# ARTIFICIAL BEE COLONY ALGORITHM FOR PROFIT BASED UNIT COMMITMENT USING MODIFIED PRE-PREPARED POWER DEMAND TABLE

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**Abstract -** *The electric power industry has been experiencing a procedure of restructuring since the nineties decade. The restructuring process of electrical power system specifies the splitting of vertically integrated utilities to generation, transmission and distribution companies with a system coordinator known as independent system operator (ISO). Restructuring process leads into a competitive climate among power generation companies. The generation companies i.e. GENCOs plan their generators to maximize profit as opposed to fulfill load demand request. Scheduling of power generations and reserve generations, planning for operation, maintenance etc. are crucial aspects in power system. Unit commitment decision concerns of identifying the units which are to be committed or de-committed during each hour over a specified period, by considering some constraints such as power demand constraint, power generation constraint, reserve constraints, constraints on the startup and shut down of units etc. So, in the profit based unit commitment the main objective is to maximize the profit which can be obtained by subtracting the cost from the revenue rather than minimization of cost as in traditional unit commitment. There are many optimization techniques which can be used for unit commitment problem. Here, Modified Pre-Prepared Power Demand (MPPD) table is used for scheduling of units which are to be committed over the specified period. Artificial Bee Colony (ABC) algorithm is used to solve for the generation of the committed units in each and every hour. The suggested method has been analyzed on a system having 10 units with a scheduling period of 24 hours.*

***Key Words*: Restructuring process, Competitive climate, Power generation, Reserve generation, Profit based unit commitment, Modified Pre-prepared Power Demand table, Artificial Bee Colony algorithm**

## 1. INTRODUCTION

In power system planning, operation, maintenance and scheduling of generation are vital angles. The power demand varies all the day and the load curve shows power demand variation with respect to time during the course of the day. The load pattern of many utilities varies between peak and off peak hours. It is not economical that all the units are on-line for the whole duration. Therefore, there is a problem of Unit Commitment for the generating companies so that they can meet the varying power demand in economical way. So it is necessary for the utility companies to plan for generation in hourly basis for the whole day. The unit commitment (UC) can be defined as the selection of generating units i.e. start up and shut down arrangement which supply power to the load of the system at a minimum cost over a specified time period as well as providing a fixed amount of reserve, known as spinning reserve. The unit commitment selects units which are to be turned on or turned off and generate the power and the reserve margin for each unit. In general the commitment and the generating arrangement are done on hourly basis. Unit commitment determines the on/off status as well as the active power output of the generator while satisfying the objective function subjects to some constraints. Unit commitment is considered as a standout amongst the most noteworthy optimization task in the operation of energy framework. Unit commitment assumes an imperative part for the financially utilization of energy creating unit in the power framework. There was a general expert to control all exercises of generation, transmission and distribution of power, which is known as vertically integrated market. So it was tough to split the cost involved in generation, transmission and distribution. Since nineties decade the electric power industry has been experiencing a continuous procedure of move and rebuilding. The restructuring procedure includes the detachment of generation, transmission and distribution companies from the vertically integrated utilities, with a central coordinator known as Independent System Operator (ISO) to balance supply and demand in real time and to maintain system reliability and security. The restructuring process has been introduced in all the power activities. In deregulated environment, the unit commitment problem has a different objective that includes the electricity market than that of traditional system. The main objective is to maximize the profit of the individual generating companies i.e. GENCOs and that profit can be found by subtracting the total cost of generation from the revenue. The unit commitment under deregulated environment changes its objective from minimization of the cost to maximization of profit. GENCOs made a schedule which generates power less than the forecasted load demand but create maximum profit.

For power industry reliability is an important aspect. There should be provision of backup power for power failure. Therefore reserve generation is included in the unit commitment formulation under deregulated environment. In a deregulated environment all the generators, loads and Independent System Operator (ISO) have the ability to sell or purchase the reserve generation. The reserve market is different from the spot market one. The power traded in the spot market are scheduled in advanced while reserve power will be available on-line when a system contingency occur. Although the reserve price are different from the spot price but it is directly depends on the spot price. There are mainly three methods for reserve generation payments and they are payment for power delivered in which reserve price is higher than spot price, payment for reserve allocated in which reserve price is lowered than the spot price and price process for reserve price [1]. In the first method, the power producers receive the reserve price for that reserve only if the reserve power is actually used. In the second method, the producers receive the reserve price for all the time whether the reserve is allocated or not. In deregulated environment for profit maximization the possibility of generator failure should also be included i.e. the profit depends on the probability of failure. Thus the economical balance is maintained for backup generation for the system.

