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# An Solution for Unit Commitment Problem of Wind and PV based Smart Grid using BAT Algorithm

**Md. Asif, Sardar Ali, N. Sambasiva Rao, K. Jaiganesh**

***Abstract:** With the technological advancement, renewable energy sources are becoming more integrated to grid. With the smart grid technologies, the renewable energy sources will penetrate more into the grid. With increase of penetration of these renewable sources, will affect the unit commitment process. This paper concentrate the inducing Hybrid renewable energy sources in the smart grid. Unit commitment problem of Hybrid renewable energy sources into a smart grid is discussed in this paper . The IEEE reliable 24 bus system is considered to test the proposed unit commitment problem using bat algorithm. The paper shows the reduction of production cost when the penetration of wind power into the power system.*

***Keywords:**Unit Commitment, dynamic programming, wind and solar penetration, bat algorithm*

## I. INTRODUCTION

The new advantages of technology integration leads to more secure and reliable control of grids, leads to the smart grids. Smart grids is the integration of software and communication layer over the conventional power system grid. With integration of renewable energy sources, with the advantage of two communication, the generation commitment can be according to dynamic and prioritised based load curves.

The renewable energy sources are penetrating more into power system day by day. This penetrations arises new challenges of uncertain power generation commitment.

The Scheduling of Generated energy as per the demand in electricity production is concerned with the fuel cost based scheduling of on/off decisions and output levels for generating units in a power system over a certain time zone and it can be split into Unit Commitment and Economic load dispatch problems.

Unit commitment gives the scheduling of generators over a time horizon subjected to minimum up and down constraints.

Economic load dispatch deals with the scheduled generator operating output based on fuel cost of particular generator for given load.

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* Correspondence Author
**Md Asif***, Associte Professor/EEE ,Vardhaman College of Enginering, asif_eee@rediffmail.com
**Dr Sardar Ali**, Professor/ EEE, Deccan College of Engineering, dr.saliswcc@gmail.com
**Dr. N. Sambasiva Rao,** Professor/ EEE , Swarna Bharti Institute of Technology, snandam@gmail.com
**Dr. K. Jaiganesh,** Professor, EEE, Vardhaman College of Engineering, jaiganesh@vardhaman.org



These problem combinations leads to complex solution. Many deterministic methods are available to solve these unit commitment problem also economic load dispatch. Here economic load dispatch is achieved using lambda iterative method.

The unit commitment with different analytical methods like priority list method and dynamic programming discussed in [2] deeply. The feasible generator group can be identified on the base of the priority using production cost of full load average. Dynamic programming is based on strict priority list. This makes the enumeration simple and makes the solution faster. The priority list enumeration can be formulated based on different object function by combining economic load dispatch or minimum ramp up or down limit constraints. The objective function can be solved by conventional methods like non-linear integer programming and by heuristic techniques like Genetic algorithm (GA), binary coded GA, and artificial bee colony [1], [4], [5] and [6].

In this paper bat algorithm based unit commitment is proposed, with penetration of wind and solar energy sources. The introduction and literature survey presented in section I, Section II deals with problem formulation consists of modelling of wind turbine generator, modelling of photovoltaic cell and its characteristics, unit commitment using dynamic programming, bat algorithm. Section III deals with results, which discuss about the various effects of penetration of renewable sources on unit commitment problem. Section IV deals with conclusion.

## II. METHODOLOGY

### 2.1 A Wind Turbine Generator Model

The wind power is converted into electrical energy wind turbines. For large scale power generation horizontal wind turbines are most preferred, which converts the wind rotational power into electrical power. The generated power from the wind turbine is directly proportional to (velocity)$^3$ of wind, swept area of by rotor of wind turbine. The efficiency of practical wind turbine is limited by Betz limit, is around 59.2%. The wind turbine power output is given by

$$P_T = \frac{1}{2}\,\rho\, A\, v^3 C_P \qquad (1)$$

Where PT is power output of the turbine, ρ is air density, v is velocity, CP is Power coefficient, is the ratio extracted by turbine (PT) to total power of wind (PW), $C_p = \frac{P_T}{P_W}$.

### 2.2Solar Cell Modelling

photovoltaic effect is the working principle of photovoltaic (PV) cell.

