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Optimizing Hybrid Wind/Diesel Generator System Using BAT Algorithm

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ABSTRACT
Hybrid system comprising of Wind/Diesel generation system for a practical standalone application considers Wind turbine generators and diesel generator as primary power sources for generating electricity. Battery banks are considered as a backup power source. The total value of cost is reduced by meeting energy demand required by the customers. Bat optimization technique is implemented to optimize wind and battery modules. Wind and battery banks are considered as primary sources and diesel generator as a secondary power source for the system
Keywords: Hybrid Wind- Diesel system, Bat optimization, optimal sizing.

I. INTRODUCTION

With the increase in the power demand and decrease in the fossil fuels, mankind has been forced to search new alternative techniques to fulfill the energy demand. Power can be generated from non conventional resources of energy such as solar, hydropower, wind, geothermal, oceans and many more. These are the renewable sources of energy. Energy obtainable from such sources is pollution free. Moreover these sources are available in plenty. Many techniques have been put forward to generate electricity from renewable energy sources [1]. Solar radiations have been utilized to generate electricity on small as well as on large scale. But these solar radiations are not available at night. Similarly power of wind speed can be utilized to rotate the rotor of wind turbine generators that can produce immense amount of electricity. But as wind speed depends upon the climatic conditions. Therefore hybrid combination can be used to obtain the uninterrupted supply from these renewable sources. This combination can be with diesel generator and battery banks. Battery banks are used to store the charge.The immense amount of energy produced by renewable resources can be used to charge the battery banks which can be used later when required. Diesel generator serves as a primary back up power generation source. Considering the effect of atmospheric emissions and need of fuel, diesel generator should not be used as primary power generation source. But only be used as back up power source [2].

Renewable resources offers various advantages like they are available in large amount, environment friendly, do not require any fuel, do not leave any harmful pollutants behind. On the other hand they offer some disadvantages too like they are difficult and costly to install.

Hybrid system comprising of wind turbine units with battery banks and diesel generator as backup power source has the potential to supply power to stand alone stations that are still not connected to utility lines

The speed of wind was used earlier for propelling ships, water pumping from wells, for irrigation purposes and numerous other purposes [3].

By 1990s wind energy to electrical energy has become economically competitive in areas of favourable wind (e.g. Gujarat, Tamil Nadu) and wind-electric energy projects are now on the forefront of renewable energy utilization projects sponsored by the Department of Non Conventional Renewable Energy (DNRE) [5].

Wind Turbine Generator (WTG) units are the most promising technologies to serve the load for rural and stand alone areas. However a drawback common for these units is the unpredictable climatic conditions. Sometimes over sizing of wind turbine units can serve the purpose but it makes the system expensive. Hence the hybrid system compromising of wind/diesel generator units with battery storage can be more reliable that also reduces the cost of system.
R. Ramakumar and Imad proposed a solution for LPSP problem for standalone wind energy conversion system having energy storage system with assumptions – load is uniformly distributed and load, wind speed are statistically independent [3].

II. HYBRID SYSTEM DESIGN

The design of hybrid system for the energy provision of remote rural area comprises of three major subsystems: wind turbine units, battery banks and diesel generator. The operational and modelling strategy of these subsystems has been explained in the following subsections. Load of one day is shown in figure 2.

2. A. Wind Power

The power output of wind units is calculated hourly from various hub heights. The speed of wind is measured at different hub heights. The historical data gives the wind speed at various hub heights. In the area under study, this wind speed can be found at three different hub heights and calculated by interpolation [1]. The expression for calculating the wind speed with reference to the reference height is given by:

$$v(t) = v_r(t).\left(\frac{h}{h_r}\right)^{\gamma} \quad (1)$$

v_r *is speed of wind at reference height*
γ is power law exponent

At a very low wind speeds, the wind turbines do not rotates. As the speed of wind increases, the wind turbine starts rotating and gives power output. The speed associated with this level is called cut in speed. As the wind speed increases, more power is generated. The maximum power obtainable from wind speed generators is called rated power output and speed associated with this power is called rated wind speed. But sometimes due to the drastic weather conditions, wind speed attains large values; this type of wind speed can cause damage to the wind turbine generator. So braking systems are provided that do not allow the rotor to rotate. The speed associated with this level is called cut out speed. With large turbine generators, as the wind speed attains large value, rotor blades are adjusted by blade angle control technique. By Considering this explanations, gives the electrical power output of a wind turbine is represented by piece vice linear equation 2. Four different types of wind turbines with different hub heights and turbine diameters are considered for the simulation process [1], shown in the table 1.

