# Unit Commitment of Thermal Power Plant in Integration With Wind and Solar Plant Using Genetic Algorithm

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***Abstract*— Power sector faces the problem of the most economics unit commitment. Integration of renewable energy with the conventional power station is done the complication in the problem increases. Renewable energy is not enough to provide total demanded power. Thus coherent operation of renewable energy resources (wind and solar) with the conventional energy is a big problem. The generation schedule must meet the demand under constraint of variation of renewable generating station. The problem of unit commitment can be solved by Genetic algorithm. The Solution of Genetic algorithm can be improved by utilizing its output as initial feasible point for conventional mathematical optimization tool like quadratic programming. The solution improved by hybridizing GA is done in the project under the constraint of renewable energy integration with conventional resources. In this paper with integration of wind and solar power station the total generation cost is reduced as well as total carbon emission is also reduced.**

***Keywords*— Genetic Algorithm (GA), Unit Commitment(UC), unit commitment problem(UCP),Emission coefficient, Generation Cost***

## I INTRODUCTION

The most important problem in the scheduling of electric power generation is unit commitment. Unit commitment means scheduling of generating units for short duration to meet forecast demand of the loads. The unit commitment problem is a complex optimization problem. It has both integer and continuous variable. The recent scenario of electric power generation is installing large size power generators. This turns power system network more complex and tends our concern towards environmental pollution. Hence we need a better approach for determination of economic –emission unit commitment schedule. Before doing economic load dispatch solution, unit commitment problem should be solved. This is because, only those units are considered for generation which was allocated to generating duties by the unit commitment solution. UC is utilized in a power system for determining the different schedule of units to match the predetermined load, in a certain period. Mostly two fundamental decision is utilized which are “the unit commitment decision” and the “economic dispatch decision”. The UC decision includes the determining of the developing unit to undergoing in each hour plan horizon, consider about capability requirements, involving the spare, and the norms on the starting and stopping of the units. The requirement of the demand and its allotment and spare capability of the operating unit at certain time is considered in “economic dispatch decision”. The above two decision are interrelated to each other.

Due to introduction of renewable energy sources we can reduce the total fuel cost, quantity of carbon emission and execution time. In this paper wind energy and solar energy sources are integrated with thermal generation unit and results are compared.



*Problem Formulation and equations used*

The optimization of the total generation costs over the scheduling possibility is the basic purpose of the UC problem. The entire costs consist of,

- Fuel cost
- Start-up cost
- Shut down cost

Fuel cost is calculated using “fuel price information” as well as “unit heat rate”. Certain amount of energy is required to the units which are online because the temperature and the pressure of the plant build gradually. This energy does not result in MW output power and the cost corresponding to this action is called start up cost. Start up cost are two types ,“hot start up cost and cold start up cost” .

When the boiler is cool down and heated back to the operating temperature to turn ON generation is called cold start up cost. If boiler is in ON condition and supplied a few amount of energy to just maintain the operating temperature to turn ON generation is called hot start up cost.

Formula for Cold start up cost:

$$\text{STC}= C_c(1- \varepsilon^{\frac{-t}{\alpha}})\ \text{F}+C_f \quad (1)$$

Formula for Hot start up cost:

$$\text{STC}=C_t t\ \text{F}+C_f \quad (2)$$

Where

$C_c = cold\ start$

STC=start up cost
F=fuel cost
$C_f$ =Fixed cost includes maintenance and crew expense
$C_t$=Cost in MBtu/h for maintaining the operating temperature ofunit.
α=“thermal time constant of unit”
t=time of unit allowed to cool.
Generally shut down cost taken a constant value.

