UTILIZATION OF DYNAMIC PROGRAMMING METHOD FOR THE ARRANGEMENT OF UNIT COMMITMENT PROBLEM FOR OPTIMAL POWER FLOW FOR IEEE 26 BUS SYSTEM

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Abstract: An efficient and economic power generation has always held an important position in the electric power industry. Operational Economics involving power generation and delivery can be subdivided as – Economic Load Dispatch and Unit Commitment. The main objective of Economic Load Dispatch is the process of allocating the required load demand between the available generation units such that the cost of generation is minimum. Furthermore, Unit Commitment is an optimization technique that determines the units that are feasible and should be committed over a period of time to serve the load demand at minimum operating cost, satisfying all plant and system constraints. The test system is also analyzed under 3-phase symmetrical fault with its effect on generation. There exist various UC scheduling algorithms among which my research work is based on Dynamic Programming method which is robust in nature, takes less computation time and includes plant constraints like start-up cost, fuel cost etc. The performance of Dynamic Programming method is further enhanced by adopting Sequential Combination – DP method which involves reduction in the dimensionality state of the solution space and faster computation speed. The effectiveness of the proposed technique is investigated on 26-Bus Multi Machine system consisting of six thermal generating units and is carried out using MATLAB.
Keywords: Unit commitment, Dynamic Programming, Fuel cost, Voltage stability, Economic dispatch.

I. 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 consider each 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 way out 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 ever increasing load demand on power systems, its elements are operated in an overloaded 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.

II. FORMULATION OF UNIT COMMITMENT PROBLEM

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 Where a i , b i , c i 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 [10] 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

b. Power Generation Limits

The total generated power of a unit should be within its minimum and maximum power limits.

III. PROBLEM SOLUTION USING DYNAMIC PROGRAMMING METHOD

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 [7, 8]. 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 backpedaling from the arrangement with smallest amount of total cost at the final hour throughout the finest path to the arrangement at the preliminary hour the most economical schedule is acquired [7]. 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. Where F M (P) is the minimum cost in Rs./hr of generation of P MW by M generating units. FM(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. 1

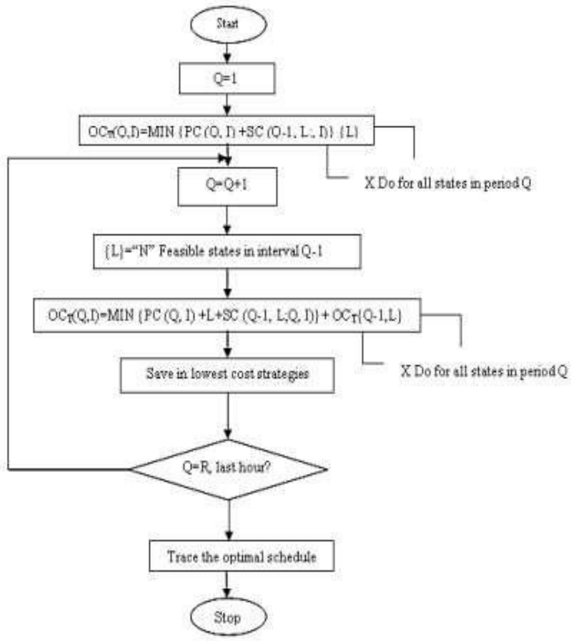
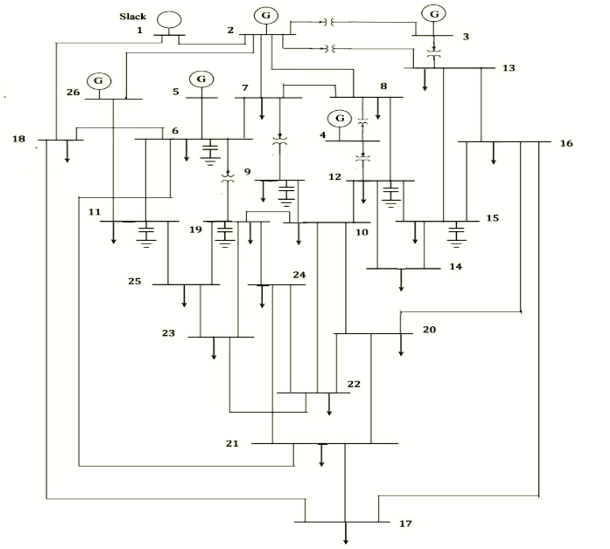


Fig.1 Flow chart for Dynamic Programming method

The major competent cost-effective combination of units can be well determined using the recursive relation. Considerable computational saving can be attained by using this method. It is not obligatory to solve the co-ordination equations. The total figure of units accessible, their individual cost haracteristics and load cycle are supposed to be known. Only when the operations at the earlier stages are not affected by the decisions at the later stages this method is appropriate.

