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SOLUTION OF UNIT COMMITMENT PROBLEM FOR OPTIMAL POWER FLOW FOR IEEE 26 BUS SYSTEM BY DYNAMIC PROGRAMMING METHOD

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Abstract: This paper presents a Dynamic programming based an algorithm to solve the Unit Commitment problem accounting voltage stability consideration and inequality constraints. In the present electricity environment, where power demands are in its peak, it has become very difficult for operators to fulfil the demand. There are many conventional and evolutionary programming techniques used for solving the unit commitment (UC) problem. Dynamic programming is conventional algorithm used to solve the deterministic problem. The developed algorithm has been implemented on IEEE-14 bus system. The results obtained from this technique was validated with the available techniques and outcome found satisfactory. The commitment in such a way that total cost of generation is reduced to minimum.
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

F(Pgi)=aiPgi2+biPgi+Ci (1)

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]

$$OC_{total} = \sum_{t=1}^{T} \sum_{i=1}^{NG} [U_i^t FP_{gi} + U_i^t (1 - U_i^{t-1}) STC_i + U_i^{t-1}(1 - U_i^t) STD_i] \quad (2)$$

Where, U_i^t 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:

Power Balance Constraint

The total generated power and load at corresponding hours must be equal

$$\sum_{i=1}^{ng} P_{gi} = P_d \qquad (3)$$

Power Generation Limits

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

$$P_{gimin} \leq P_{gi} \leq P_{gimax} \qquad (4)$$

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.

$$F_M(P) = \min[F_M(Q) + F_{M-1}(P - Q)] \qquad (5)$$

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.

- A state consists of a group of units with only precise units in service at a time and the remaining off-line.
- While the unit is in off state the start-up cost of a unit is independent of the time specifically it remains fixed.
- For closing the unit there will be no cost involved.
- 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

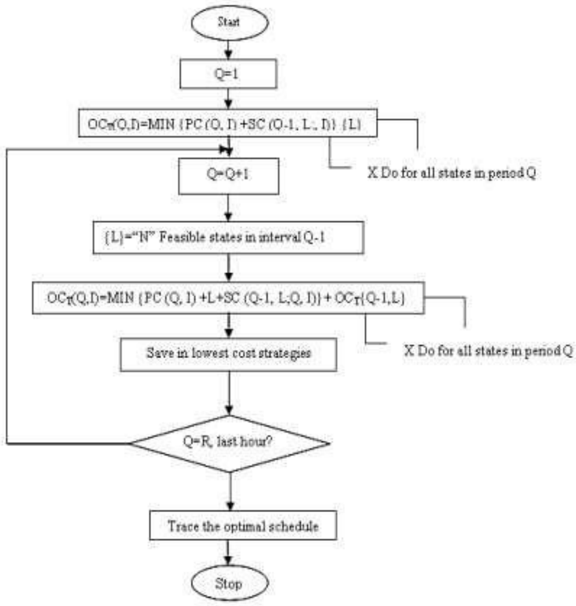
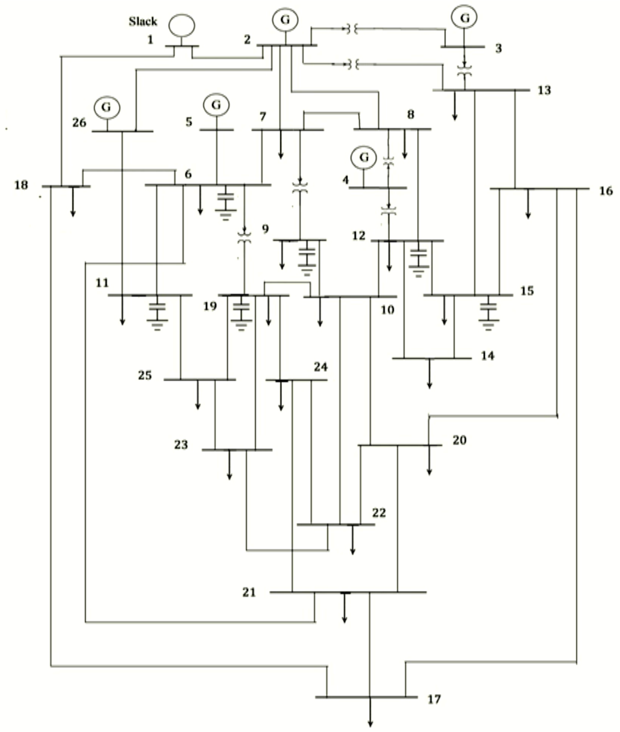