*Constraints*

- System power balance (demand + losses + exports)
- System reserve requirements
- Unit primary conditions
- Unit high and low MW limits (economic, operating)
- Unit minimum-up time
- Unit minimum-down time
- Unit status restrictions (must run, fixed-MW, unavailable, available)
- Unit rate limits
- Unit start-up ramps
- Unit shut-down ramps
- Unit flame stabilization fuel mix
- Unit dual or alternate fuel usage
- Unit or plant fuel availability
- Crew constraints

All units contain “system power balance and reserve requirement” called system or coupling constraints. Most of constraint concern entity units are called local constraints. There are many constraints which come under the local constraint entail in all units in a plant.

*Objective function*

The objective function of thermal unit commitment is to optimize the fuel cost, start up cost and fuel emission of generating units. The given function is expressed as

$$FC\,(P\,(t)) = \sum_{h=1}^{24}\sum_{i=1}^{10}(a_i + b_i P_{i,h}(t) + c_i P_{i,h}{}^2(t))U_{i,h} \; + \text{start-up cost+ fuel emission} \quad (3)$$

Such that

$$P_i^{min} \le P_i(t) \le P_i^{max}$$

$$\sum_{i=1}^{10} P_{i,h}\,(t) U_{i,h} + Wind_h + Solar_h = Demand_h \quad (4)$$

Where
$a_i$,$b_i$, $c_i$ are positive fuel cost coefficients of unit i.
U= binary operator 0 or 1 for uncommitted and committed unit respectively
Fuel emission of the power plant is considered as quadratic in nature as given by

$$\varepsilon C_i\,(P_i\,(t)) = \alpha_i + \beta_i P_i\,(t) + \gamma_i P_i^2\,(t) \quad (5)$$

Where
$\alpha_i$, $\beta_i$, $\gamma_i$ are the emission coefficients of unit i.

## II GENETIC ALGORITHM(GA) METHOD

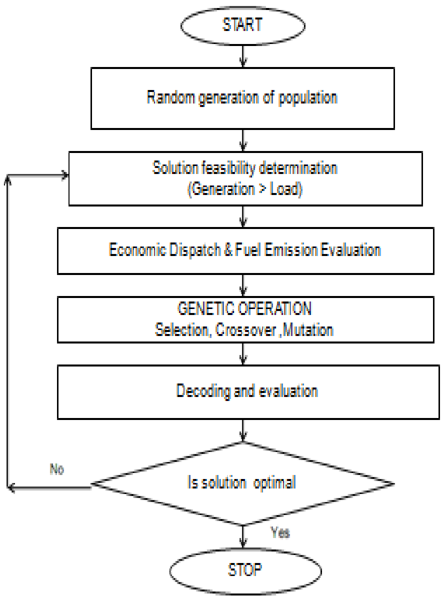
Genetic algorithm is a search method that employs processes found in natural biological evolution. These algorithms search or operate on a given population of potential solutions to find those that approach some specification or criteria. To do this, the genetic algorithm applies the principle of survival of the fittest to find better and better approximations. At each generation, a new set of approximations is created by the process of selecting individual potential solutions (individuals) according to their level of fitness in the problem domain and breeding them together using operators borrowed from natural genetics. This process leads to the evolution of population of individuals that are better suited to their environment than the individuals that they were created from, jusas in natural adaptation.

*Operators of GA*

A basic genetic algorithm comprises three genetic operators.