PV cell is made of two types of semiconductor materials, one is positively charged another is negatively charge and are combined to form P-N junction.

When the PV cell is exposed to solar irradiation, electrons-hole pairs are produced due to incident of photos. This acts like a P-N junction diode. The V-I characteristics of photovoltaic cell is given as

$$I = I_P + I_O \left(e^{\frac{qV}{nKT}} - 1\right) \quad (2)$$

Where $I_P$ is the photon current , $I_o$ is reverse saturation current and the Equation resembles diode characteristics excluding photon current. When the practical PV cell can be modelled with a shunt and series resistors across the diode and the current source. Where the series and shunt resistors are equivalent resistances when the PV is connected to load. The PV characteristic equation is obtained from equivalent circuit shown below. The Output current equation when PV connected with load is given by

$$I = I_P + I_O \left(e^{\frac{q(V+IR_S)}{nKT}} - 1\right) + \left(\frac{V+IR_S}{R_{sh}}\right) \quad (3)$$

Where Rs is the equivalent resistance in series and Rsh equivalent resistance of shunt. The equivalent circuit is given by

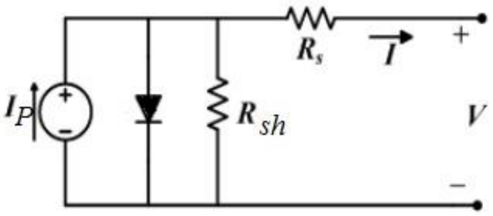


**Fig. 1 PV model**

### 2.2.1 Voltage -Current characteristics of Photo Voltaic cell

when the sunlight falls on the PV cells, the current flowing through the PV cell is $I_P$, and it is due to photons. At this instant the voltage across the PV cell is zero. This current is the short circuit current of the PV cell and it is given as

$$I_{sc} = I_P \text{ when } V = 0 \quad (4)$$

When Photo Voltaic current passes through the PV cell a terminal voltage will be developed across the PV cell. When the PV cell output current is zero, the terminal voltage, the open circuit voltage is given by

$$V_{OC} = \frac{KT}{q} \ln \frac{I_P}{I_O} \quad (5)$$

From the above equations V-I characteristics can be determined and they depend on solar irradiation as well as the temperature of PV cell. The solar irradiation is directly proportional to current $I_P$ .but the temperature effects the PN junction characteristics. The relation between photon current and solar irradiation is given as

$$I_P(G) = \frac{G}{G_O} I_P(G_O) \quad (6)$$

## III. UNIT COMMITMENT

Unit commitment is determination of available power generators for given load based on their economic load dispatch. The unit commitment can be solved by Priority List method and dynamic programing method. Priority list method based on enumeration scheme of generators.

The photon programming is good over the enumeration scheme, the chief advantage being a reduction in the dimensionality of the crisis. Based on the average cost rate of full load a strict priority is made. This reduces the problem complexity.

To compute the minimum cost in hour K the algorithm used is ,

Fcost(I,K)= min[Pcost(I,K)+Scost(K-1,L:K,I)+Fcost(K-1,L)] (7)

Where

Fcost(I,K)=least total cost to arrive at state(I,K)

Pcost(I,K)= production cost for state(I,K)

Scost(K-1,L:K,I)= transition cost from state (K-1,L) to state (I,K)

## IV. BAT ALGORITHM

This Bat algorithm is a metaheuristic algorithm. and it is based on the echo-location sensing of the bats. Bats use sonar sensing called, echolocation to detect prey, avoid obstacles, and locate their roosting crevices in the dark. These bats emit a very loud sound pulse and listen for the echo that bounces back.

Bats fly at a velocity Vi when at a position xi with frequency f(Fixed), wavelength λ(varying) and loudness A to search for prey and can automatically adjust the wavelength (or frequency) of their emitted pulses and adjust the rate of pulse emission r ∈ [0, 1], depending on the proximity of their goal

Though the loudness varies in many ways but we consider that the loudness changes from a big (positive) $A_0$ to a minimum constant value $A_{min}$.

