



## A Practical Approach for Profit Based Unit Commitment in Deregulated Electricity Market

P.Shivsankari

EEE Department, SRM University (Chennai)  
India.

Vikas Dubey

EEE Department, SRM University (Chennai)  
India.

**Abstract**— In this paper, Genetic Algorithm is used to solve the profit based unit commitment for deregulated power system in order to achieve optimal generation schedule and maximum profit of GENCOS. Deregulation of power system means unbundling of vertically integrated power system into generation, transmission and distribution companies. This proposed algorithm or approach is tested on IEEE-30 bus system with 6 generating units as an individual GENCO.

**Keywords**— degeneration, profit based unit commitment, genetic algorithm, ELD.

### I. INTRODUCTION

. Earlier we have vertically integrated power system, but now we are moving towards deregulated power system. As explained, deregulation means unbundling of vertically integrated power system into generation, transmission and distribution companies. The main aim of deregulation is to create competition among GENCOS in order to facilitate the electrical power to consumer at cheaper prices while the main objective of the GENCOS are to maximize their profit where in the vertically integrated system the main objective was to minimize the fuel cost. So deregulation leads to change in various strategies. One of them is the unit commitment problem. The unit commitment means economically scheduling the ON/OFF status of the generators and the outputs to meet the forecasted load. But in the case of deregulation, the main aim of the GENCOS is to maximize their profit. So in this case unit commitment is now termed as profit based unit commitment (PBUC).

Earlier many approaches are used to solve the unit commitment problem like linear programming, non linear programming, dynamic programming and evolutionary techniques. But with this optimal solution is not obtained and execution time is also large for that. So, here we have used Genetic Algorithm to solve profit based unit commitment which we obtain improved solution, with improved execution time. Here, profit will be maximized for selling not only the energy but also spinning and non spinning reserve energy and ancillary services are optimized simultaneously and the PBUC result provides a portfolio of energy and ancillary service bids.

### II. PROBLEM FORMULATION

- Here PBUC problem is formulated as a objective function subjected to various constraints. In this problem, profit of all units is given as

$$\text{Max} \sum_i \sum_t P(i,t) \quad (1)$$

where

$$P(i,t) = \{\sigma_{gm}(t)G(i,t) + \sigma_{rm}(t)K(i,t) + \sigma_{nm}(t)L(i,t) - C_i(G(i,t) + K(i,t)\sigma_{gm}(t)L(i,t)) - S(i,t)\}I(i,t) + \{\sigma_{nm}(t)L(i,t) - C_iL(i,t)\}(1 - I(i,t)) \quad (2)$$

Where

$P(i,t)$  = Profit of unit 'i' at  $t^{\text{th}}$  hour.

$\sigma_{gm}(t)$  = forecasted market price for generation at  $t^{\text{th}}$  hour

$\sigma_{rm}(t)$  = forecasted market price for spinning reserve at  $t^{\text{th}}$  hour

$\sigma_{nm}(t)$  = forecasted market price for non spinning reserve at  $t^{\text{th}}$  hour

$C$  = cost function of unit 'i'.

$S(i,t)$  = start up cost of unit 'i' at  $t^{\text{th}}$  hour

$I(i,t)$  = Commitment state of unit 'i' at  $t^{\text{th}}$  hour

IS<sub>i</sub> = initial state of units  
G = Generation,  
R = Spinning Reserve  
M = Non spinning reserve.

