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Research paper

Power Management of Grid Connected Hybrid PV/Wind/Battery Power System

K.Ranjith Kumar[1], Dr.M.Surya Kalavathi[2]

[1] *Research Scholar, EEE Department, JNTU Hyderabad , ranjitkatkuri@gmail.com*
Professor, EEE Department, JNTU Hyderabad, munagala12@jntuh.ac.in

Abstract

The ever increasing energy demand and depletion of fossil fuels creates an importance in renewable energy systems. Photovoltaic (PV) and wind are the two prominent sources among the different available renewable energy sources. But due to intermittent nature of these sources the power system network may not be reliable. Therefore a hybrid power system (HPS) is the best solution to overcome this drawback. The main challenging task in HPS is coordination among the different sources. The HPS should achieve the power balance between the supply and demand under all the varying weather conditions like temperature, irradiation and wind speed. The aim of this paper is to design an optimal power management strategy for the renewable energy based hybrid power system (HPS). In HPS, PV and wind are used as the primary energy sources and battery is used as the energy storage system. In this work Genetic Algorithm (GA) is used for power management of HPS. The hybrid power system has been simulated using MATLAB using practical load and weather data of PV and wind system: which gives better performance under all operating conditions

Keywords

1.Introduction

Renewable energy sources got the importance because of many reasons like fast depletion and adverse environmental effects of fossil fuels and ever increasing of energy demand. PV and wind are the two prominent sources among the different available renewable sources because of complementary nature of these sources. But due to some limitations renewable energy sources are not widely using. HPS is the best solution to overcome these drawbacks [1].

HPS merge two or additional energy sources, which after integrated, overwhelmed restrictions characteristic in either. HPS can report limits in relations of fuel elasticity, efficiency, consistency, emissions and economics. In HPS, PV and wind used as the primary energy sources and battery used as the energy storage system. Battery energy storage system (BESS) is used to mitigate the fluctuations in generation. It will absorb the excess power and supply the deficit power.

But the main challenging tasks in HPS are: coordination among the energy sources energy storage system and power balance should be achieved at every instant of time then only power system network will be reliable. Therefore to achieve the aforementioned objectives HPS needs an effective power management strategy (PMS).

A PMS is required for the HPS to accomplish the power flow in demand to fulfil the load necessities. The key purpose of the PMS is to enhance the process of HPS.

Authors propose different power management strategies in the existing literature:

Caisheng Wang et. al. propose power management of ac-based stand-alone PV/wind/FC hybrid power system [2].

Ipsakis et. al. [3] recommended three power management schemes for a renewable hybrid system. Battery SOC and Fuel Cell power output are taken as constrictions to relate these PMSs. These PMSs effectively influence the lifetime of FC and Electrolyzer. Gupta et.al [4] suggests a combined dispatch strategy better than the single dispatch strategy under dynamic working conditions. Jiang [5] presented power management strategy for a PV/Battery/FC hybrid system associated to the dc bus over suitable dc-dc power electronic converters and controls. The PV-Battery subsystem is organized in two ways: BVL mode and MPPT mode. The BVL method avoids the battery from overcharging and the MPPT method draws maximum power from the PV panels. Prabodh Bajpai et. al. [6] propose a PMS for HPS which make certain that the load is delivered successively and the battery is getting charged inside the greatest quantified charging rate by means of a two-stage charging technique. Kang and Won [7] considered a PV/FC/Battery hybrid system. This paper suggests a Genetic Algorithm based PMS which confirms that the load is delivered successively and the battery is charged inside the extreme quantified charging rate. The control system overpowers the short term variations in source and load power by the practice of battery.

2.Hybrid Power System Configuration

Figure 1 shows the grid connected HPS containing of solar, wind and battery. Solar and Wind are the main sources of the HPS to yield complete benefit of renewable source, and battery bank is also used to supply transient power. The energy sources and storage system in the proposed system are combined through DC bus. When the load demand is not met by the PV, wind and battery it will be purchased from the grid.