Fig.1 Flow chart for Dynamic Programming method

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 characteristics 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



The test system that has been considered here is the 26 – Bus multi machine system which consist of twenty six Buses, six generator and seven transformer. Shunt capacitor has been usedat bus 6, 9,11,12,15 and 19 respectively. Bus 1 has been considered as slack bus or swing bus or reference bus. All the parameters or values are taken in p.u. The Bus data, Line data, Generator real power limits and generator cost functions have been tabulated below.

Number of Iterations

From Table 4.1.1 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 slight increase 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.4.1.1. is the bar chart depicting the comparison of the iteration requirement of the algorithms for the three test system.

Table 4.1.1 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

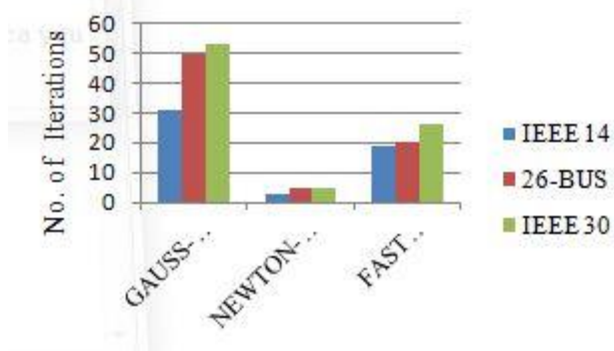


Fig.4.1.1 Comparison of Number of Iterations for the 3 test system

Execution Time

As seen from Table 4.1.2, the time per iterations increases gradually with increase 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& Fast-Decoupled method. The time per iteration is least in case of Gauss-Seidal method. Shown in Fig.4.1.2. is the bar chart depicting the comparison of the execution time requirement of the algorithms for the three test system.

Table 4.1.2 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

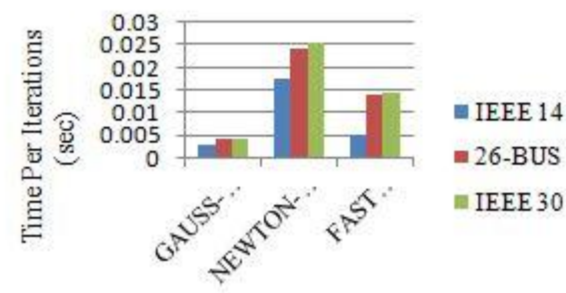


Fig.4.1.2 Comparison of Execution Time for the 3 test system

Power Mismatch

The convergence characteristic of the power flow method is best described by plotting the maximum power mismatch for the test systems. From Table 4.1.3 it has been observed that the power mismatch is least for Newton-Raphson algorithm which indicates its faster convergence rate and precise accuracy. Shown in Fig.4.1.3 is the bar chart depicting the comparison of the maximum power mismatch of the algorithms for the three test system.

Table 4.1.3 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

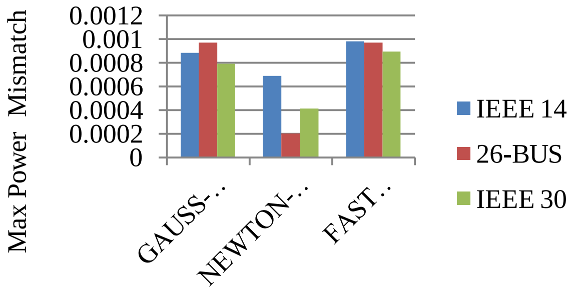


Fig.4.1.3 Comparison of Maximum Power Mismatch for the 3 test system

V. CONCLUSION

For energy conservation and economic aspects, allocation of load demand along with proper scheduling of feasible generating units is necessary. This gives arise to the concept of Optimal Load Dispatch with Unit Commitment using Dynamic Programming method which has been discussed and investigated for 26-bus multi-machine system consisting of six thermal generating units using MATLAB. The following conclusions have been drawn through the research work and are presented below as follows -