$$p_{w,j}(t) = \begin{cases} 0 , & v_j(t) < v_{ci,j} \\ p_{w,j}^{rated} . \frac{v_j(t) - v_{ci,j}}{v_j^{rated} - v_{ci,j}} , & v_{ci,j} \le v_j(t) < v_j^{rated} \\ p_{w,j}^{rated} , & v_j^{rated} \le v_j(t) \le v_{co,j} \\ 0 , & v_{co,j} \le v_j(t) \end{cases} \quad (2)$$

Where,

v_{ci} *is cut in speed*
v^{rated} *israted output speed of wind*
v_{co} *is cut out wind speed*
p_w^{rated} *israted power output*
j indicates type of wind turbine

Table 1

Characteristics of different types of wind turbines [1]

TYPE	1	2	3	4
v_{ci}	3.5	3	3.5	3
v^{rated}	13	12	10	7.4
v_{co}	35	28	24	26
p_w^{rated}	2.4	5	10	25
Tower height (m)	10.6	14	18	27
Rotor diameter (m)	3.72	5.5	9.7	10.8

2. B. Diesel Generator

Sometimes in hybrid renewable system, the resultant energy obtainable is not sufficient to serve the load demand. In such cases, an independent power backup source is required which can be a diesel generator or a fuel cell system. As we know fuel cell system can act as a backup power source for only micro systems and that too portable ones. So diesel generator is selected here as a backup power source to avoid chance of loss of load. The type and nature of load taken will estimate the size of diesel generator that can be calculated by connecting diesel generator directly to the load demand. Hence the rated capacity of diesel generator would be the maximum load served by it. But this method is not used here and the size of diesel generator is regarded as one of the optimization variable. The size of diesel generator should be found on the basis of installation and operating cost of the generator comparing to the cost of reinforcing the other parts of system (if possible)[11].

2. C. Battery Banks

When the energy obtained from the non conventional resources is less than the energy demand, the remaining power demand can be met with battery bank storage units. The state of charge of battery banks is calculated from the difference of energy produced by renewable resources and energy demand of an area [7]. If the energy produced by the non conventional resources is more than the demand, it charges the battery banks. But when renewable sources do not serve the demand, the battery banks discharges and provide the required energy demand. Four different types of battery banks are considered for simulation [1], shown in the table II.

TABLE II
Characteristics of different types of batteries[1]

Type	1	2	3	4
V^{rated}	6	6	12	12
P_{pv}^{rated}	0.12	0.15	0.14	0.18
Efficiency (%)	85	85	85	85
Cost ($/KW)	348	415	521	567

Proposed framework

Block diagram of hybrid system is shown below in the figure 1. It can be seen that diesel generator is used as a back up for renewable source and battery banks. The load pattern for one day has been shown in figure 2.

III. BAT ALGORITHM

Nature has always been inspiration for research scholars. Many nature inspired techniques have been put forward to solve the real world problems. Some of these optimization techniques are the genetic algorithm, particle swarm optimization, ant colony optimization, bat algorithm and many more. Bat algorithm is the optimization techniques which combines the functions of particle swarm optimization and genetic algorithm and offers better results [4].Bat algorithm is a metaheurisitic algorithm developed by Xin-She-Yang in 2010. Microbats or virtual bats use the echoes to search their prey and find their obstacles. They keep on varying their loudness, frequency and pulses rates to search the prey during their random walk. Hence they reached at best solution among the solution retrieved while optimization ends. This technique of bats can be used to optimize the objective function of real world problems. In bat optimization we initialize type and limits for wind and battery modules. When the iteration starts random value and type for wind and battery modules is generated and kwatt generated by modules is calculated and stored as fitness value. As the iteration loops precede, new bats from existing bats is selected i. e. new modules and types are selected for kwatt generation. After comparing the fitness value for parent and child bats we choose best bat among all which gives best results with reduced cost.Hence it can be implemented in various engineering, industrial application for optimizing real world problems [8]. Flowchart of bat algorithm is represented in figure 3.

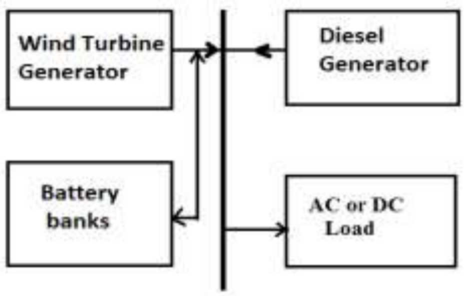

Figure 1:-Hybrid renewable system with battery banks

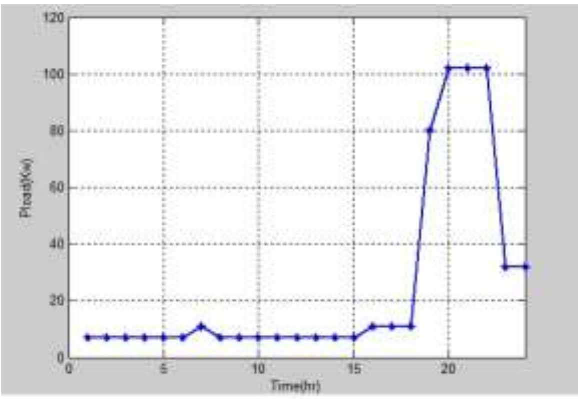

Figure 2: Load Pattern [9]