i. Selection
ii. Crossover
iii. Mutation

Fig. (1) flow chart of unit commitment using GA



*Generator input data and limit:*

Table 1(a) Generator input data and limit for 1-5 units

| units → | U-1 | U-2 | U-3 | U-4 | U-5 |
|---|---|---|---|---|---|
| $P_{g(Max)}$ | 455 | 455 | 130 | 130 | 162 |
| $P_{g(min)}$ | 150 | 150 | 20 | 20 | 25 |
| Minimum UP time(h) | 8 | 8 | 5 | 5 | 6 |
| minimum DOWN time(h) | 8 | 8 | 5 | 5 | 6 |
| Initial status(h) | 8 | 8 | -5 | -5 | -6 |
| a($/h) | 1000 | 970 | 700 | 680 | 450 |
| b($/Mwh) | 16.19 | 17.26 | 16.6 | 16.5 | 19.7 |
| c($/$Mw^2$h) | .00048 | .00031 | .002 | .00211 | .00398 |
| hc($/h) | 4500 | 5000 | 550 | 560 | 900 |
| Cc($/h) | 9000 | 10000 | 1100 | 1120 | 1800 |
| Tcold(h) | 5 | 5 | 4 | 4 | 4 |
| $\alpha_i$(Kg/h) | 10.33908 | 10.33908 | 30.0391 | 30.0391 | 32.00006 |
| $\beta_i$(Kg/Mw) | -.24444 | -.24444 | -.40695 | -.40695 | -.38132 |
| $\gamma_i$(Kg/$Mw^2h$) | .00312 | .00312 | .00509 | .00509 | .00344 |

Table 1(b) Generator input data and limit for 6-10 units

| units → | U-6 | U-7 | U-8 | U-9 | U-10 |
|---|---|---|---|---|---|
| $P_{g(Max)}$ | 80 | 85 | 55 | 55 | 55 |
| $P_{g(min)}$ | 20 | 25 | 10 | 10 | 10 |
| Minimum UP time(h) | 3 | 3 | 1 | 1 | 1 |
| minimum DOWN time(h) | 3 | 3 | 1 | 1 | 1 |
| Initial status(h) | -3 | -3 | -1 | -1 | -1 |
| a($/h) | 370 | 480 | 660 | 665 | 670 |
| b($/Mwh) | 22.26 | 27.74 | 25.92 | 27.27 | 27.79 |
| c($/$Mw^2$h) | .00712 | .00079 | .00413 | .00222 | .00173 |
| hc($/h) | 170 | 260 | 30 | 30 | 30 |
| Cc($/h) | 340 | 520 | 60 | 60 | 60 |
| Tcold(h) | 2 | 2 | 0 | 0 | 0 |
| $\alpha_i$(Kg/h) | 32.00006 | 33.00056 | 33.00056 | 35.00056 | 36.00012 |
| $\beta_i$(Kg/Mw) | -.38132 | -.39023 | -.39023 | -.39524 | -.398664 |
| $\gamma_i$(Kg/$Mw^2h$) | .00344 | .00465 | .00465 | .00465 | .0047 |

Load demand
Table (2)

| Hour | Power demand(MW) | Hour | Power Demand(MW) |
|---|---|---|---|
| 1 | 700 | 13 | 1400 |
| 2 | 750 | 14 | 1300 |
| 3 | 850 | 15 | 1200 |
| 4 | 950 | 16 | 1050 |
| 5 | 1000 | 17 | 1000 |
| 6 | 1100 | 18 | 1100 |
| 7 | 1150 | 19 | 1200 |
| 8 | 1200 | 20 | 1400 |
| 9 | 1300 | 21 | 1300 |
| 10 | 1400 | 22 | 1100 |
| 11 | 1450 | 23 | 900 |
| 12 | 1500 | 24 | 800 |

Renewable energy schedule
Table (3)

| Hour | Wind Generation | Solar Generation | Hour | Wind Generation | Solar Generation |
|---|---|---|---|---|---|
| 1 | 10.54 | 0 | 13 | 25.5 | 36.78 |
| 2 | 25.27 | 0 | 14 | 24.82 | 31.59 |
| 3 | 25.5 | 0 | 15 | 20.74 | 9.7 |
| 4 | 25.5 | 0 | 16 | 14.62 | 12.92 |
| 5 | 25.5 | 0 | 17 | 25.5 | 0 |
| 6 | 25.5 | 0 | 18 | 19.04 | 0 |
| 7 | 25.5 | 0.09 | 19 | 25.5 | 0 |
| 8 | 25.5 | 17.46 | 20 | 18.02 | 0 |
| 9 | 25.5 | 31.45 | 21 | 25.5 | 0 |
| 10 | 25.5 | 36.01 | 22 | 21.42 | 0 |
| 11 | 25.5 | 38.06 | 23 | 0 | 0 |
| 12 | 25.5 | 35.93 | 24 | 2.55 | 0 |

## III RESULT

*GA PARAMETER*

- ***Population Size=25***
- ***Generations=304***
- ***Crossover Probability=0.9***
- ***Mutation Probability=0.01***

The problem of economic load dispatch is Tested for ten thermal generators units and three Condition is taken.