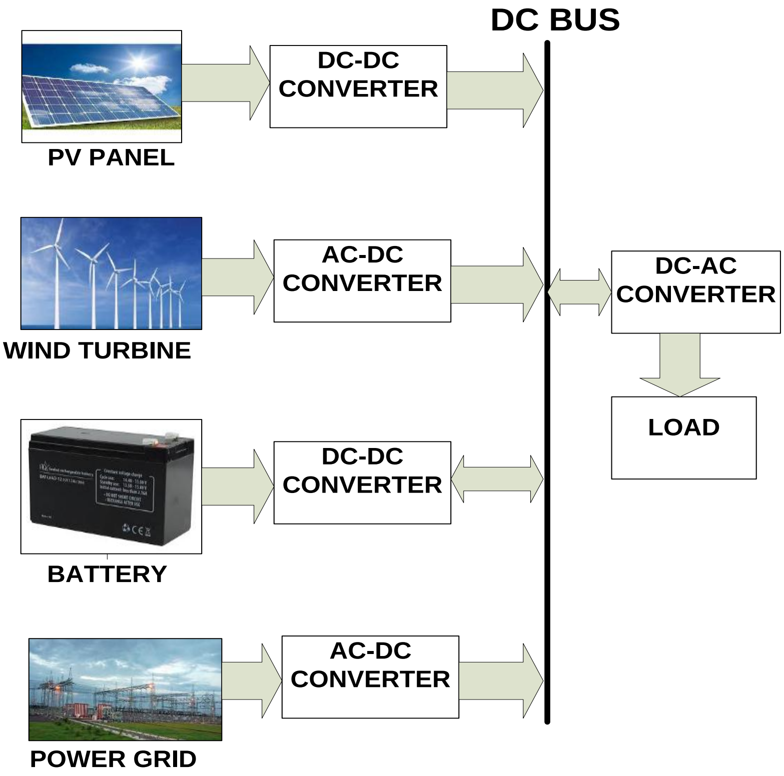

Figure 1: Hybrid Power System

2.1. PV panel modeling

The power generated from the PV panel is depends on the solar irradiance and ambient temperature of the location moreover the characteristics of the panel itself. The PV output power is calculated using the following equations [8]

$$T_C = T_A + I_S\left(\frac{T_{NO}-20}{0.8}\right) \quad (1)$$

$$I = I_S(I_{SC} + K_I(T_C - 25)) \quad (2)$$

$$V = V_{OC} - K_V \times T_C \quad (3)$$

$$P_{PV} = N \times FF \times V \times I \quad (4)$$

$$FF = \frac{V_{MPP} I_{MPP}}{V_{OC} I_{SC}} \quad (5)$$

T_C=Cell Temperature in °C
T_A=Ambient Temperature in °C
T_{ON}=Nominal Operating Temperature in °C
I_S=Solar Insolation
I=solar current in Amps
V=solar voltage in Volts
I_{SC}=Short Circuit Current in Amps
V_{OC}=Open Circuit Voltage in Volts
K_I=Current Temperature Coefficient A/ °C
K_V=Voltage Temperature Coefficient V/ °C
FF=Fill Factor
The range of the PV array rating is considered to vary between 100 kW and 500 kW to decide on the optimal size.

2.2. WT power unit modeling

Wind turbine converts kinetic energy of the wind into AC electricity according to a particular power curve. The power generated from of a wind turbine is depends on the wind speed at the location and also the parameters of the power performance curve. The output power is calculated using the following equations [8]

$$P_{WT}\,(v) = \begin{cases} 0, & 0 < v_a < v_{ci} \\ P_r\,\frac{(v_a - v_{ci})}{(v_r - v_{ci})}, & v_c \le v_a \le v_r \\ P_r, & v_r \le v_a \le v_{co} \\ 0, & v_{co} \le v_a \end{cases} \quad (6)$$

From the above equation P_{WT} is the wind power is a function of wind velocity. V_a, V_r, V_{ci} and V_{co} are the average wind velocity, rated wind velocity, cut-in wind velocity and cut-off wind velocity respectively.
The rating of each wind turbine considered is 50 kW. Range of 2 to 6 numbers of such for optimal size.

2.3. Battery system modeling

Battery storage system is used to store surplus power and to supply when the system has scarcity power. Its lifetime depends on the number of charge/ discharge cycles per day. The rating of each battery is 12 V, 200 Ah, 2.4 kWh.

2.4. Converter modeling

The rating of the converter is chosen according to the total PV panel output, as the total PV panel output is converted in to AC by the converter. Hence, the size considered for converter is 125 kW to 575 kW.

2.5. Utility grid

In this model, the building is connected to the utility grid, and the building produces maximum demand of 600 kW on the utility grid.

3.Power Management Strategy

A PMS is required for the HPS to accomplish the power flow in demand to fulfil the load necessities. The key purpose of the PMS is to enhance the process of HPS. Balance of supply and demand is the basic function of PMS.

P_{pv} is the generated power by PV system, P_{wind} is the generated power by the wind, P_{bat} is the battery power, P_{grid} is the power supplied by the main grid and P_{load} is the load demand.