Objective function f(x), x = (x1, x2……xn)
Initialize the bat population xi
Initialize the pulse frequency fi at xi
Initialize pulse rates r , loudness A
when (t <Max number of iterations)
Generate solutions by varying frequency,
and update velocities and locations/solutions

$$f_i = f_{min} + (f_{max} - f_{min})\beta \quad (8)$$

Where β is random variable

$$v_i^t = v_i^{t-1} + (x_i^t - x_*)f_i \quad (9)$$

$$x_i^t = x_i^{t-1} + v_i^t \quad (10)$$

Where x* current global best location
if (rand > r)
Identify a best solution among the available solutions
Obtain a local solution around the selected best solution
end if
Obtain solution by flying randomly
if (rand < A & f(xi) < f(x*))
Finalize the new solution
Raise R and decrease A
end if

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Rank the bats and find the current best x*
end while
Post process results and visualization

## V. RESULTS

IEEE 24 bus reliable test system is taken as test case in this paper. 24 bus system consists 33 generators at 10 buses. These 33 generators of Fossil-oil, Fossil-coal, nuclear, thermal and hydro power plant type. To simulate the addition of wind power the wind generator is placed on the 14th bus.

The load of on 24 bus system is given below in figure 2. The load curve is having the evening peak characteristics.

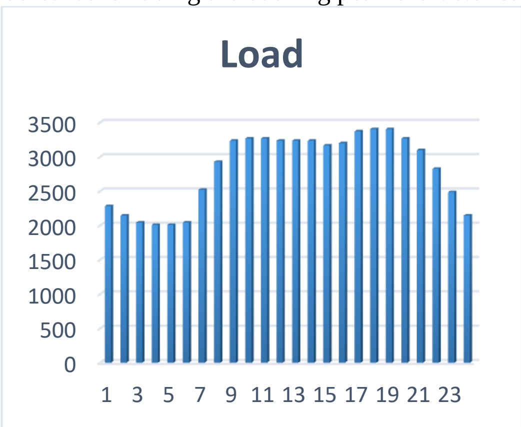



**Fig. 2 Load data for 24 hours**

Wind speeds for 24 hours span is taken from the Iowa Environmental Mesonet. The speed of the is shown in the figure3. The wind power is calculated based on speed of the wind and based on equation (1). The renewable energy penetration is taken as 30% of maximum load on the power system. The typical wind generation for 24 is shown in figure 4.

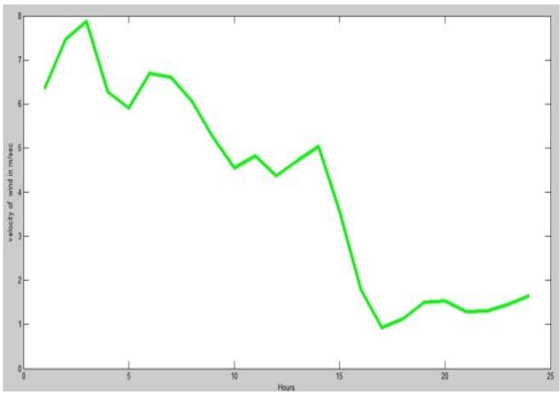


**Fig. 3 wind speed vs 24 hours**

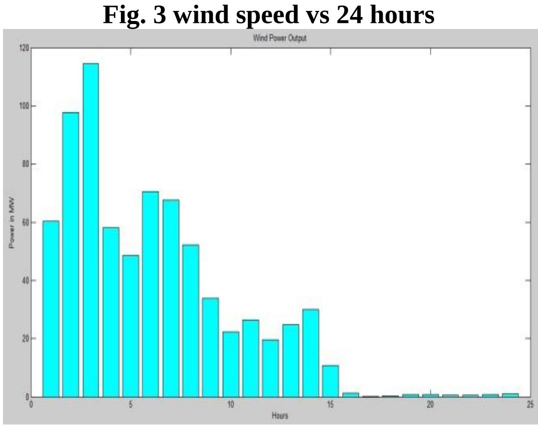


**Fig.4 Wind Power generated for 24 hours**

The solar cell characteristics are simulated based on equations (3), (4), (5) and the V-I, P-V characteristics of a single PV cell is shown in figure 5 and 6. The modelling is done based on practical PV module [4]. The power generated from solar panels is calculated based on equation (3). The Power generated from solar panels over a period of 24 hours shown in figure 7.