In this work, an Artificial Bee Colony (ABC) algorithm has been proposed to address the profit based unit commitment problem (PBUC) under deregulated environment. Here, the unit commitment scheduling has been done by Modified Pre-prepared Power Demand (MPPD) table while Artificial Bee Colony (ABC) algorithm is utilized to solve the economic dispatch problem.

## 2. FORMULATION OF THERMAL UNIT COMMITMENT PRROBLEM

Unit commitment can be defined mathematically as optimal power flow problem as follows:

### 2.1 Objective function

The main objective of the unit commitment under deregulated environment is to maximize the profit fulfilling the system constraint. The profit can be found by subtracting the total operating cost of the company from the revenue which can be obtained from sale of energy with market price. The total operating cost over the entire scheduling period is the sum of the running cost and the startup/shutdown cost for all the generating units. Here the shutdown cost is considered as negligible. The overall objective function is given as

$$\text{Maximize } PF= RV-TC \tag{2.1}$$

In deregulated environment there are two markets i.e. spot market and reserve market. Spot market is used for selling power and reserve market is used for selling reserve power. Here we will use mainly two methods for profit calculation considering both the market.

**Method A:** Payment for power delivered

Here the power producer receives reserve price only for the time when the reserve is used. Therefore the reserve price is higher than the spot price in this method.

$$RV=\sum_{t=1}^{T}\sum_{i=1}^{N}(P_{it}\, SP_t)U_{it}+ \sum_{t=1}^{T}\sum_{i=1}^{N} r RP_t\, R_{it}\, U_{it} \tag{2.2}$$

$$TC=(1-r)\sum_{t=1}^{T}\sum_{i=1}^{N} C_{it}\,(P_{it})U_{it}+ r.\ \sum_{t=1}^{T}\sum_{i=1}^{N} C_{it}\,(P_{it}+R_{it})U_{it}+ST\, U_{it} \tag{2.3}$$

**Method B:** Payment for Reserve Allocated

In this strategy the power producers receive reserve price for all the time whether the reserve power is allocated or not. Here the reserve price is much lowered than the spot price.

$$RV=\sum_{t=1}^{T}\sum_{i=1}^{N}(P_{it}\, SP_t)U_{it}+\sum_{t=1}^{T}\sum_{i=1}^{N}((1-r)\, RP_t + r.\, SP_t)\, R_{it}\, U_{it} \tag{2.4}$$

$$TC=(1-r)\sum_{t=1}^{T}\sum_{i=1}^{N} C_{it}\,(P_{it})U_{it}+ r.\ \sum_{t=1}^{T}\sum_{i=1}^{N} C_{it}\,(P_{it}+R_{it})U_{it}+ST\, U_{it} \tag{2.5}$$

Where,

$$C_{it}(P_{it}) = a_i + b_i P_{it} + c_{it} P_{it}^2 \tag{2.6}$$

PF= Total profit of the generating companies
RV= Total revenue of the generating companies
TC= Total operating cost of the generating companies
T= Number of time period considered
N= Number of generating units considered
r= Probability that the reserve is called and generated
$P_{it}$= Real power output of $i^{th}$ generator $t^{th}$ hour
$R_{it}$= Reserve power generation of $i^{th}$ generator at $t^{th}$ hour
$SP_t$= Forecasted spot price at $t^{th}$ hour
$RP_t$= Forecasted reserve price at $t^{th}$ hour
$U_{it}$= On/off status of $i^{th}$ generating unit at $t^{th}$ hour
$C_{it}(P_{it})$= Fuel cost function of $i^{th}$ generating unit at $t^{th}$ hour
$a_i, b_i, c_i$= Cost coefficient of $i^{th}$ generator
ST= Startup cost