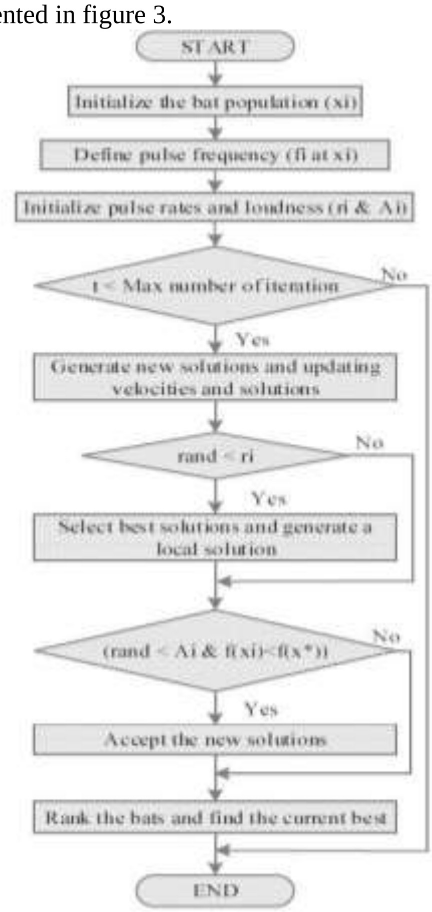

Figure 3-Flowchart of Bat algorithm.

IV. RESULTS AND DISCUSSION

The remote rural area considered for simulation is situated at the vicinity of city, Kerman, Iran. The required data for wind velocities and solar irradiance can be found from the metrological organization [9]. As already discussed, single day is considered for the simulation as shown in the figure 2.

The sum of investment and installation cost of wind turbines is taken to be 1950 dollars/ kwh and the maintenance cost is taken as 0.06 dollars per kwh of output energy.

The sum of investments and installation cost of diesel generator is taken to be 900 dollars per kW of its rated power. The operation and maintenance costs are considered as 0.05 and 0.02 dollars / KWh which depends on its output power. The battery banks cost of each type is summarised in table II.

4. A. Results Retrieved From Bat Algorithm:

The solution of BAT optimization problem for the hybrid system is represented in table III. The results are the best solutions retrieved from the BAT algorithm. The table represents the number of optimized modules of wind turbine and battery banks.

TABLE III
Result for Optimized number of modules

UNITS	Type- 1	Type- 2	Type -3	Type - 4
Wind turbines	8	0	0	0
Battery Banks	0	0	39	0

The objective function related to each subsystem of hybrid system is given as:-

$$\text{Total cost} = \sum_{j=1}^{4}\{N_{w,j}.[Cost_{w,inv,j} + Cost_{w,ins,j} + PH.Cost_{w,m,j}]\} + \sum_{k=1}^{4}\{N_{bat,s,k}.N_{bat,p,k}.[Cost_{bat,inv,k} + Cost_{bat,ins,k} + LT_{bat,k}.Cost_{bat,m,k}] * \frac{PH}{LT_{bat,k}}\} + Cost_{diesel,ins}(Pg_{diesel}^{max}) + Cost_{diesel,inv}(Pg_{diesel}^{max}) + \sum_{i=1}^{T} Cost_{diesel,op}(Pg_{diesel}(t)) \quad (3)$$

Where, PH and T are the planning horizon in year and time respectively. LT refers to the lifetime of subsystem. N denotes the number of wind and battery units. Index j and k denotes the type of wind and battery banks.

The results obtained from the simulation for the objective function is represented in the table IV:

TABLE IV
Results obtained for objective function

Investment cost of wind	334286 $/ year
Investment cost of diesel generator	6 $/ year
Investment cost of battery banks	152816 $/ year
Diesel size	0.006667 Kw
Cost of supply from the grid	0.07 $/ kWh
Total cost of supply from the grid	6 $/ year
Total cost	487108 $/ year

V. CONCLUSION

Our study focused on designing a system that helps us to optimize the number and type and of hybrid wind/diesel units with battery banks. An optimal combination of the hybrid system is achieved with Bat optimization simulation technique. The objective was to meet the load using our designed hybrid system, while minimizing costs.

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