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Profit based Unit Commitment using Improved Pre-Prepared Demand (IPPD) Table and Memory Management Algorithm (MMA)

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Abstract-In this paper, Improved Pre-prepared Power Demand (IPPD) table and Memory management algorithm is used to solve Profit Based Unit Commitment (PBUC) problem. In conventional market, Unit commitment (UC) is the process of determining the On/Off status of the generating unit to meet forecasted load by satisfying certain operating constraints that minimize the operating cost. In restructured power market, unit commitment involves commitment of generating unit of an Individual Generation company (GENCO) for maximization of his profit rather than satisfying the power demand of its consumer. In this proposed method, PBUC problem is solved in two steps. In first step unit commitment scheduling is done by IPPD table and then the problem of fuel cost and revenue function is done by Memory Management Algorithm. The IPPD table gives the information of committed unit for any predicted power demand and information about forecasted price to reduce complexity in the problem during calculation. Memory management algorithm uses Best fit and Worst bit allocation for scheduling the generator in order to receive maximum profit by considering power and reserve generation. This approach has been tested on a 3 unit system using MATLAB and the simulation result is compared with the result of previous published method obtained by other optimizing technique.

Keyword- Deregulation Improved Pre-Prepared Power demand (IPPD) table, Generation Company (GENCO), Memory Management Algorithm (MMA), and Profit Based Unit Commitment (PBUC).

I. INTRODUCTION

In deregulation environment, Profit Based Unit Commitment PBUC is most optimization problem of power system operation. Earlier power producer were dominated by Vertically integrated Electric Utilities (VIEU) that performs unit commitment in a utility to minimize the total generation cost over the time period but now in deregulation this VIEU is unbundled into Generation (GENCOs), Transmission (TRANCOs) and Distribution (DISCOMs) where the objective is to create competition among generating companies and provide different choice of generation option to the consumer at cheaper price. The main aim of GENCO is to maximize their own profit instead of minimizing the total generation of the power system. This problem is referred as Profit Based Unit Commitment (PBUC) problem.

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Here generator economically schedule their units based on forecasted dates such as spot price ,reserve price, power demand and unit characteristics which makes solution of PBUC complex . Therefore PBUC problem is divided into two sub problems. First is to determine status of generating units and second is to determine output power of committed units. Earlier, Profit Based Unit Commitment problems were solved by using conventional methods such as Dynamic Programming (DP) and Lagrange relaxation (LR) method. Due to curse of dimensionality with increase in number of generating units, LR suffers from numerical convergence and DP take large computational time to achieve optimal solution. Recent Genetic Algorithm (GA) has been used to solve PBUC problem due to its high potential for global optimization. The drawback of GA is that the final solution may not be satisfactory and heuristic in nature. So a Meta heuristic technique such as particle swarm optimization is used to solve PBUC problem. Here the solution quality depends on control parameters thereby it requires huge computational time to reach its final solution. From Literature Survey it is observed that most of existing algorithms have certain limitation in providing qualitative solution within considerable computational time. Therefore the present papers develops Improved Pre-prepared Power Demand (IPPD) table to solve PBUC Problem and Memory management algorithm (MMA) to solve Economic Dispatch (ED) using MATLAB on Pentium IV , 3GHZ PC with 512MB RAM .

II. PROFIT BASED UNIT COMMITMENT (PBUC) PROBLEM

The objective function of Profit Based Unit Commitment (PBUC) is to determine the generating unit schedule for maximizing the Profit of Generation Company (GENCOs). Here Profit is the difference between Revenue obtained from sale of energy with market price and total operating cost of Generation Company.