The startup cost is given as

$$ST_i(t)= h-cost_i; \qquad MD_i \leq T_i^{off} \leq H_i^{off} \tag{2.7}$$

$$ST_i(t)=c-cost_i; \qquad T_i^{off} > H_i^{off} \tag{2.8}$$

Where,

$T_i^{off}$= Minimum time that the $i^{th}$ unit has been continuously offline
$H_i^{off}= MD_i + c-s-hour_i$
$MD_i$ = The minimum down time of the $i^{th}$ unit
$h-cost_i$= hot start cost of $i^{th}$ generator
$c-cost_i$= cold start cost of $i^{th}$ generator
$c-s-hour_i$= cold start hour of $i^{th}$ generator

### 2.2 Constraints

1) **Load demand constraint:** The generated power from all the committed units must be less than or equal to the system load demand and the equation is

$$\sum_{i=1}^{N} P_{it} U_{it} \leq PD_t\ ;\ 1\leq t\leq T \tag{2.9}$$

Where,

$PD_t$= Forecasted system demand during hour t

2) **Spinning Reserve constraint:** The sum of reserve power of all committed units during the planning period must be less than or equal to total spinning reserve of power plants and it can be mathematically be defined as

$\sum_{i=1}^{N} R_{it} U_{it} \leq SR_t$; $1 \leq t \leq T$ (2.10)

Where,

$R_{it}$= Reserve power of $i^{th}$ generating unit at $t^{th}$ hour

$SR_t$= Spinning reserve during $t^{th}$ hour

3) **Generator and Reserve power limits constraint:** The equations are

$P_{imin} \leq P_i \leq P_{imax}$; $1 \leq i \leq N$ (2.11)

$0 \leq R_i \leq P_{imax} - P_{imin}$; $1 \leq i \leq N$ (2.12)

$P_i + R_i \leq P_{imax}$; $1 \leq i \leq N$ (2.13)

Where,

$P_i$=Real power generation of $i^{th}$ generating unit

$R_i$=Reserve power generation of $i^{th}$ generating unit

$P_{imin}$= Maximum limit of $i^{th}$ generating unit

$P_{imax}$= Minimum limit of $i^{th}$ generating unit

4) **Minimum up/down time constraints:** There is a certain time for which the running unit must be on. This time is known as minimum up time. On the other hand when a unit is de-committed, there is also a minimum time to recommit the unit. This time is known as minimum down time. These constraints can be represented as

$T_i^{on} \geq MU_i$; i=1,2,……N (2.14)

$T_i^{off} \geq MD_i$; i=1,2,……N (2.15)

Where,

$T_i^{on}$= Minimum time that the $i^{th}$ unit has been continuously online

$T_i^{off}$ =Minimum time that the $i^{th}$ unit has been continuously offline

$MU_i$ = The minimum up time of the $i^{th}$ unit

$MD_i$ = The minimum down time of the $i^{th}$ unit

5) **Unit initial status:** Generally the initial status of the units is represented by either positive or negative value. The positive number indicates that the corresponding unit is committed for those hours. Similarly if it is a negative number, it means that the unit is put off during that period.

6) **Must run unit:** Generally in a power system, some of the units are given a must run status in order to provide voltage support for the network or for other reasons such as fuel constraints etc.

7) **Must out units:** These are the Units which are on forced outages or maintenance unavailable for commitment.

## 3. SOLUTION METHODOLOGY FOR UNIT COMMITMENT

The unit commitment problem can be considered as a two linked optimization sub problem. Here the unit commitment scheduling is obtained from the Modified Pre-prepared Power Demand (MPPD) table and economic load dispatch is carried out by using Artificial Bee Colony (ABC) algorithm.

### 3.1 Unit commitment scheduling by MPPD table

All the steps which are involved to form the Modified Pre-Prepared Power Demand (MPPD) table are described below:

**Step 1:** For each generating units, the minimum and maximum values of lambda (λ) at their minimum and maximum output power i.e. $P_{imin}$ and $P_{imax}$ are calculated by using the equations

$$\lambda_{jmin} = \frac{P_{imin} + \frac{b_i}{c_i}}{\frac{1}{2c_i}} \quad (3.1)$$

$$\lambda_{jmax} = \frac{P_{imax} + \frac{b_i}{c_i}}{\frac{1}{2c_i}} \quad (3.2)$$

**Step 2:** Now these lambda values are arranged in ascending order and index them as $\lambda_j$, where j=1,2,……2N and N is the number of generating units.

