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Fuzzy Dynamic Programming Approach Based Economic Load Dispatch of Thermal Power Generating Stations

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Abstract—In India maximum power is generated from Thermal Generating Power Stations. Hence, it is necessary to reduce the generation cost. The discussion is carried out in view of the money saving, computational speed up and expandability which can be achieved by using Fuzzy logic Controller. This Paper shows a use of the Fuzzy Logic to the issues of Unit Commitment and Load Scheduling with specified goal to discover generation scheduling to such an extent that the total generation cost can be optimum. In this paper as case study, Fuzzy dynamic programming based Economic Load Dispatch technique is proposed, implemented and tested by using MATLAB Environment to demonstrate the feasibility and advantages of using Fuzzy Logic Controller in Power System applications. Favourable position of this strategy is the capacity to enhance over a more prominent assortment of working conditions. The experimental results prove that the proposed method provides feasible solution with significant saving sandaled for real-time operations.

Keywords: Unit Commitment, Load scheduling, Dynamic Programming, fuzzy Logic, Optimization, MATLAB/SIMULINK.

1.INTRODUCTION

Due to the nature of changing technology, unit commitment is also undergoing a change in its solution method. This is because there must be an efficient method to commit the generators to meet the load. Many methods have been introduced to solve unit commitment. Even if the methods have advantages, most of the methods suffer from local convergence and curse of dimensionality. While Scheduling the operation of the generating units at minimum operating cost at the same time fulfilling the equality and inequality limits is the optimization crisis involved in commitment of the units. The high dimensionality and combinatorial nature of the unit commitment problem curtails the attempts to develop any rigorous mathematical optimization method capable of solving the whole problem for any real-size system. For both deterministic and stochastic loads the unit commitment problem is applicable. The deterministic approach provides us definite and unique conclusions. However the faithful results are not obtained for stochastic loads. Nevertheless the constraints are changed into controlling constraints in stochastic models and then by any of the usual algorithms the formulation can be worked out. In state enumeration method the UC problem is solved by detailing all probable amalgamations of the generating units and then the combination that gives the smallest amount of the cost of operation is selected as the best possible solution [1]. While considering the priority list method for the committing the units, replication time and memory are saved, and it can also be pertained in a genuine power system. In contrast, the priority list method has shortcomings that consequence into suboptimal solutions since it won't considereach and every one of the possible combinations of generation[3].Dynamic programming is the one of the methodologies which gives optimal solution. To provide eminence solutions to the UC problem numerous solution approaches are proposed. These include autocratic and hypothetical search approaches [4]. Autocratic approaches include the Priority List method [5], Dynamic Programming [6], Lagrangian Relaxation and the Branch and Bound[6] methods. Even though the autocratic methods are simple and fast, they suffer from mathematical convergence and wayout eminence problems. This paper provides a detailed analysis of the unit commitment problem solution using Dynamic Programming method, major contribution is determination of UC schedule with attention towards what is known as system voltage security. The attempt is first of its kind in UC computation. Given the present trend of everincreasing load demand on power systems, its elements are operated in anoverloaded and stressed environment owing to the comparatively slow infrastructure developments. As a consequence, bus voltages go below operating limits endangering normal system operation. These demands a voltage secure UC schedule for satisfactory system operation. In the thesis, system voltage security is added as an additional constraint in the OPF evaluation using an indicator called global L-index. It provides a good measure of the distance of a given system operating state from the collapse point. Experimentations are carried employing L-index and relaxing the hard voltage limits on load buses to show the effectiveness. By selecting a desired measure of L-index in feasible range allows the committed generators and the system to operate far enough from the collapse point ensuring secure operation. Section -2 presents problem formulation. Section-3 presents problem solution using DP algorithm. Section-4 gives implementation of developed algorithm on IEEE-14-bus system and section-5 gives conclusion.

2.CONCEPT OF FUZZY LOGIC

For implementation of Fuzzy Logic Based Economic Load Dispatch (FLBELD) is executed in the following process and is explained in a brief as follows.