Power balance can be calculated by using following equation

$$P_{gen}=P_{load} \quad (7)$$

Where P_{gen}=power generated by the primary sources

$$P_{gen}=P_{pv}+P_{wind} \quad (8)$$

If $P_{gen}> P_{load}$, i.e., Excess power supplied to battery (9)

And if $P_{gen}< P_{load}$, i.e., deficit power supplied by battery if SOC >0.6 otherwise power will be supplied by the grid.

3.1. Genetic Algorithm:

In this work the energy management will be achieved by using Genetic Algorithm [9].

Genetic Algorithm (GA) is an evolutionary search algorithm which imitates the procedure of natural evolution; it is well-thought-out to be vigorous method since no limitations on the solution space are made throughout the procedure. Considering it is a nonlinear optimum problem with some constrains, the elementary flow of GA is defined as follow:

Step-I: Produce arbitrary initial collection of solutions;

Step-II: Check and review the results affording to constraints;

Step-III: Objective function assessment is useful to check if the finest solution is found. If the finest solution is obtained, go to Step-V; otherwise continue;

Step-IV: Update new group with crossover and mutation, then jump to Step-II;

Step-V: Finish and output the best solution.

It can be seen that the core of GA is the method to generate new group with crossover and mutation, the definition of crossover and mutation method will definitely affect the performance of GA.

4. Discussion

4.1.Case study description

In this case study, the considered building is an educational organization located at Hyderabad, India. The existing architecture of the building is that it is connected to the utility grid that serves the entire load connected. The new proposed architecture of the system is that the electric energy produced from the PV, WT and BESS augments the grid supply to meet the demand.

4.2. Load Profile

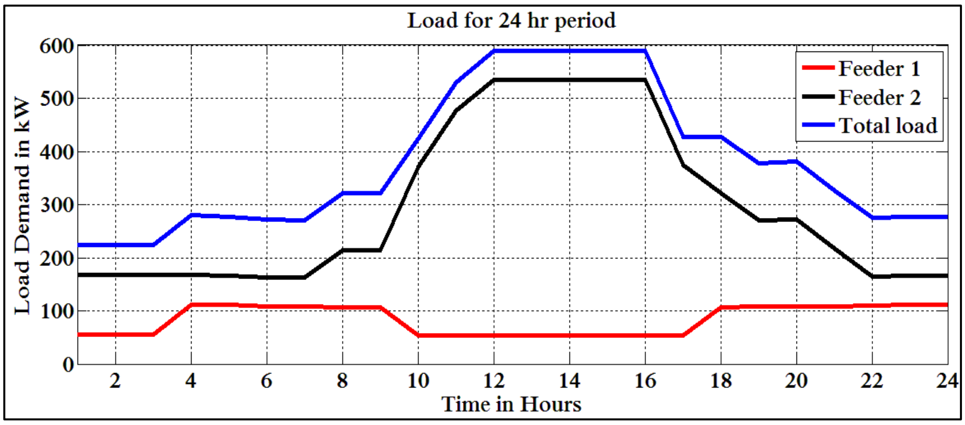

Figure 2: Daily Load Profile

Figure 2 shows the daily load profile of the considered case study. From the load data daily average energy consumption is 4580 kWh/day and peak load is 600 kW. JNTU University buildings are supplied with two feeders each 11 kV rating from distribution substation. One feeder is supplied to JNTU quarters and another feeder is supplied to JNTU college campus.

The selected site is located at latitude of 17.3850^0 (North), longitude of 78.4867^0 (East), and an altitude of around 500 m. The selected place is sanctified with around 5.35 kWh/m^2 annual average daily solar radiations and the average wind speed in a year is 4.54 m/s. The solar and wind data can be obtained from the database of NASA [10].