**Step 3:** For each λ value, the output powers of all generators are calculated using the equation

$$P_{ji} = \frac{\lambda - b_i}{2c_i} \quad (3.3)$$

**Step 4:** The minimum and maximum output powers of each generator are fixed as follows:

For minimum output power limit

If $\lambda_j < \lambda_{imin}$ then put $P_{ji}=0$ (3.4)

If $\lambda_j = \lambda_{imin}$ then put $P_{ji}=P_{imin}$ (3.5)

For maximum output power limit

If $\lambda_j > \lambda_{imin}$ then put $P_{ji}=P_{imax}$ (3.6)

**Step 5:** Lambda (λ) value, output powers ($P_{ji}$) and sum of output powers (SOP) for each λ are recorded in a table in ascending request. This table is referred to as Modified Pre-Prepared Power Demand (MPPD) table.

**Step 6:** In this step we prepare the Reduced Modified Pre-Prepared Power Demand (RMPPD) table.

Profit is gotten just when the forecasted price at the given hour is more than the incremental fuel cost of the given unit. The forecasted energy price plays an important role in preparing the RMPPD table. Therefore, the forecasted price is taken as the principle file to choose the Reduced MPPD (RMPPD) table from the MPPD table.

**Step 7:** Now it is required to form the Reduced Committed Units (RCU) table which gives the status of committed units. The RCU table is obtained from RMPPD table by substituting the binary values such a way that if any element in the table is non-zero, then it is replaced by 1. Therefore, if the value is 1, then it is indicate that the unit is in on state. Similarly if the binary value is 0, then the unit is in off state.

**Step 8:** In this step we incorporate the no load cost. Formulation of MPPD table is based on incremental fuel cost (λ). Therefore no-load cost is not assumed in MPPD table. There is a simple procedure to amalgamate the no-load cost.

i) Production cost at the average of minimum output power and maximum output power is evaluated for all units.
ii) Now according to the production cost all units are arranged in ascending order.
iii) On/off status of the units is also modified according to the ascending order of the production cost.
iv) Keep going on-state unit at every hour is distinguished. Status of the units are supplanted as follows:

If any unit on the left side of the last on-state unit is in off state then it is converted as on- state unit.

**Step 9:** Now it is required to check for the minimum up time and down time constraints. In the event that the off time of the unit is not as much as the minimum down time, the status of the unit will be off. Similarly if the on time of the unit is more than the up time of the unit, then the unit will be on. This information is applied in the RCU table to perform the final unit commitment scheduling.

## 3.2 Artificial Bee Colony Algorithm

### 3.2.1 Introduction

Artificial Bee Colony (ABC) algorithm was proposed by Dervis Karaboga in 2005 which simulates the forging behavior of a bee colony. This algorithm provides populace based inquiry method. Here the food position are changed by the simulated honey bees with time and the target of the honey bee is to discover the spots of food source with high nectar amount lastly the one with most noteworthy nectar. The food source represents a conceivable solution of the optimization issue. The ABC colony consists of three types of bees and they are employed bees, onlooker bees and scout bees. The employed bees occupy one half of the colony and the onlooker bees occupy the other half.

At first the employed bees search for the food sources. The number of food source and the number of employed bees are equal. The employed bees find a neighboring food source around that area and the corresponding nectar amount of the food source is evaluated. Now, the employed bees convey this information to other bees by a form of dance in the dancing area i.e. in the hive. Now, each onlooker bees which is equivalent to the number of food source watches the dance of employed bees and decide on a food source to exploit based on the information shared by the employed bees. Now the abandoned food sources are discovered and these are replaced with the new food sources which are discovered by scouts.

The intelligent behavior of foraging bees can be summarized in three steps.