Formation of PBUC Problem is done mathematically by the following equation

Maximum PF = RV –TC ----- (1)

Subjected to

1. Power demand constraint

$$\sum_{i=1}^{N} P_{it} X_{it} \leq PD_t \quad 1 \leq i \leq N \qquad \text{----- (2)}$$

2. Generator limits Constraint

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$P_i^{min} \le P_i \le P_i^{max} \quad 1 \le i \le N$ ----- (3)

3. Reserve Constraint

$\sum_{i=1}^{N} R_{it} X_{it} \le SR_t \quad 1 \le i \le N$ ----- (4)

$0 \le R_i \le Pi^{max} - Pi^{min}$ ------ (5)

$Ri+Pi \le Pi^{max}$ ------- (6)

4. Minimum Up/ Down time

$Ton_i \ge Tup_i \quad i=1\ldots\ldots N$ ------ (7)

$Toff_i \ge Tdowni \quad i=1\ldots.N$ --------(8)

Where variable are defined as follows

PF = Profit of GENCO;

RV = Revenue of GENCO;

TC = Total Cost of GENCO

P_{it} = Power generation of generator at hour t;

R_{it} = Reserve generation of generator at hour t.

X_{it} = ON/OFF status of generator at hour t;

PD_t = Power demand at hour t.

SR_t = Forecasted reserve at hour t;

P_i^{min} = minimum generation limit of generator i.

P_i^{max} = maximum generation limit of generator i.

n = number of generating unit.

t = number of hours

III. ENERGY MARKETS IN DEREGULATED POWER SYSTEM

In deregulated power system, the power producer can sell power in a spot market and reserve in reserve market. The exact scheduling plan of power and reserve depends on the way reserve payments are made.

3.1 Payment for power delivered (Method A)

In this method, reserve price is paid only when reserve power is used. Therefore the reserve price is higher than spot price. Revenue and Total cost in equation (1) can be calculated from

$$RV = \sum_{i=1}^{N}\sum_{t=1}^{T}(P_{it}.SP_t)X_{it} + \sum_{i=1}^{N}\sum_{t=1}^{T}(r.R_{it}.RP_t)X_{it} \text{ ----------------(9)}$$

$$TC=(1-r)\sum_{i=1}^{N}\sum_{t=1}^{T}F_i(P_i)X_{it}+r\sum_{i=1}^{N}\sum_{t=1}^{T}F_i(P_{it}.+R_{it})X_{it}+ST.X_{it} \text{ ------(10)}$$

Where

SPt = Forecasted spot price at hour t.

$F_i(P_{it})$ = Fuel cost function of generator i

ST = Start up Cost

r = Probability that reserve is called and generated

3.2 Payment for reserve allocated (Method B)

In this method, GENCO receives the reserve price for every time period that the reserve is allocated and not used. If the reserve is used, GENCO will receive the spot price for that reserve power. Here reserve price is much lower than spot price. The revenue and Total cost in equation (1) can be calculated from

$$RV = \sum_{i=1}^{N}\sum_{t=1}^{T} (P_{it}.SP_t)\, X_{it}+\sum_{i=1}^{N}\sum_{t=1}^{T} (1-r)RP_t+r(SP_t).R_{it}.X_{it} \text{ ----(11)}$$

$$TC = (1-r) \sum_{i=1}^{N}\sum_{t=1}^{T} F_i\, (P_{it})\, Xit+ r \sum_{i=1}^{N}\sum_{t=1}^{T} Fi(P_{it}+R_{it}).X_{it}+ST.X_{it} \text{ --(12)}$$

IV. SOLUTION METHODOLOGY FOR PROFIT BASED UNIT COMMITMENT (PBUC)

Solution of the PBUC problem is obtained in the following stages

4.1 Formation of the IPPD table

The procedure to form IPPD table is given below.

Step1: Determination of λ_i^{min} and λ_i^{max} for all generating unit at their P_i^{min} and P_i^{max}. For each units we get two λ values. Arrange these λ values in ascending order and indicate them as λ_j where j=1,2,2N.-----------------(13)

Step2: Determine output power $Pji = (\lambda_j - b_i)/2c_i$ for all generators at each λ_j value. The generator constraints such as minimum and maximum output power are considered as follows

(a)If $\lambda_j \le \lambda_i^{min}$ then $P_{ji} = 0$ ------(14)

(b)If $\lambda_j = \lambda_i^{min}$ then $P_{ji} = P_i^{min}$ ---(15)

(c)If $\lambda_j \ge \lambda_i^{max}$ then $P_{ji} = P_i^{max}$ ---(16) for Must run generator and maximum output power.