1. Preprocessing
2. Fuzzification
3.Rule-based creation
4. Fuzzy inference mechanism
5. Defuzzification

In preprocessing block, ranges are mentioned for all inputs and outputs which show the relevant positions of the controlled process i.e., identifying the variables (Inputs, States and Outputs) of the plant.Selection of fuzzy control variables depends uponnatureof power system to operate anygenerator uniteconomicallyand to distributetheloadoneachgeneratorunitFuzzificationist heprocessofconvertingacrispinputvariable into their corresponding fuzzy variables. In other words it can call the Fuzzification as the process of assigning the membership functions to input as well as output variables each of the FLBELD input and output signals have number of linguistic variables and each linguistic variable is associated with one membership function. The number of linguistic variables varies depending on the application. Depending upon the problem to be solved, rules are formulated using Input and Output variables and those are stored in rule base of a fuzzy the measurements of Input variables of fuzzy controller are properly combined with the relevant fuzzy information rules to make inferences regarding the output variables. Here, rules are formulated using IF, AND THEN Rule format. Defuzzification means, theprocessofconversion values.

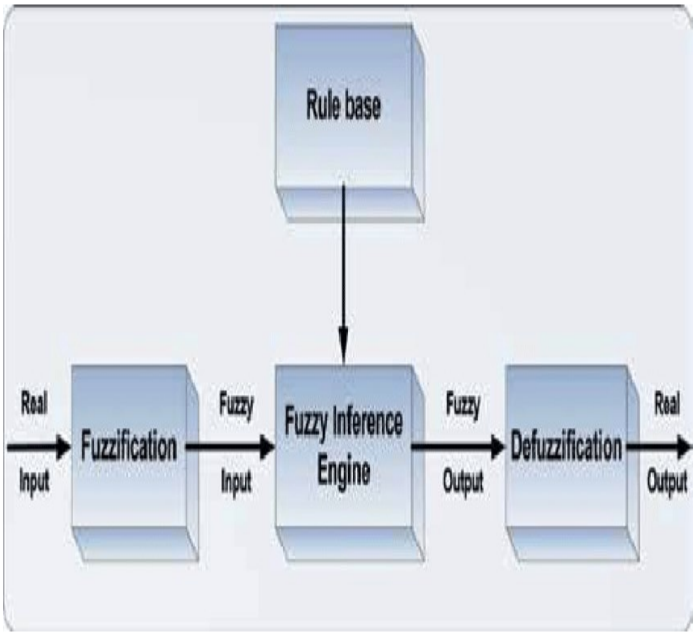

Fig 1: Block Diagram of Fuzzy Logic Controller

That meanstheresultfromrule base and Fuzzy Inference Engine is a fuzzy value which is converted into a single value. In this case, a Centroid Defuzzification method is selected for converting each input obtain from the inference engine which is expressed in terms of fuzzy set. Finally this fuzzy value is converted into the crisp value. With this analysis, in this paper, consider four thermal generating units with parameters listed in theTable1and the load demand of the Thermal Power Generating Station for a particular Day is given in the appendix. The Load demand on the power system is not constant and hence it varies on the station from time to time. Hence the generators in Thermal Power Generating Stations

Table1: Generating Unit Parameters ForThe Sample System

Generator	Capacity (MW)	Cost Curve Parameters

Number	Min	Max	A(Rs/MW)^2	B(Rs/MW)
1	1.0	12	0.77	23.5
2	1.0	12	1.60	26.5
3	1.0	12	2.00	30.0

Table 2: Generating Unit Parameters for the MATLAB Simulation

Generating units	Capacity (MW)		Cost Curve parameters	
	Min	Max	A(RS/MW)	B(RS/MW)
Gen 1	50	300	0.02	2.5
Gen 2	30	250	0.017	2.0
Gen 3	20	200	0.015	1.8

3.PROBLEM FORMULATION

The intent of the UC problem is minimizing the total operating cost in order to meet the demand. It is assumed that the production cost, for unit i in a given time interval is a quadratic function of the output power of the generator

$$F(P_{si})=a_iP_{gi}^2+b_iP_{gi}+C_i$$

Where ai, bi, ci are the corresponding unit's cost coefficients. For the scheduling period T the sum of the production cost's obtained from the corresponding committed units gives the total operating cost

$$OC_{total}=\sum_{t=1}^{T}\sum_{I=1}^{NG}[U_i^tFP_{gi}+U_i^t(1-U_i^{t-1})STC_i+U_i^{t-1}(1-U_i^t)STb_i]$$

Where, is a binary variable to signify the on/off status of the unit i at time t. The objective is to lessen subjected to a number of constraints. The assumption is that the total system demand is supplied by all the generators connected to the same bus.