***1-*** Generation schedule without renewable energy sources:

2) Generation schedule with wind energy source:

3) Generation schedule with wind +solar energy source:

For each case which set of generators is going to be on is decided and then their generation is decided ,so that total Cost of production is least.

Table 4(a) Unit commitment schedule without renewable energy resources:

| Hour | U-1 | U-2 | U-3 | U-4 | U-5 | U-6 | U-7 | U-8 | U-9 | U-10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 3 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 4 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| 5 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| 6 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| 7 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 |
| 8 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| 9 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 |
| 10 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 11 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 12 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 13 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 14 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 15 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 16 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 |
| 17 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| 18 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| 19 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 20 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 21 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 22 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 23 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| 24 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |

Table 4(b) Generation schedule without renewable energy sources:

| Hour | U-1 | U-2 | U-3 | U-4 | U-5 | U-6 | U-7 | U-8 | U-9 | U-10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 455 | 235 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| 2 | 455 | 220 | 0 | 0 | 0 | 0 | 0 | 55 | 10 | 10 |
| 3 | 455 | 185 | 130 | 0 | 0 | 0 | 25 | 55 | 0 | 0 |
| 4 | 455 | 275 | 130 | 0 | 0 | 0 | 25 | 55 | 0 | 10 |
| 5 | 455 | 305 | 130 | 0 | 0 | 20 | 25 | 55 | 10 | 0 |
| 6 | 455 | 395 | 130 | 0 | 0 | 20 | 25 | 55 | 10 | 10 |
| 7 | 455 | 325 | 130 | 130 | 0 | 20 | 25 | 55 | 10 | 0 |
| 8 | 455 | 420 | 130 | 130 | 0 | 20 | 25 | 0 | 10 | 10 |
| 9 | 455 | 455 | 130 | 130 | 0 | 40 | 25 | 55 | 10 | 0 |
| 10 | 455 | 455 | 130 | 130 | 120 | 20 | 25 | 55 | 10 | 0 |
| 11 | 455 | 455 | 130 | 130 | 162 | 28 | 25 | 55 | 0 | 10 |
| 12 | 455 | 455 | 130 | 130 | 162 | 68 | 25 | 55 | 10 | 10 |
| 13 | 455 | 455 | 130 | 130 | 120 | 20 | 25 | 55 | 10 | 0 |
| 14 | 455 | 455 | 130 | 130 | 30 | 20 | 25 | 55 | 0 | 0 |
| 15 | 455 | 395 | 130 | 130 | 25 | 20 | 25 | 0 | 10 | 10 |
| 16 | 455 | 285 | 130 | 130 | 25 | 0 | 25 | 0 | 0 | 0 |
| 17 | 455 | 205 | 130 | 130 | 25 | 0 | 0 | 55 | 0 | 0 |
| 18 | 455 | 285 | 130 | 130 | 25 | 0 | 0 | 55 | 10 | 10 |
| 19 | 455 | 395 | 130 | 130 | 25 | 0 | 0 | 55 | 10 | 0 |
| 20 | 455 | 455 | 130 | 130 | 110 | 20 | 25 | 55 | 10 | 10 |
| 21 | 455 | 440 | 130 | 130 | 25 | 20 | 25 | 55 | 10 | 10 |
| 22 | 455 | 380 | 0 | 130 | 25 | 20 | 25 | 55 | 10 | 0 |
| 23 | 455 | 210 | 0 | 130 | 25 | 0 | 25 | 55 | 0 | 0 |
| 24 | 455 | 230 | 0 | 0 | 25 | 0 | 25 | 55 | 0 | 10 |