Step3: For each λ values, output power and sum of output power (SOP) is determined and arranged in ascending order in a table known as IPPD table. IPPD table features are given below.

(i) The generating unit with minimum λ value is in the first row of the IPPD table. Minimum output power of the first generating unit is available and output power of the remaining unit are zero in the first row. Therefore the available power is the P_i^{min} of that generating unit with minimum λ value.

(ii) From the second row onwards, generating units are added in the IPPD table based on the ascending order of λ value of the generating unit.

(iii) On/Off Status of generating unit are available in the IPPD table up to the addition of last generating unit.

4.2 Formation of the Reduced Improved Prepared Power Demand (RIPPD) table.

When forecasted price is greater than incremental cost of that unit, Profit is obtained. Therefore forecasted price is important factor to select the Reduced IPPD from IPPD table. There are two ways to select RIPPD from IPPD table. They are

(i) At the predicted forecasted price, two rows from IPPD table are selected such that the price lies within the lambda limits .Assume m and m+1 are the corresponding rows.

(ii) At the predicted power demand, two rows from IPPD table are selected such that the predicted power lies within the lambda limits .Assume n and n+1 are the corresponding rows.

4.3 Incorporation of No Load Cost

Incremental fuel cost (λ) is considered while No Load Cost is not considered in IPPD table. But in some generating unit, No load cost is huge and less incremental fuel. Hence incorporation of no load cost is needed to reduce the total fuel cost. Some unit may operate at lower output power than maximum output power .Therefore priority list may not exactly reflect on the actual status of the generating unit.

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This lead to higher operational cost for medium units.
Step1: Production cost of the units at average of minimum output power and maximum output power is evaluated for all units.
Step2: All units are arranged in Ascending order of the production cost .
Step3: Status of units is also modified according to the ascending order of the production cost .
Step4: Last on state unit at each hour is identified. Status of the unit is changed to on state unit if the left side of Last on state unit is in off state.

4.4 De-commitment of units:

The profit of GENCO s depends on the proper scheduling of the generating unit . Sometime the spinning reserve of the system is high due to the large gap between the selected lambda values in the RIPPD table. So it is necessary to decommit the unit to improve the financial benefits of GENCOs. Following step are used to de-commit the units.
Step1: Identify the committed units
Step2: De-commit the last ON state unit in unit commitment after incorporating No load cost and Check the spinning reserve. If spinning reserve constraint is satisfied after de-commitment of the unit, then decommit that unit.
Step3: Repeated step2 and decommit remaining units without violating the spinning reserve constraint.

4.5 Minimum Up time and Minimum down time constraints

The OFF time of the unit is less than the minimum down time, and then status of that unit will be OFF. If ON time of the unit is less than the up time of the unit, then that unit will be ON. This information is applied in RIPPD table to perform the final unit commitment scheduling. Then memory management algorithm is used to solve the economic dispatch problem.