The profit based unit commitment is subjected to various constraints

$$\sum_i G(i,t)I(i,t) \leq G_{\max}(t) \quad (3)$$

$$\sum_i K(i,t)I(i,t) \leq K_{\max}(t) \quad (4)$$

$$\sum_i L(i,t)I(i,t) \leq N_{\max}(t) \quad (5)$$

These constraints give flexibility to GENCOS in order to control maximum level of generation, spinning reserve and non spinning reserve that GENCOS are willing to produce. Some other constraints.

$$G(i,t)I(i,t) \geq 0 \quad (6)$$

$$G_{g \min}(i) \leq G(i,t)I(i,t) + K(i,t)I(i,t) + L(i,t)I(i,t) \leq G_{g \max} \quad (7)$$

$$K(i,t)I(i,t) \leq K_s(i,t)I(i,t) \quad (8)$$

where

$$K_s(i,t) = \min\{10^*MSR(i), G_{g \max}(i) - h(i,t)\} \quad (9)$$

$$h(i,t) \leq l_0(i,t) \quad (10)$$

$$l_0(i,t) = q(i), \text{ if unit 'i' is off} \quad (11)$$

$$l_0(i,t) = l_s(i,t), \text{ if unit 'i' is on} \quad (12)$$

$$K_s(i,t) = \min\{10^*MSR(i), P_{g \max}(i) - P(i,t) - R(i,t)\} \quad (13)$$

where K<sub>s</sub>(i,t) contribution of unit 'i' to spinning reserve at t<sup>th</sup> hour

MSR is the maximum sustained ramp rate (MW/min) the spinning reserve is unloaded synchronised generation that can ramp up in 10 minutes.

Unit minimum ON/ OFF duration

$$\begin{aligned} [X^{on}(i,t) - T^{on}(i)] * [I(i,t-1) - I(i,t)] &\geq 0 \\ [X^{off}(i,t) - T^{off}(i)] * [I(i,t-1) - I(i,t)] &\geq 0 \end{aligned}$$

Where

X<sup>on</sup> = time duration for which unit I has been ON at time 't'  
X<sup>off</sup> = time duration for which unit I has been OFF at time 't'  
T<sup>on</sup> = minimum ON time of unit 'i'  
T<sup>off</sup> = minimum OFF time of unit 'i'

### III. GENETIC ALGORITHM

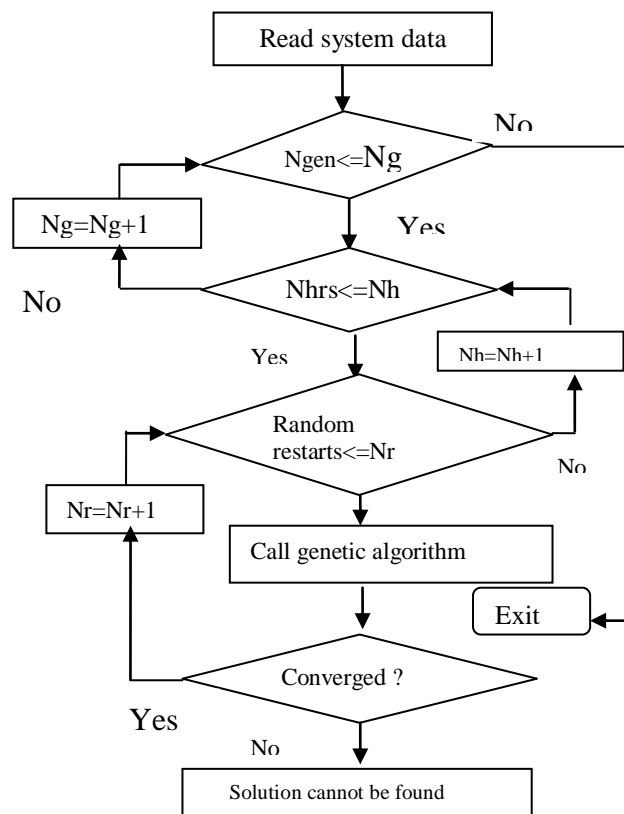
It is an optimization technique based on natural evolution process. In GA, each variable is represented as binary number of m-bits. Various steps of GA-

- (i) Creation of initial population and size determination.
- (ii) Here variable are read, decoded and fitness values are calculated.
- (iii) Reproduction where weaker members are replaced by stronger based as fitness values.
- (iv) Crossover is performed in the fourth step in order to produce offspring.
- (v) Mutation is performed in the fifth step so that prevent selection and cross over operations do not lead to identical individuals.