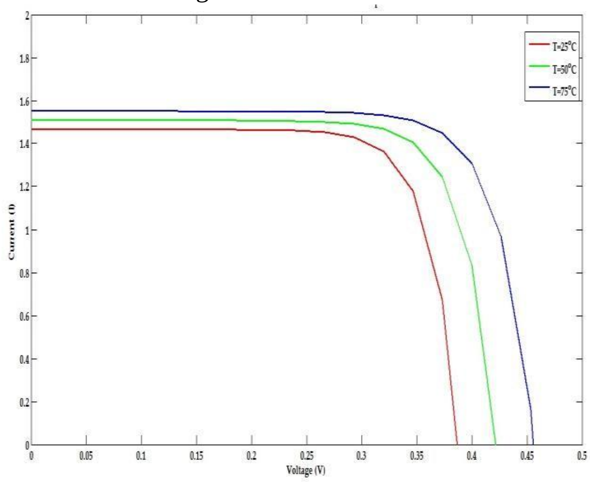


**Fig. 5 PV cell V-I characteristics.**

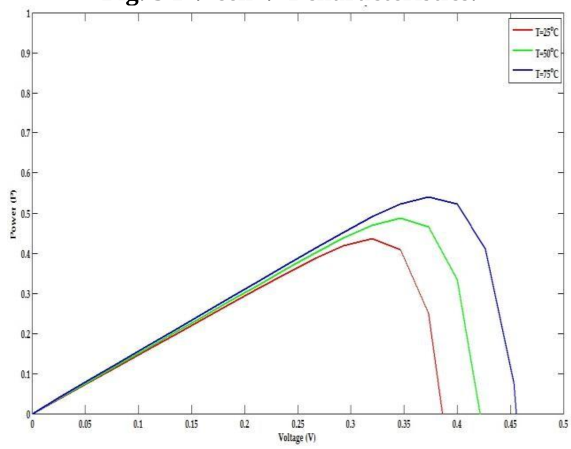


**Fig. 6 PV cell V-P characteristics.**

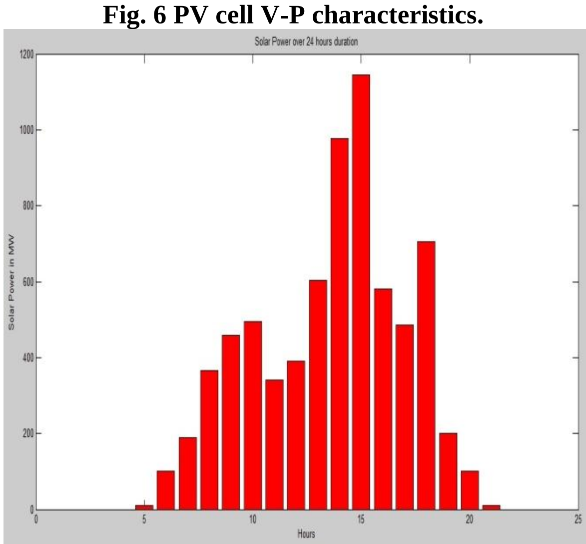
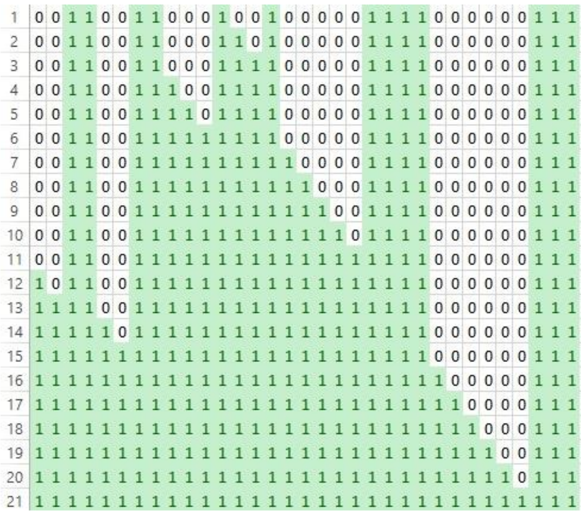