The following constraints are included:

a. Power Balance Constraint The total generated power and load at corresponding hours must be equal.

$$\sum_{i=1}^{ng}P_{gi}=P_d$$

b. Power Generation Limits The generated power of a unit should be within its minimum and maximum power limits.

$$P_{gmin}\leq P_{gi}\leq P_{gimax}$$

4.SOLUTION TO THE PROBLEM

The basis for Dynamic Programming (DP) is the theory of optimality elucidated by Bellman in 1957. This method can be used to explain crises in which many chronological conclusions are to be taken in defining the optimum operation of a system, which consists of distinct number of stages. The searching may be in forward or backward direction. Within a time period the combinations of units are known as the states. In Forward Dynamic programming an excellent economic schedule is obtained by commencing at the preliminary stage amassing the total costs, then retracing from the combination of least accumulated cost starting at the last stage and finishing at the initial stage. The stages of the DP problem are the periods of the study horizon. Each stage usually corresponds to one hour of operation i.e.,combinations of units steps forward one hour at a time, and arrangements of the units that are to be scheduled are stored for each hour. Finally, by back pedaling from the arrangement with smallest amount of total cost at thefinal hour throughout the finest path tothe arrangement at the prelimnary hour the most economical schedule is acquired. The estimation of each and every combination is not convenient evidently. Additionally, several of the combinations are prohibited due to insufficient existing capacity.

The step by step procedure for dynamic programming approach is as follows:

1) Start randomly by considering any two units.

2) Assemble the collective output of the two units in the form of discrete load levels.

3) Determine the most economical combination of the two units for all the load levels. It is to be observed that at each load level, the economic operation may be to run either a unit or both units with a certain load sharing between the two units.

4) Obtain the more cost-effective cost curve for the two units in discrete form and it can be treated as cost curve of single equivalent unit.

5) Add the third unit and the cost curve for the combination of three units is obtained by repeating the procedure.

6) Unless all the existing units are considered the procedure is repeated.

The benefit of this method is that having the best way of running N units, it is simple to find out the best way for running N + 1 units. The DP approach is based on the subsequent recurring equation.

$$F_M(P)=\min [F_M (Q)+F_{M-1}(P-Q)]$$

Where $F_m(P)$ is the minimum cost in Rs/hr of generation of P MW by M generating units. $F_m(Q)$ is the cost of generation of Q MW by Mth unit.F_{m-1}(P-Q) is the minimum cost of generation of (P-Q) MW by the remaining (M -1) units. In its elemental form, the dynamic programming algorithm for unit commitment problem inspects every possible state in every interval. The dimensionality of the problem is significantly declined which is the chief advantage of this technique. The postulations for structuring the step by step procedure for dynamic programming method are tracked below.

1) A state consists of a group of units with only precise units in service at a time and the remaining off-line.

2) While the unit is in off state the start-up cost of a unit is independent of the time specifically it remains fixed.

3) For closing the unit there will be no cost involved.

4) The order of precedence is firm and a small quantity of power must be in operation in each interval.