Initially GA terminated with random solution. So random restarts were done to generate initial population and optimal solutions were obtained.

#### A. Implementation of algorithm

1. At first step, number of generator ( $N_g$ ), number of hours ( $N_h$ ) and number of random of restarts ( $N_r$ ) along heat rate coefficients, fuel cost, ramp rate, quick start capability,  $P_{min}$  and  $P_{max}$  are noticed.
2. Various options are mentioned for genetic algorithm-
  - a. Mutation function
  - b. Stall time
  - c. Population
  - d. Initial population-generated by random restarts
3. Genetic algorithm is called by using fitness function, number of variables ,lower bound and upper bound on variables , constraints and options as in step 2
4. The following stopping criterion for genetic algorithm, if any of following violates the predefined value in step 2
  - a. Number of generators
  - b. Stall generations
  - c. Stall time limit
  - d. Function tolerance
  - e. Constraints tolerance
5. Step 1 to 4 are repeated for all  $N_g$  and  $N_h$ .



**B. . Different parameter related genetic algorithm**

POPULATION SIZE - it is the number of individuals in each generation .having large population size gives optimal solution but leads to longer convergence time; here population size is selected as 120 with four variables in fitness function.

SELECTION - It is used to choose parents for next generations. Here uniform selection process was used.

REPRODUCTION - It is used to specify how to create children for next generation.

MUTATION - It is used to specify small random changes in population to create mutation children

CROSSOVER-It is used to specify how the combination of two parents is performed to form a crossover child. Single point crossover is used here. In single point crossover, a random partition is chosen two populations and then respected parts are interchanged.

**Simulation and Results**

IEEE 30 bus systems with six generating units as an individual GENCO has been considered to illustrate the performance of PBUC schedule with operational constants.

Table (i) Unit power generation in MW for optimal UC schedule using genetic algorithm for PBUC.

| HR \ UNIT | 1     | 2     | 3     | 4     | 5      | 6     |
|-----------|-------|-------|-------|-------|--------|-------|
| U1        | 0     | 0     | 0     | 0     | 37.2   | 37.2  |
| U2        | 0     | 0     | 0     | 37.2  | 37.2   | 37.2  |
| U3        | 0     | 0     | 112.2 | 112.2 | 112.2  | 112.2 |
| U4        | 150.2 | 150.2 | 150.2 | 150.2 | 150.2  | 0     |
| U5        | 262.3 | 262.3 | 262.3 | 262.3 | 262.23 | 262.3 |
| U6        | 300   | 300   | 300   | 300   | 300    | 300   |

Now in below table spinning reserve is given for all 6 hours. Spining reserve is defined as total amount of generation available for all the units synchronized on the system minus the load & the losses being supplied and non-spinning reserve is the reserve that is available all time whether units are on-line or off-time.

Table (ii) Spining reserve in MW

| HR \ UNIT | 1  | 2  | 3  | 4  | 5   | 6   |
|-----------|----|----|----|----|-----|-----|
| U1        | 0  | 0  | 0  | 0  | 0.6 | 0.6 |
| U2        | 0  | 0  | 0  | 1  | 1   | 1   |
| U3        | 0  | 0  | 1  | 1  | 14  | 14  |
| U4        | 2  | 2  | 2  | 19 | 19  | 19  |
| U5        | 34 | 13 | 13 | 34 | 34  | 34  |
| U6        | 39 | 39 | 39 | 39 | 39  | 39  |

Table 3 Non spinning reserve in MW

| HR \ UNIT | 1    | 2    | 3    | 4    | 5    | 6    |
|-----------|------|------|------|------|------|------|
| U1        | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 |
| U2        | 1.4  | 1.4  | 1.4  | 1.4  | 1.4  | 1.4  |
| U3        | 1.4  | 1.4  | 1.4  | 1.4  | 22.2 | 2.2  |
| U4        | 3    | 3    | 3    | 29   | 29   | 29   |
| U5        | 52.3 | 21   | 52.3 | 52.3 | 52.3 | 52.3 |