Table 5(a) Unit commitment schedule with wind energy source:

| Hour | U-1 | U-2 | U-3 | U-4 | U-5 | U-6 | U-7 | U-8 | U-9 | U-10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 3 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 |
| 4 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 |
| 5 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 6 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 |
| 7 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 8 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 9 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 10 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 11 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 12 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 13 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| 14 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 15 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 16 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| 17 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 18 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 19 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 |
| 20 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| 21 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 22 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 23 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 24 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |

Table 5(b) Generation schedule with wind energy source:

| Hour | U-1 | U-2 | U-3 | U-4 | U-5 | U-6 | U-7 | U-8 | U-9 | U-10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 455 | 234 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 455 | 198 | 0 | 0 | 0 | 0 | 0 | 55 | 10 | 10 |
| 3 | 455 | 255 | 0 | 0 | 25 | 0 | 25 | 55 | 10 | 0 |
| 4 | 455 | 364 | 0 | 0 | 25 | 0 | 25 | 55 | 0 | 0 |
| 5 | 455 | 374 | 0 | 0 | 25 | 20 | 25 | 55 | 10 | 10 |
| 6 | 455 | 354 | 130 | 0 | 25 | 20 | 25 | 55 | 0 | 10 |
| 7 | 455 | 394 | 130 | 0 | 25 | 20 | 25 | 55 | 10 | 10 |
| 8 | 455 | 315 | 130 | 130 | 25 | 20 | 25 | 55 | 10 | 10 |
| 9 | 455 | 455 | 130 | 130 | 40 | 20 | 25 | 0 | 10 | 10 |
| 10 | 455 | 455 | 130 | 130 | 84 | 20 | 25 | 55 | 10 | 10 |
| 11 | 455 | 455 | 130 | 130 | 145 | 20 | 25 | 55 | 0 | 10 |
| 12 | 455 | 455 | 130 | 130 | 162 | 42 | 25 | 55 | 10 | 10 |
| 13 | 455 | 455 | 130 | 130 | 149 | 20 | 25 | 0 | 0 | 10 |
| 14 | 455 | 455 | 130 | 130 | 60 | 20 | 25 | 0 | 0 | 10 |
| 15 | 455 | 319 | 130 | 130 | 25 | 20 | 25 | 55 | 10 | 10 |
| 16 | 455 | 220 | 130 | 130 | 25 | 20 | 0 | 55 | 0 | 0 |
| 17 | 455 | 235 | 130 | 130 | 25 | 0 | 0 | 0 | 0 | 0 |
| 18 | 455 | 321 | 130 | 130 | 25 | 0 | 0 | 0 | 10 | 10 |
| 19 | 455 | 424 | 130 | 130 | 25 | 0 | 0 | 0 | 10 | 0 |
| 20 | 455 | 455 | 130 | 130 | 112 | 0 | 25 | 55 | 10 | 10 |
| 21 | 455 | 425 | 130 | 130 | 25 | 20 | 25 | 55 | 0 | 10 |
| 22 | 455 | 359 | 0 | 130 | 25 | 20 | 25 | 55 | 0 | 10 |
| 23 | 455 | 310 | 0 | 0 | 25 | 20 | 25 | 55 | 10 | 0 |
| 24 | 455 | 307 | 0 | 0 | 25 | 0 | 0 | 0 | 10 | 0 |