4.6 Memory Management Algorithm (MMA)

The Memory Management Modules are concerned to primary memory management. Primary memory means the processors from which instructions and data can be directly accessed. MMA has four functions. They are
(1) Keeping track of the status of each location of primary memory
(2) Determining memory allocation.
(3) Allocation techniques –once it is decided to allocate memory y ,the specified location must be selected and allocation information will be updated
(4)Re-allocation of policy and techniques.
Generally, a set of holes with different sizes are scattered thought out the memory at any given time. When a process arrives and needs memory, the system searches this set for the holes that is large enough for the process. There are three kinds of allocation algorithms are available. They are: First fit, Best fit and Worst Fit.Best Fit allocates forecasted demand from smaller capacity of given generating unit where Worst Fit allocates forecasted demand from larger capacity of given generating unit. In PBUC, memory present in the system is equated to the maximum capacity of generator units and the process is equated to the forecasted demand. The algorithm is used for solving PBUC by including the effect of r. MMA uses Best Fit allocation and Worst Fit allocation for allocating forecasted demand. The method chooses this algorithm based on the number of generators units used in the system. Worst Fit allocates forecasted demand from higher capacity of the generator in such a way that minimum numbers of generators are committed to reduce fuel cost and maximize profit.
There are many benefit to power industry by developing MMA are:
(1) Online price comparison of energy customers
(2) Improved customer relationship management
(3) Online sign up to electricity supplier
(4) Establishment of remote e-partnerships
Best Fit and Worst Fit allocate forecasted demand from capacity of available generator by satisfying the mentioned constraints in equation (1) to (7). The flow chart of memory management algorithm is given in fig I.

V. TEST CASES AND SIMULATION RESULTS

The proposed approach has been implemented in MATLAB and executed on a Pentium IV (3GHz) personal computer with 512 MB RAM. The proposed has been tested on 3 generating unit to solve profit based unit commitment problems.

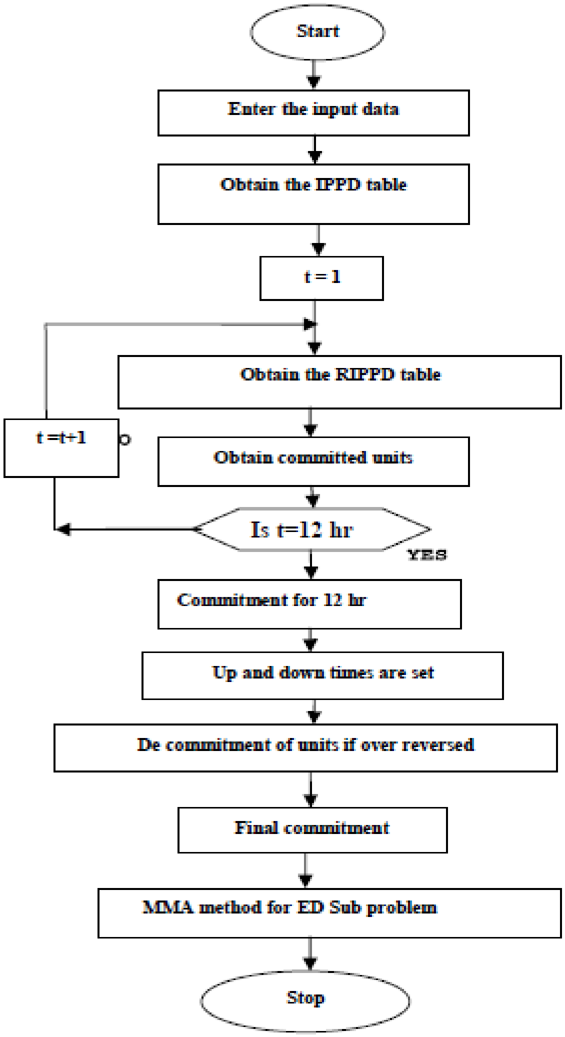

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Table 5.1. Input Characteristics of 3 unit 12 period system

	Unit 1	Unit2	Unit3
Pmax (MW)	600	400	200
Pmin (MW)	100	100	50
a	500	300	100
b	10	8	6
c	0.002	0.0025	0.005
e	300	200	150
f	0.0315	0.042	0.063
Min up time	3	3	3
Min down time	3	3	3
Start up cost	450	400	300

Table 5.2. Forecasted spot and reserve power for 12

Hour	Forecasted demand (MW)	Forecasted reserve (MW)
1	170	20
2	250	25
3	400	40
4	520	55
5	700	70
6	1050	95
7	1100	100
8	800	80
9	650	65
10	330	35
11	400	40
12	550	55