At the very first step, the bees start to explore the environment randomly so that they can find a food source. At the second step, when the bees find a food source, the bee can be referred to as an employed forager. Now the employed bees start to exploit the discovered scouts. The employed bees find the nectar amount and then return to the hive and give the nectar information to other bees. At the third step, the onlooker bees watch the dance performance of the employed bees and choose a source site depending on the frequency of the dance proportional to the quality of the source.

### 3.2.2 Control Parameter of ABC Algorithm

There are for the most part four control parameters utilized as a part of ABC algorithm and they are the number of employed bees, the number of unemployed or onlooker bees, the limit value and the colony size. Generally, the number of employed or onlooker bees is equivalent to the quantity of food source. The value of limit is the quantity of trials for discharging a food source.

### 3.2.3 Steps involved in ABC algorithm

**Step 1: Initialization of Food Sources:**

Initially the food sources are generated by control variable between their boundaries.

$$X_{ij} = X_{jmin} + rand(0,1) * (X_{jmax} - X_{jmin}) \tag{3.7}$$

Where i=1, 2……..SN
SN= Number of food source
J=1, 2………. D
D= Number of optimization parameter

**Step 2: Searching of Food Source by the Employed Bees:**

Now the employed bees produce a modification on the position of the food source and for this they use the following expression.

$$V_{ij} = X_{ij} + \Phi_{ij}(X_{ij} - X_{kj}) \tag{3.8}$$

Where $V_{ij}$= Neighbouring food source of $X_{ij}$

i= 1, 2………SN
j=1, 2………..D
k=1, 2……….SN, which is different from i
$\Phi_{ij}$ is a random number in the range [0,1]

If $X_i > X_{imax}$, then $X_i = X_{imax}$ (3.9)

If $X_i < X_{imin}$, then $X_i = X_{imin}$ (3.10)

**Step 3: Finding the fitness value**

The fitness of the solution i can be found as

Fitness (i) = 1+abs f(i) , if X<0 (3.11)
= 1/(1+f(i)), if X≥0 (3.12)

Where f(i)= objective function with the value of $V_i$

The objective function can be directly used as a fitness function for maximization problem. The fitness value represents the nectar amount of the food source corresponding to $X_i$ and $V_i$. If the source at $V_i$ is greater than

$X_i$ in terms of fitness value, the employed bees memorize the new position and forgot the old one.

**Step 4: Calculating the Probability value**

The onlooker bees assess the nectar information. The onlooker bees pick a food source contingent upon the probability value which is related with the food source.

$$\text{Probability, } P_i = \frac{\text{fitness}(i)}{\sum_{i=1}^{N} \text{fitness}(i)} \quad (3.13)$$

Now for each source a real random number is generated within the range [0, 1]. If the probability value of that food source is more than this random number then a modification on the position of this food source is occurred by the onlooker bees. Now the onlooker bees either memorize the new position by forgetting the old one or keep the old one.