Table 4. Profit of GENCOS

| HR \ UNIT | 1 | 2 | 3 | 4 | 5 | 6 | Profit (\$) |
|-----------|---|---|---|---|---|---|-------------|
| U1        | 0 | 0 | 0 | 0 | 1 | 1 | 849.5       |
| U2        | 0 | 0 | 0 | 1 | 1 | 1 | 522         |
| U3        | 0 | 0 | 1 | 1 | 1 | 1 | 1760.5      |
| U4        | 1 | 1 | 1 | 1 | 1 | 0 | 9662.5      |
| U5        | 1 | 1 | 1 | 1 | 1 | 1 | 15990       |
| U6        | 1 | 1 | 1 | 1 | 1 | 1 | 22371       |

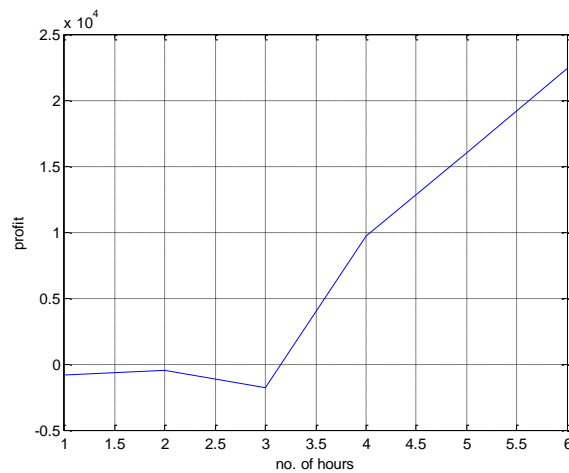


Fig 1. Variation of profit with hour

#### IV. Conclusion

In this paper, Genetic algorithm is used to solve the unit commitment problem. Considering all the operational constraints of constructed power system. Using this algorithm we obtain most economical plan for GENCOS, which is showing the best unit commitment with maximum profit. Present algorithm and analysis could be beneficial to GENCO. With the number of generators to maximize the profit and bid in electricity market.

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APPENDIX

Table No. (A) Price table

| Hour | Energy price (\$/MWh) | Spinning reserve price (\$/MWh) | Non spinning reserve price (\$/MWh) |
|------|-----------------------|---------------------------------|-------------------------------------|
| 1    | 13.70                 | 14.70                           | 15.00                               |
| 2    | 5                     | 6                               | 6.39                                |
| 3    | 12.56                 | 13.52                           | 13.80                               |
| 4    | 19.14                 | 20.12                           | 20.23                               |
| 5    | 23.7                  | 24.6                            | 25.2                                |
| 6    | 28.32                 | 24.9                            | 25.7                                |

Table No. (B) Input

| UNIT | Pmax | Pmin | SUCi  | HSCi | MUi | MDi | ISi |
|------|------|------|-------|------|-----|-----|-----|
| 1    | 150  | 455  | 9000  | 4500 | 8   | 8   | 5   |
| 2    | 150  | 455  | 10000 | 5000 | 8   | 8   | 5   |
| 3    | 20   | 130  | 1100  | 550  | 5   | 5   | 4   |
| 4    | 20   | 130  | 1120  | 560  | 5   | 5   | 4   |
| 5    | 25   | 162  | 1800  | 900  | 6   | 6   | 4   |
| 6    | 20   | 80   | 340   | 170  | 3   | 3   | 2   |

for six unit system

Table No.(C) Cost Coefficient of six unit system

| UNIT | ai  | bi    | ci     |
|------|-----|-------|--------|
| 1    | 100 | 16.19 | .0048  |
| 2    | 970 | 17.26 | .00031 |
| 3    | 700 | 16.6  | .002   |
| 4    | 680 | 16.5  | .00211 |
| 5    | 450 | 19.7  | .00398 |
| 6    | 370 | 22.26 | .00712 |