Table 6(a) Unit commitment schedule with wind+solar energy source:

| Hour | U-1 | U-2 | U-3 | U-4 | U-5 | U-6 | U-7 | U-8 | U-9 | U-10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| 4 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| 5 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| 6 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| 7 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 |
| 8 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 9 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| 10 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 11 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 12 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 13 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 14 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 15 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 16 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 17 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 18 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| 19 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| 20 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 21 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 22 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 |
| 23 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 24 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 6(b) Generation schedule with wind +solar energy source:

| Hour | U-1 | U-2 | U-3 | U-4 | U-5 | U-6 | U-7 | U-8 | U-9 | U-10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 455 | 234 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 455 | 248 | 0 | 0 | 0 | 0 | 25 | 0 | 0 | 0 |
| 3 | 455 | 314 | 0 | 0 | 0 | 20 | 25 | 0 | 10 | 0 |
| 4 | 455 | 239 | 130 | 0 | 0 | 20 | 25 | 55 | 0 | 0 |
| 5 | 455 | 280 | 130 | 0 | 0 | 20 | 25 | 55 | 10 | 0 |
| 6 | 455 | 249 | 130 | 130 | 0 | 20 | 25 | 55 | 0 | 10 |
| 7 | 455 | 299 | 130 | 130 | 0 | 20 | 25 | 55 | 10 | 0 |
| 8 | 455 | 297 | 130 | 130 | 25 | 20 | 25 | 55 | 10 | 10 |
| 9 | 455 | 448 | 130 | 130 | 25 | 20 | 25 | 0 | 0 | 10 |
| 10 | 455 | 455 | 130 | 130 | 48 | 20 | 25 | 55 | 10 | 10 |
| 11 | 455 | 455 | 130 | 130 | 151 | 20 | 25 | 0 | 10 | 10 |
| 12 | 455 | 455 | 130 | 130 | 149 | 20 | 25 | 55 | 10 | 10 |
| 13 | 455 | 455 | 130 | 130 | 48 | 20 | 25 | 55 | 10 | 10 |
| 14 | 455 | 384 | 130 | 130 | 25 | 20 | 25 | 55 | 10 | 10 |
| 15 | 455 | 320 | 130 | 130 | 25 | 20 | 25 | 55 | 10 | 0 |
| 16 | 455 | 302 | 0 | 130 | 25 | 20 | 25 | 55 | 10 | 0 |
| 17 | 455 | 345 | 0 | 130 | 25 | 20 | 0 | 0 | 0 | 0 |
| 18 | 455 | 396 | 0 | 130 | 25 | 20 | 0 | 55 | 0 | 0 |
| 19 | 455 | 455 | 0 | 130 | 49 | 20 | 0 | 55 | 10 | 0 |
| 20 | 455 | 455 | 0 | 130 | 162 | 80 | 25 | 55 | 10 | 10 |
| 21 | 455 | 425 | 130 | 130 | 25 | 20 | 25 | 55 | 0 | 10 |
| 22 | 455 | 304 | 130 | 130 | 25 | 0 | 25 | 0 | 10 | 10 |
| 23 | 455 | 250 | 130 | 0 | 0 | 0 | 0 | 55 | 10 | 0 |
| 24 | 455 | 212 | 130 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 7 Total fuel emission and fuel cost for various combination of generating units:

| POWER SOURCE | FUEL EMISSION(TON/HR) | COST($/H) |
|---|---|---|
| THERMAL | 1081.8044 | 24503.4208 |
| THERMAL+WIND | 1062.2702 | 23829.8090 |
| THERMAL+WIND+SOLAR | 1051.7715 | 23672.3093 |

**Processor and RAM of my computer**

- Processor: AMD A4-3330 MX APU @ 2.20 GHz
- RAM: 2.00GB
- System type: 64 bit operating system

**MATLAB 2011** used for the execution of the program

Total execution time

| POWER SOURCE | Execution Time(sec) |
|---|---|
| THERMAL | 24 |
| THERMAL+WIND | 18 |
| THERMAL+WIND+SOLAR | 12 |



## IV CONCLUSION

Cost of generation is reduced due to introduction of renewable energy resources, so profit of generation company is will increase Carbon emission is reduced so it is better for environment and society. Generators dispatch power within limit so it will increase generator life Total execution time for the calculation of fuel cost and fuel emission is reduced by using GA.

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