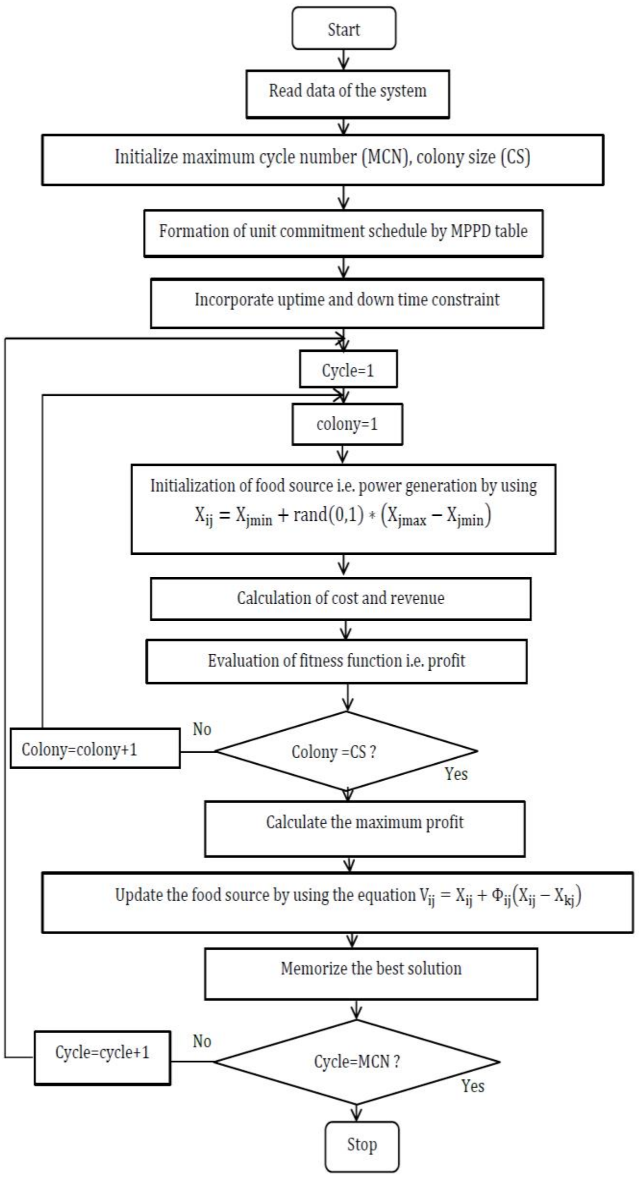


**Fig-1:** Flow chart of proposed algorithm

## 4. RESULTS AND DISCUSSION

The proposed method has been tested on systems with 10 units. The unit data and load demand, Reserve and Forecasted Price data for 24 hours for the systems with 10 units has been taken from reference [8]. The final commitment schedule for 10 units system is shown in the table-1. The comparison of the results obtained by proposed method with various methods is shown in the table-6.

**Table-1:** Commitment schedule for 10 units system

| Hour | U1 | U2 | U3 | U4 | U5 | U6 | U7 | U8 | U9 | U10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 02 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 03 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 04 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 05 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 06 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 07 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 08 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 09 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 10 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 11 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 12 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 13 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 14 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 15 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**4.1 Method A:** Payment for power delivered

The power generation and reserve generation schedule for 10 units system by using Artificial Bee Colony algorithm is shown in the table-2 and 3 respectively. Here the value of r (Probability that the reserve is called and generated) is taken as 0.05 and the forecasted reserve price at $t^{th}$ hour i.e. $RP_t$ is calculated by using the equation $RP_t = 5 * SP_t$, where $SP_t$ is the forecasted spot price at $t^{th}$ hour. Again the simulation results showing generation cost, revenue and profit obtained by ABC algorithm for 10 units systems are shown in table-4.

**Table-2:** Power Generation Schedule for 10 units system

| Hour | U1 | U2 | U3 | U4 | U5 | U6 | U7 | U8 | U9 | U10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 455 | 245 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 02 | 455 | 295 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 03 | 455 | 395 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 04 | 455 | 455 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 05 | 455 | 455 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 06 | 455 | 455 | 0 | 126 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 07 | 455 | 435 | 110 | 110 | 0 | 0 | 0 | 0 | 0 | 0 |
| 08 | 455 | 455 | 128 | 128 | 0 | 0 | 0 | 0 | 0 | 0 |
| 09 | 455 | 437 | 100 | 112 | 142 | 0 | 0 | 0 | 0 | 0 |
| 10 | 455 | 455 | 123 | 128 | 160 | 079 | 0 | 0 | 0 | 0 |
| 11 | 455 | 455 | 130 | 130 | 162 | 080 | 0 | 0 | 0 | 0 |
| 12 | 455 | 455 | 130 | 130 | 162 | 079 | 0 | 0 | 0 | 0 |
| 13 | 455 | 450 | 125 | 123 | 157 | 071 | 0 | 0 | 0 | 0 |
| 14 | 455 | 452 | 100 | 127 | 158 | 0 | 0 | 0 | 0 | 0 |
| 15 | 455 | 455 | 112 | 130 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 455 | 335 | 130 | 130 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 455 | 415 | 0 | 090 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | 455 | 455 | 0 | 120 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | 455 | 455 | 0 | 130 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | 455 | 455 | 0 | 126 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 455 | 455 | 0 | 130 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 455 | 455 | 0 | 119 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 455 | 445 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 455 | 345 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table-3:** Reserve allocation Schedule