The flow chart for Dynamic Programming method is shown in Fig. 2

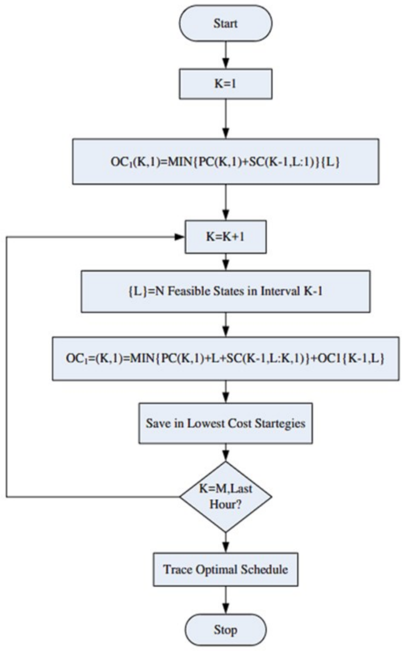

Fig.2Shows the Flow chart of Dynamic Programming

5.RESULTS AND DISCUSSIONS

The proposed method is considered optimal load scheduling problem for scheduling thermal generating units to minimize the operating costs.A MATLABPROGRAM is developed for optimal load scheduling of the plant by using Dynamic Programming Method and Fuzzy Logic Controller is implemented in order to get optimal load scheduling of the plant. When the Load on the Generating Station is lightly loaded or fully loaded, thereis no difference between

the Conventional method of load sharing and propose method shows in Table.3

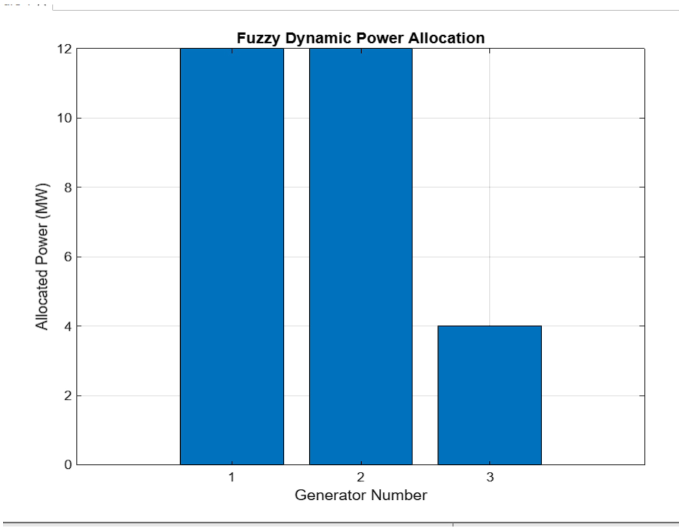

Fig.3Fuzzy Dynamic Power Allocation

Table 3: Unit Commitment table for Sample System of

Load Range	Generator Number		
	1	2	3
10	10	0	0
28	12	12	4
36	12	12	12

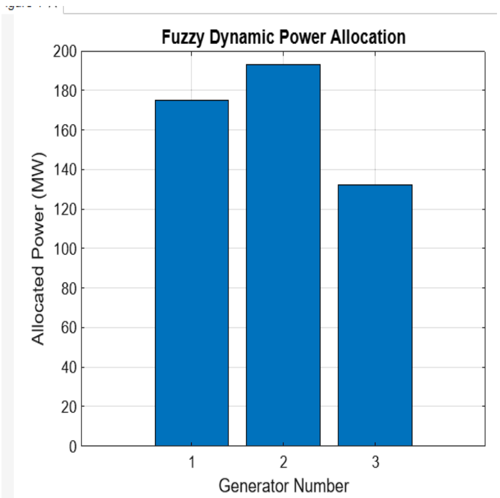

Fig 4: Fuzzy Dynamic Power Allocation for MATLAB Simulation

Table-4: Outputs of MATLAB Simulation

S NO	Total Load in MW	Gen 1	Gen 2	Gen 3
1	1	1	-	-
2	75	75	-	-
3	100	100	-	-
4	300	175	125	-
5	350	175	140	35
6	400	175	140	85
7	450	175	192.9833	82.0167
8	500	175	192.9833	132.0167
9	550	175	192.9833	152.6857
10	600	300	250	50

6.CONCLUSIONS

Manual computation of load scheduling problem involves much more time and as such same time, the computation time increases with the increase in the number of units in theplant.But,theprogrammingmethodminimizesthecomputationtimealotandthetimeremainsconsiderablyconstantirrespectiveof number of units in the plant. Optimal load scheduling obtained by using Fuzzy Logic Controller provides better results compared to conventional method and Implementation of Fuzzy Logic results in the reduction of generating cost by a large amount. The proposed method can be extended to N –number of units of a Thermal Power Generating Station

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