Hours

Table 5.3. Forecasted spot and reserve price for 12

Hour	Forecasted spot price ($/MWh)	Forecasted reserve price ($/MWh) Case:A	Forecasted reserve price ($/MWh) Case:B
1	10.55	31.65	0.4220
2	10.35	31.05	0.4140
3	9.00	27.00	0.3600
4	9.45	28.35	0.3780
5	10.00	30.00	0.4000
6	11.25	33.75	0.4500
7	11.30	33.90	0.4520
8	10.65	31.95	0.4260
9	10.35	31.05	0.4140
10	11.20	33.60	0.4480
11	10.75	32.25	0.4300
12	10.60	31.80	0.4240

Hours

Table 5.4. IPPD table for 3 units system

Sl no	Lambda	P1	P2	P3	SOP
1	6.5	0	0	50	50
2	8	0	0	200	200
3	8.5	0	100	200	300
4	10	0	400	200	600
5	10.4	100	400	200	700
6	12.4	600	400	200	1200

In this example, Lambda values are computed for all units at their minimum and maximum output powers are evaluated and IPPD is formulated.

Table 5.5. Priority list based on lambda value

Sl no	Unit	Lambda	priority order
1	1	10.4	3
2	2	8.5	2
3	3	6.5	1

Table 5. 6. RIPPD table at 170 MW for 3 units system

Sl no	Lambda	P1 (MW)	P2 (MW)	P3 (MW)	SOP
1	6.5	0	0	50	50
2	8	0	0	200	200

Table 5.7. Simulation result of PBUC by the proposed method for a 3 unit system using Method A

Hr	P1	P2	P3	R1	R2	R3	RV	TC	Profit
1	0	0	170	0	0	20	1802	1265	537
2	0	0	200	0	0	0	2070	1500	570
3	0	0	200	0	0	0	1800	1500	300
4	0	320	200	0	55	0	4922	4620	302
5	0	400	200	0	0	0	6000	5400	600
6	0	400	200	0	0	0	6750	5400	1350
7	0	400	200	0	0	0	6780	5400	1380
8	0	400	200	0	0	0	6390	5400	990
9	0	400	200	0	0	0	6210	5400	810
10	0	130	200	0	35	0	3702	2885	817
11	0	200	200	0	40	0	4307	3503	804
12	0	350	200	0	50	0	5838	4910	928
Total									9382

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Table 5.8. Simulation result of PBUC by the proposed method for a 3 unit system using Method B

Hr	P1	P2	P3	R1	R2	R3	RV	TC	Profit
1	0	0	170	0	0	20	1802	1265	537
2	0	0	200	0	0	0	2070	1500	570
3	0	0	200	0	0	0	1800	1500	300
4	0	320	200	0	55	0	4937	4619	318
5	0	400	200	0	0	0	6000	5400	600
6	0	400	200	0	0	0	6750	5400	1350
7	0	400	200	0	0	0	6780	5400	1380
8	0	400	200	0	0	0	6390	5400	990
9	0	400	200	0	0	0	6210	5400	810
10	0	130	200	0	35	0	3714	2885	829
11	0	200	200	0	40	0	4319	3503	816
12	0	350	200	0	50	0	5856	4910	946
Total									9446