- The Optimum Power Flow solution techniques consisting of Gauss-Seidal, Newton-Raphson and Fast-Decoupled method has been discussed. Among these, Newton-Raphson method has emerged to be the best Power Flow iterative method due to its faster convergence speed and reliability and therefore has been used for carrying out Economic Load Dispatch for the considered system.
- Economic Load Dispatch using Newton-Raphson power flow method has been carried out considering with or without losses as case study. The simulation result revealed that losses and generation cost are minimized by the use of shunt capacitors that injects reactive power in the system.
- The system has been analyzed for 3-phase symmetrical fault and its effect on generation has been observed. Test cases shows that the during-fault voltages, currents and generation cost are greatly affected by the system unbalance and the fault impedance. The increase of the fault impedance reduces the fault current and therefore the effect of the system unbalance on during-fault voltages and current diminishes. Larger fault impedance values produce fault currents similar to nominal load currents and therefore the effect of these faults in terms of during-fault voltages and currents cannot be differentiate from nominal operation conditions. Therefore, it has been observed that the faulty unbalance system returns to its steady-state normal condition at larger fault impedance.
- Economic power generation has been achieved through Unit Commitment using Dynamic Programming method which commits only the feasible generating units thus minimizing the total generation cost and saving millions of rupees which has been observed in comparison to Economic Load Dispatch. The proposed algorithm for solving Unit Commitment problem has the advantage that its practical in nature, satisfies all the system constraints and can be implemented for any size of the system.

The performance of Dynamic Programming method has been further enhanced by adopting Sequential Combination Dynamic Programming method (SC-DP) which involves reduction in the dimensionality state of the solution space and faster computation speed when compared to Conventional Dynamic Programming method.

REFERENCES

[1] Sivanagaraju.S and Sreenivasan.G." Power system operation and control", Pearson education. 2009
[2] Padhy,N.P. Unit commitment -a bibliographical survey, IEEE Transactions on Power Systems, Vol 19, No. 2, 2004, pp.1196-120.
[3] Vijay Kumar Shukla, Bhupinder Singh and Preeti Khurana. Unit Commitment in Electrical Power System-A Literature Review, IEEE International Power Engineering and Optimization Conference (PEOCO2012), Melaka, Malaysia. June 2012
[4] Senjyu, T., Shimaukuro, K., Uezato, K., and Funabashi, T. " A fast technique for unit commitment problem by extended priority list", IEEE Transactions on Power Systems, Vol 18, No. 2, may 2003 pp.882-888.
[5] Senjyu, T., Miyagi, T., Saber, A. Y., Urasaki, N., and Funabashi, T. ,"Emerging solution of large-scale unit commitment problem by stochastic priority list", Elect. Power Syst. Res., Vol 76, Mar. 2006 pp. 283–292.
[6] Wood, A. J and Wollenberg, B. F., "Power generation, operation and control", New York: John Wiley & Sons,1996
[7] Virmani, S., Adrian, E. C., Imhof, K. and Mukherjee, S. "Implementation of a Lagrangian relaxation based unit commitment problem", IEEE Transactions on Power Systems, Vol 4, No.4, Nov 1989,pp. 1373-1380.
[8] Navpreet Singh Tung, Ashutosh Bhadoria, Kiranpreet Kaur, Simmi Bhadauria." Dynamic programming model based on cost minimization algorithms for thermal generating units", International Journal of Enhanced Research in Science Technology & Engineering, Vol 1, issue 3,Dec 2012 pp.2319-7463.
[9] P.Attaviriyanupap, H. Kita, E. Tanaka and J.

Hasegawa, Member, IEEE A Hybrid LR–EP for Solving New Profit- Based Competitive Environment, IEEE Transaction on Power Systems, May 2005.

[10] R.H. Kerr, J.L. Scheidt, A.J. Fontana and J.K. Wiley, “Unit Commitment”, IEEE Transactions on Power Apparatus and Systems, vol.PAS-85, No.5,May 1966, pp.417-421,