| Hour | U1 | U2 | U3 | U4 | U5 | U6 | U7 | U8 | U9 | U10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 75 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 20 | 20 | 20 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 18 | 30 | 18 | 20 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 7 | 2 | 2 | 1 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 13 | 0 | 5 | 5 | 7 | 5 | 9 | 0 | 0 | 0 | 0 |
| 14 | 0 | 3 | 30 | 3 | 4 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 0 | 105 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 0 | 40 | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table-4:** Simulation result showing generation cost, revenue and profit

| Hour | Generation cost ($) | Revenue($) | Profit($) |
|---|---|---|---|
| 1 | 13744 | 15893 | 2148 |
| 2 | 14620 | 16912 | 2293 |
| 3 | 16354 | 19982 | 3627 |
| 4 | 17353 | 21521 | 4168 |
| 5 | 17353 | 20248 | 2894 |
| 6 | 20153 | 23803 | 3650 |
| 7 | 22125 | 25313 | 3188 |
| 8 | 23058 | 25866 | 2809 |
| 9 | 25403 | 28924 | 3521 |
| 10 | 28838 | 41175 | 12337 |
| 11 | 29036 | 42556 | 13519 |
| 12 | 29020 | 44660 | 15640 |
| 13 | 28465 | 34157 | 5692 |
| 14 | 26173 | 31885 | 5712 |
| 15 | 22805 | 26012 | 3207 |
| 16 | 21106 | 24011 | 2906 |
| 17 | 18903 | 21805 | 2902 |
| 18 | 20059 | 22774 | 2715 |
| 19 | 20214 | 23088 | 2874 |
| 20 | 20155 | 23494 | 3339 |
| 21 | 20213 | 24023 | 3810 |
| 22 | 20043 | 23686 | 3643 |
| 23 | 17187 | 20532 | 3345 |
| 24 | 15497 | 18491 | 2994 |
| Total | 507880 | 620810 | 112930 |