IV. TEST SYSTEM AND SIMULATION RESULTS

DESCRIPTION OF THE TEST SYSTEM



SELECTION OF OPTIMUM POWER FLOW METHOD

Number of Iterations

From Table 6.1.1 it shows that with increase in number of buses the number of iterations increases proportionally in case of Gauss-Seidal method and there is a slightincrease in number of iterations in Fast-Decoupled method. On the other hand, the number of iterations remains nearly constant in case of Newton-Raphson method. That's the reason why, Newton-Raphson method has faster convergence and is independent of the system size and can be applied to both small and large system. Whereas, Gauss-Seidal method is applicable to only smaller systems and Fast Decoupled to only large system. Shown in Fig.6.1.1. is the bar chart depicting the comparison of the iteration requirement of the algorithms for the three test system.

Table 6.1.1 Number of Iterations

Test System	Gauss Seidal	Newton Raphson	Fast Decoupled
IEEE 14	31	3	19
26-BUS	50	5	20
IEEE 30	53	5	26

EXECUTION TIME

As seen from Table 6.1.2, the time per iterations increases gradually within crease in number of buses for all algorithms. As Newton-Raphson method involves more number of steps per iteration and is complicated the execution time is more as compared to GAUSS-SEIDAL NEWTON-RAPHSON FAST DECOUPLED Gauss-Seidal& Fast-Decoupled method. The time per iteration is least in case of Gauss-Seidal method. Shown in Fig.6.1.2. is the bar chart depicting the comparison of the execution time requirement of the algorithms for the three test system.

Table 6.1.2 Time per Iterations

TEST SYSTEM	GAUSS SEIDAL	NEWTON RAPHSON	FAST DECOUPLED
IEEE 14	0.00287	0.01766	0.0053684
26-BUS	0.00442	0.0244	0.0142
IEEE 30	0.0045283	0.0256	0.0144

POWER MISMATCH

The meeting normal for the power stream strategy is best portrayed by plotting the greatest power befuddle for the test frameworks. From Table 6.1.3 it has been watched that the power confound is minimum for Newton-Raphson calculation which demonstrates its speedier joining rate and exact exactness. Appeared in Fig.6.1.3 is the bar diagram portraying the correlation ofthe greatest power crisscross of the calculations for the three test framework.

Table 6.1.3 Maximum Power Mismatch

TEST SYSTEM	GAUSS SEIDAL	NEWTON RAPHSON	FAST DECOUPLED
IEEE 14	0.000886851	0.000687269	0.000983111
26-BUS	0.000969636	0.000201267	0.000972024
IEEE 30	0.000792111	0.000414075	0.000895755

ECONOMIC LOAD DISPATCH USING NEWTON-RAPHSON POWER FLOW METHOD

Economic Load Dispatch using Newton-Raphson method has been performed on 26-Bus multimachine system with the aim of minimizing loss and generation cost. Table 6.2.1 shows Economic Load Dispatch without losses where the total power generation is equal to the totalload demand. Whereas, Table 6.2.2 shows Economic Load Dispatch including losses where the total power generation is equal to total load demand and losses.

Table 6.2.1 Economic Load Dispatch without Losses

S.NO	LOAD (MW)	P_1 (MW)	P_2 (MW)	P_3 (MW)	P_4 (MW)	P_5 (MW)	P_{26} (MW)	λ (Rs/MWh)	COST (Rs/h)
1.	400	120	50	80	50	50	50	546.84	328129.2
2.	650	294.767	59.3023	145.9302	50	50	50	700.984	487389.24
3.	900	367.6636	113.0153	202.6272	63.7383	102.9556	50	765.279	671295.9
4.	1100	414.7511	147.7113	239.2508	100.3619	144.1572	53.7677	806.810	828576.40
5.	1263	446.7073	171.258	264.1057	125.2168	172.1189	83.5935	834.995	962383.61
6.	1400	473.5662	191.0488	284.9959	146.107	195.6204	108.6618	858.685	1078400.78

Table 6.2.2 Economic Load Dispatch with Losses

S.NO	LOAD (MW)	P_1 (MW)	P_2 (MW)	P_3 (MW)	P_4 (MW)	P_5 (MW)	P_{26} (MW)	λ (Rs/MWh)	LOSS (MW)	COST (Rs/h)
1.	400	121.766	50	80	50	50	50	550.414	1.76656	329096.61
2.	650	296.3983	62.1403	145.4514	50	50	50	711.433	3.98995	490192.23
3.	900	367.011	114.3648	199.9791	72.5397	103.0251	50	776.775	6.91976	676640.58
4.	1100	413.84	148.9951	236.2406	110.5614	140.2704	59.7759	820.4058	9.69071	836485.11
5.	1263	447.5788	173.96	262.2593	137.8827	166.8980	86.7362	851.9997	12.3149	972782.54
6.	1400	479.333	197.8665	287.0348	150	190.5847	110.2701	882.1774	15.0896	1091425.36

UNIT COMMITMENT USING DYNAMIC PROGRAMMING METHOD

For appropriate booking of the attainable producing units, unit responsibility has been performedon 26-transport multi-machine framework comprising of six-warm units utilizing Dynamic Programming technique.