**Fig. 7 PV Power generated for 24 hours.**

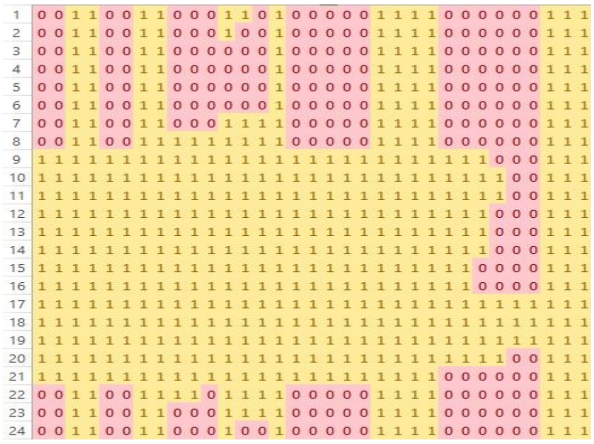
The unit commitment is determined based on the bat algorithm. The unit commitment problem includes economic load dispatch problem. It is solved based on lambda-iterative method. The process is done for both the cases that is without wind power penetration and with wind power penetration in to the power system. The typical feasible states at 4th hour without wind penetration is shown in figure 8.



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

**Fig. 8 the typical feasible states at 4th hour without wind penetration**

The typical final states (On and off) of the generator over a period of 24 shown in figure 9. The On state of generator is represented with 1 whereas off state of generator is represented with 0.



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

**Fig 9 scheduling of generator for 24 hours**

The operating costs with the load on power system for 24 hours is shown in table 1. The cost and state transition costs comparison between without wind penetration and with wind penetration shown in table 1

**Table 1 Comparison of cost with and without renewable energy source**

| Hours | Energy Units | Cost(Rs) with Conventional Generation | Cost(Rs) with wind Power added | Cost(Rs) with wind and solar Power added | State Transition Cost | State Transition Cost with wind power | State Transition Cost with wind and solar power |
|---|---|---|---|---|---|---|---|
| 1 | 2280.68 | 23528.69 | 23528.69 | 23528.69 | 0 | 0.00 | 0.00 |
| 2 | 2144.52 | 43775.18 | 43775.18 | 43775.18 | 0 | 0.00 | 0.00 |
| 3 | 2042.4 | 61733.74 | 61733.74 | 61733.74 | 0 | 0.00 | 0.00 |
| 4 | 2008.36 | 79202.12 | 79202.12 | 79202.12 | 0 | 0.00 | 0.00 |
| 5 | 2008.36 | 96670.5 | 96670.50 | 96670.50 | 0 | 0.00 | 0.00 |
| 6 | 2042.4 | 114629.1 | 114629.06 | 114629.06 | 0 | 0.00 | 0.00 |
| 7 | 2518.96 | 146751.5 | 146751.48 | 146751.48 | 3056.7 | 3056.70 | 3056.70 |
| 8 | 2927.44 | 187282.9 | 187282.88 | 187282.88 | 1725 | 1725.00 | 1725.00 |
| 9 | 3233.8 | 249864.6 | 233295.56 | 233295.56 | 1867.4 | 0.00 | 0.00 |
| 10 | 3267.84 | 315578.8 | 236782.16 | 236782.16 | 0 | 0.00 | 0.00 |
| 11 | 3267.84 | 381293.1 | 285421.03 | 284863.43 | 0 | 1152.20 | 794.60 |
| 12 | 3233.8 | 442007.4 | 288929.23 | 288371.63 | 0 | 0.00 | 0.00 |
| 13 | 3233.8 | 502721.7 | 336057.26 | 335499.66 | 0 | 707.20 | 707.20 |
| 14 | 3233.8 | 563436 | 382113.14 | 381555.54 | 0 | 0.00 | 0.00 |
| 15 | 3165.72 | 619150.2 | 385599.74 | 385042.14 | 0 | 0.00 | 0.00 |
| 16 | 3199.76 | 674864.5 | 391861.74 | 391304.14 | 0 | 1867.40 | 1867.40 |
| 17 | 3369.96 | 750578.8 | 467778.54 | 420698.74 | 0 | 0.00 | 0.00 |
| 18 | 3404 | 826293.1 | 543730.80 | 496948.76 | 0 | 0.00 | 0.00 |
| 19 | 3404 | 902007.4 | 619785.58 | 573309.98 | 0 | 0.00 | 0.00 |
| 20 | 3267.84 | 967721.6 | 685854.02 | 634689.24 | 0 | 0.00 | 0.00 |
| 21 | 3097.64 | 1013116 | 731304.24 | 638883.84 | 0 | 0.00 | 0.00 |
| 22 | 2825.32 | 1049413 | 767601.88 | 675181.48 | 0 | 0.00 | 0.00 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23 | 2484.92 | 1077728 | 795916.00 | 703495.59 | 0 | 0.00 | 0.00 |
| 24 | 2144.52 | 1097974 | 816162.48 | 723742.07 | 0 | 0.00 | 0.00 |