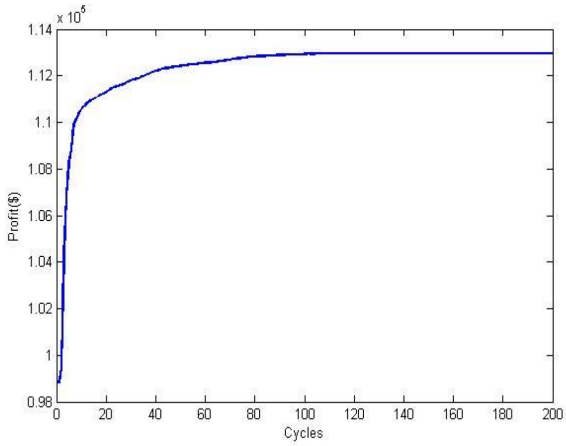


**Fig-2:** Convergence characteristics of proposed method

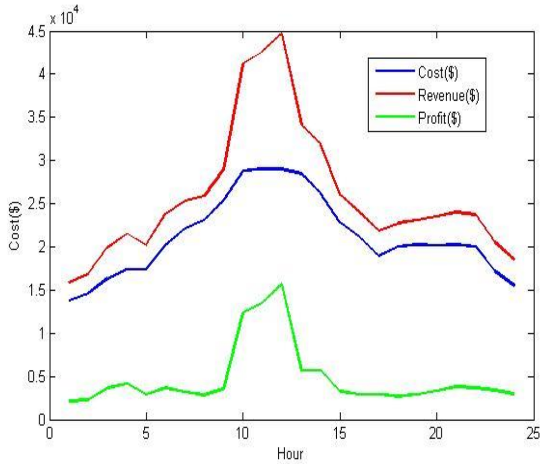


**Fig-3:** Revenue, Cost and profit for the 10 units system

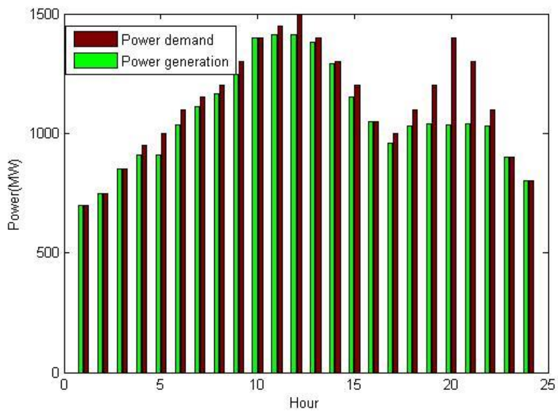


**Fig-4:** Comparison of power generation and power demand

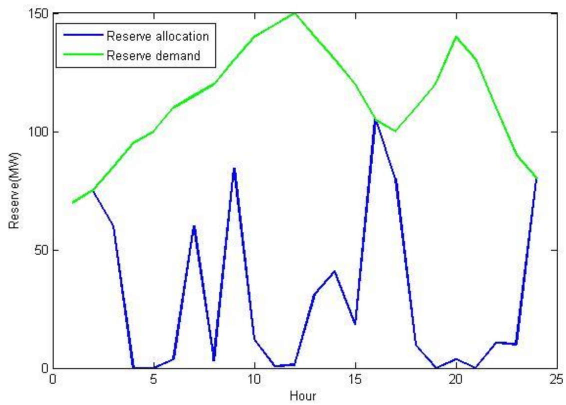


**Fig-5:** Comparison of reserve demand and reserve allocation

**4.2 Method B:** Payment for Reserve Allocated

Here the value of r (Probability that the reserve is called and generated) is taken as 0.005 and the forecasted reserve price at $t^{th}$ hour i.e. $RP_t$ is calculated by using the equation $RP_t=0.01*SP_t$, where $SP_t$ is the forecasted spot price at $t^{th}$ hour. The simulation results showing generation cost, revenue and profit obtained by ABC algorithm for 10 units systems are shown in table-5.

**Table-5:** Simulation result showing generation cost, revenue and profit by method B

| Hour | Generation cost ($) | Revenue($) | Profit($) |
|---|---|---|---|
| 1 | 13689 | 15528 | 1839 |
| 2 | 14561 | 16525 | 1964 |
| 3 | 16307 | 19656 | 3349 |
| 4 | 17353 | 21521 | 4168 |
| 5 | 17353 | 20248 | 2895 |
| 6 | 20214 | 23868 | 3654 |
| 7 | 22085 | 25003 | 2918 |
| 8 | 23009 | 25792 | 2783 |
| 9 | 26196 | 29634 | 3438 |
| 10 | 28432 | 40500 | 12068 |
| 11 | 28772 | 42098 | 13326 |
| 12 | 28376 | 43698 | 15322 |
| 13 | 28394 | 33889 | 5495 |
| 14 | 26184 | 31857 | 5673 |
| 15 | 23094 | 26309 | 3215 |
| 16 | 21032 | 23472 | 2440 |
| 17 | 19429 | 22119 | 2690 |
| 18 | 20214 | 22932 | 2718 |
| 19 | 20214 | 23088 | 2874 |
| 20 | 20189 | 23523 | 3334 |
| 21 | 20166 | 23960 | 3794 |
| 22 | 20030 | 23622 | 3592 |
| 23 | 17179 | 20478 | 3299 |
| 24 | 15434 | 18067 | 2633 |
| Total | 507906 | 617387 | 109481 |

**Table-6:** Comparison of the results by TS-RP, LR-EP and the proposed method

| Methods | TS-RP [7] | LR-EP [8] | Proposed method |
|---|---|---|---|
| Method A | 110407 | 112818.9 | 112930 |
| Method B | ---------- | 107838.5 | 109481 |

## 5. CONCLUSION

The generator maintenance planning in restructuring environment is a testing errand for the power engineers. So, the reason for this work is to acquire the optimal solution of unit commitment under deregulated environment. While tackling the profit based unit commitment problem, the data with respect to the forecasted price is known. Here the unit commitment scheduling is done by Modified Pre-Prepared Power Demand table and the generation of scheduled unit is tackled by ABC algorithm. The feasibility of the proposed strategy has been executed with the frameworks of 10 units in regard to load demand.

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