wide variation of system load and also gives a comparison between the total fuel costs between analytical solution method and fuzzy controller method.

TABLE III: FUZZY CONTROLLER OUTPUT

Pd	λ	Fuel Cost (Analytical)	Fuel Cost (Fuzzy)
450	2.6	1801.7	2750
480	2.65	1880.45	2750
500	2.68	1933.78	2750
550	2.76	2070.03	2760
600	2.85	2210.45	2750
650	2.93	2355.03	2750.05
700	3.01	2503.78	2750
720	3.05	2564.45	2823.6
750	3.10	2656.7	3035.6
780	3.15	2750.45	3180.9
800	3.18	2813.78	3170.7
850	3.26	2975	3409.8

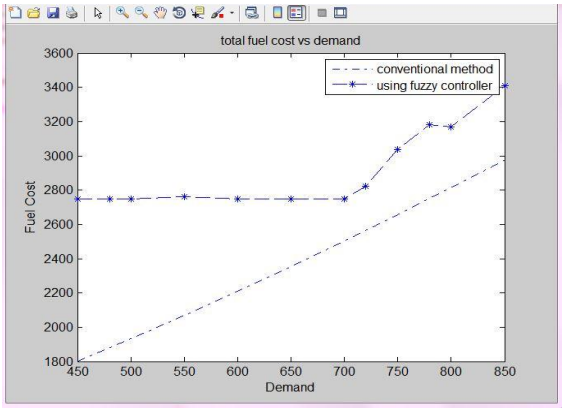

Fig 8: Comparison Between Fuel Costs

V CONCLUSION

This paper finally does a comparison between the economic load dispatch solution with analytical method and using a fuzzy controller. In Fig 8, the cost comparison curve is shown. By adjusting the MF's of the input and output quantities it was possible to bring down the fuel cost significantly but doing it leads to mismatch of the power equation. Hereby we can conclude that the analytical solution is showing better result in comparison to fuzzy method.

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