Fig.6.4.1 shows the load profile on 26-Bus multi-machine system consisting of six thermal unitsfor 24 hours in a day.

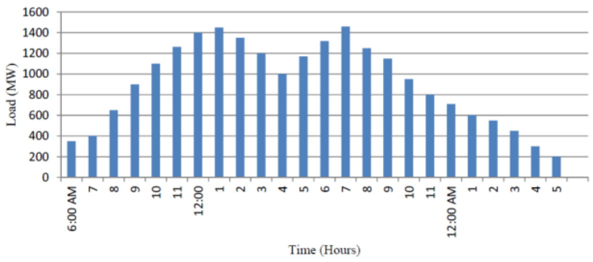


Fig. 6.4.1 Load Profile for 6-Unit Generating System

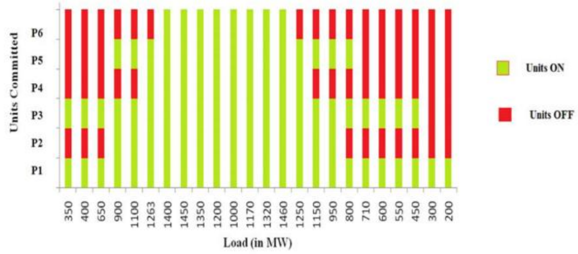


Fig.6.4.2 Feasible Units Committed for various Load Demand

The simulation using Dynamic Programming method on the test system is carried out and
analyzed using two different methods –
(1) Conventional Dynamic Programming method (C-DP)
(2) Sequential Combination Dynamic Programming method (SC-DP)

Table 6.4.1 Comparison of simulated result of Unit Commitment using Dynamic Programming Method

PARAMETERS	Conventional - DP	Sequential Combination - DP
Total Number of States	64	6
Computational Time (sec)	19.221	0.7798
Total Generation Cost (Rs)	1,65,03,451	1,65,48,042

Thus, the above simulation result reveals that SC-DP has many advantages over C-DP, the chief advantage being a reduction in the dimensionality of the possible solution space, i.e the total number of states accessed is reduced from 64 in complete enumeration to 6 in priority list scheme. Furthermore, the computation time of SC-DP is 0.7798 sec which when compared to C-DP with19.221 sec shows that SC-DP is around 95.94% faster and thus is the most efficient method.

V. CONCLUSION

For vitality preservation and monetary perspectives, designation of load request alongside appropriate planning of possible creating units is vital. This offers emerge to the idea of Optimal Load Dispatch with Unit Commitment utilizing Dynamic Programming strategy which has been talked about and explored for 26-transport multi-machine framework comprising of six warm creating units utilizing MATLAB. The accompanying conclusions have been drawn through the examination work and are exhibited beneath as takes after -
The Optimum Power Flow arrangement procedures comprising of Gauss-Seidal, Newton-Raphson and Fast-Decoupled technique has been talked about. Among these, Newton-Raphson strategy has developed to be the best Power Flow iterative technique because of its quicker meeting velocity and unwavering quality and accordingly has been utilized for doing Economic Load Dispatch for the considered framework. Economic Load Dispatch utilizing Newton-Raphson control stream technique has been done considering with or without misfortunes as contextual analysis. The recreation result uncovered that misfortunes and era cost are limited by the utilization of shunt capacitors that infuses receptive influence in the framework. The framework has been broke down for 3-stage symmetrical blame and its impact on era has been watched. Test cases demonstrates that the amid blame voltages, streams and era cost are enormously influenced by the framework unbalance and the blame impedance. The expansion of the blame impedance decreases the blame current and consequently the impact of the framework unbalance on amid blame voltages and current reduces. Bigger blame impedance values create blame streams like ostensible load ebbs and flows and accordingly the impact of these flaws as far as amid blame voltages and ebbs and flows can't be separate from ostensible operation conditions. Along these lines, it has been watched that the defective unbalance framework comes back to its enduring state typical condition at bigger blame impedance.
Economic control era has been accomplished through Unit Commitment utilizing Dynamic Programming technique which submits just the attainable producing units therefore limiting the aggregate era cost and sparing a great many rupees which has been seen in contrast with Economic Load Dispatch. The proposed calculation for tackling Unit Commitment issue has the favorable position that its down to earth in nature, fulfills all the framework imperatives and can be actualized for any size of the framework. The execution of Dynamic Programming strategy has been additionally upgraded by receiving Sequential Combination Dynamic Programming technique (SC-DP) which includes diminishment in the dimensionality condition of the arrangement space and speedier calculation speed when contrasted with Conventional Dynamic Programming strategy.

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