The comparison shows the with wind penetration the operating cost is reduced over a period of time. The same can be seen in figure 10.

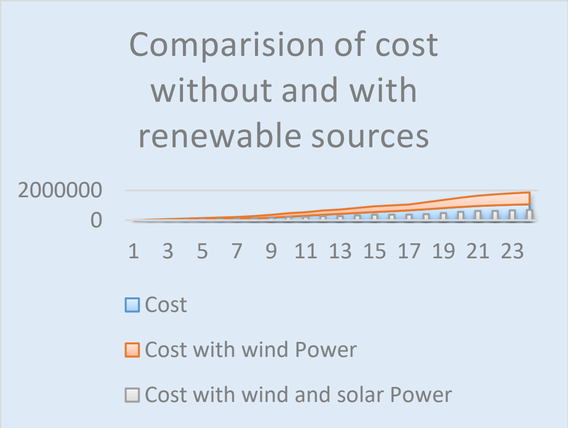



**Fig.10 comparison of costs without and with solar and wind addition**

## VI. CONCLUSION

The renewable energy sources penetration is predominantly increasing in recent years. With the increase of wind and solar power penetration into power system reduces per unit cost of production of the energy.The bat algorithm is used to improve the performance of the unit commitment problem.

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## AUTHORS PROFILE

**Md Asif** completed his B.Tech from Dr Paul Raj College of Engineering in the year 2002 .He Completed his M.Tech in the year 2009 from Jawaharlal Nehru Technological University Anantapur and currently he is pursuing his Ph.D from Jawaharlal Nehru Technological University, Hyderabad. He has a teaching experience of around 17 years.He is currently working as Associate professor in the department of Electrical and Electronics Engineering at Vardhaman College of Engineering, An Autonomous Institute,Affiliated to Jawaharlal Nehru Technological University . His research area is Micro Grids,Smart grid. He has published around 10 papers in the area of Hybrid renewable energy resources.

**Dr. Sardar Ali** received his Bachelor Degree from The Institute of Engineers in the year 2000.Dr Sardar Ali received his M.Tech from Jawaharlal Nehru Technological University Anantapur in the year 2004 .He received his Ph.D. from Jawaharlal Nehru Technological University Anantapur, in the year ,2009. He is having a teaching experience of 23 years at various Institues at various levels.He has a Industrial Experience of around 15 Years in India and abroad. Dr sardar Ali is currently working as Professor and Head in the Department of Electrical and Electronics Engineering at Deccan College of Engineering affiliated to Osmania University ,Hyderabad.

**Dr. N.Sambasiva Rao** is having a teaching experience of 30 years at various Institutes at different positions. He works as principal and professor at vardhaman College of Engineering affiliated to Jawaharlal Nehru Technological University ,Hyderabad for around 3 years. He is currently working as Professor in Swarna Bharathi Institute of Technology,Khammam Jawaharlal Nehru Technological University ,Hyderabad. He has guided more than 30 students at Post Graduate level and above 50 projects under Undergraduate level. Currently he is guiding 6 Ph.D scholars .Two of his Ph.D scholars are awarded with PhD Degree.
His research areas include Renewable Energy sources, cloud computing. He has published more than 3o papers in reputed journals and conferences

**Dr.Jai Ganesh** received **UG Degree** in EEE, 2002, from Sapthagiri College of Engineering and his PG degree **PG Degree** in Power Electronics and Drives, 2006, Bharath Institute of Science and Technology and his Ph.D in Electrical Engineering 2015, Anna University