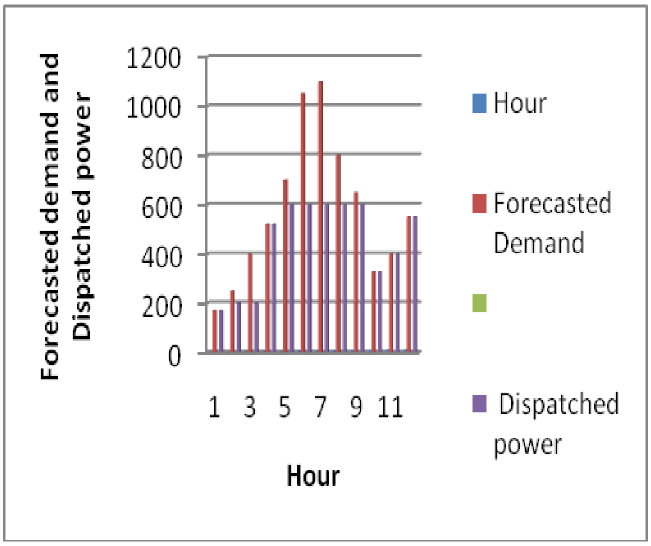

Fig. 2: Dispatched Power Demand and Forecasted Power Demands

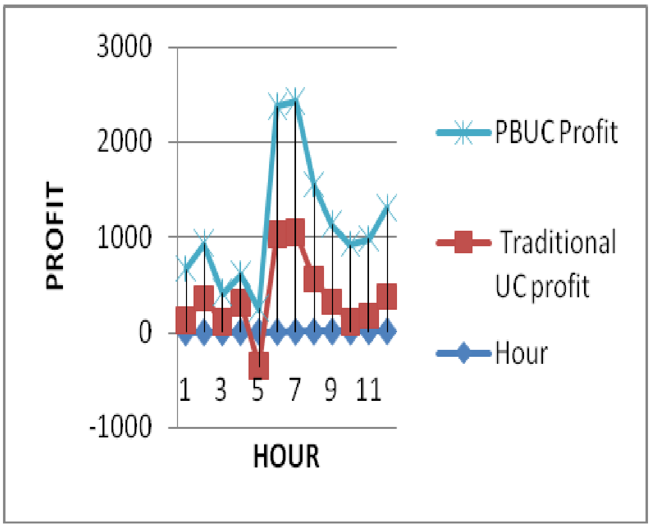

Fig. 3: Comparison of Profit by Traditional UC and PBUC in Method A

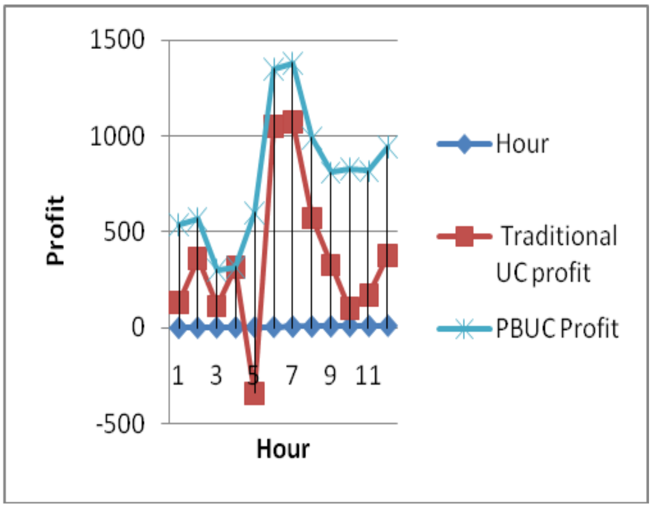

Fig. 4: Comparison of Profit By Traditional UC And PBUC In Method B

VI. COMPARISION

Table VIII: The Results of 3 Unit System with Existing Methods by Proposed Method (Method –A).

Sl no	Method	Profit ($)
1	Traditional UC	4048.8
2	PBUC by LR-EP method	9074.3
3	Proposed method	9382

Table IX. The Results Of 3 Unit System With Existing Methods By Proposed Method (Method – B).

Sl no	Method	Profit ($)
1	Traditional UC	4262.7
2	PBUC by LR-EP method	9136
3	Proposed method	9446

VII. CONCLUSION

The Simulation results obtained shows that the proposed method has been used to solve PBUC problems. This method helps GENCO to sell power and reserve in competitive market to achieve maximum profit. MMA provides more accurate solution with less computational time compared to existing and traditional method and also provide maximum profit to generation companies. In this new approach, information regarding the committed units is obtained by IPPD table and memory management method is used to solve economic dispatch.

VIII. ACKNOWLEDMMENT

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