4.3.Solar and Wind Resources

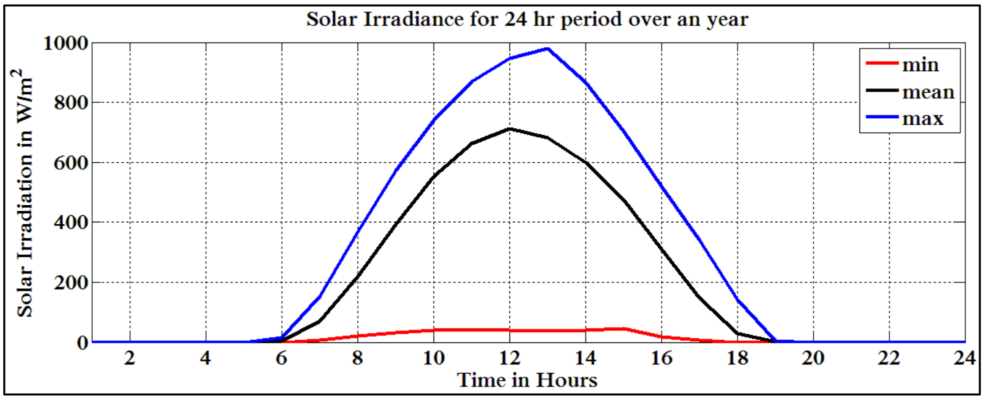

Figure 3: Solar Irradiation

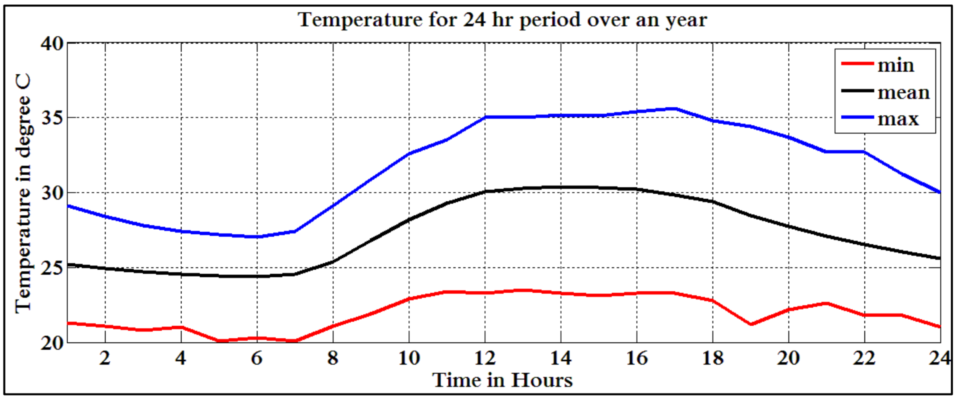

Figure 4: Temperature

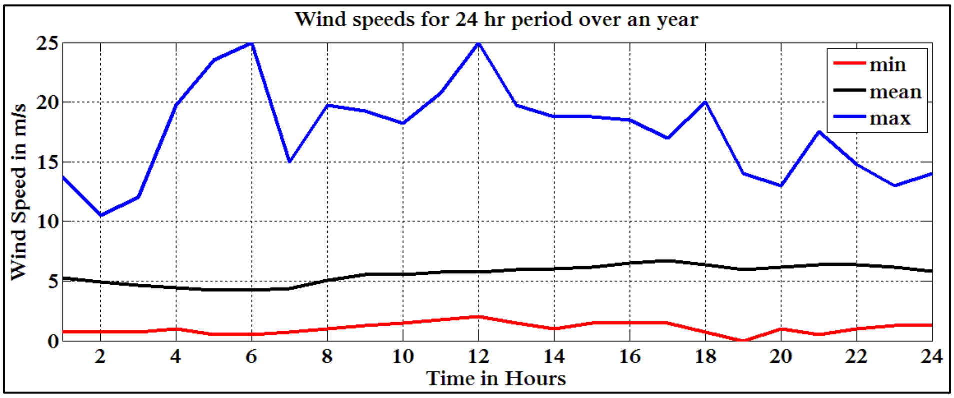

Figure 5: Wind Speed

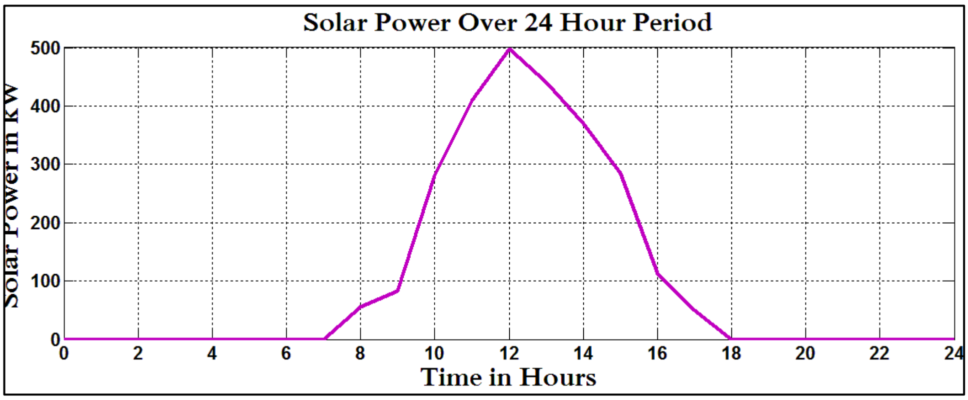

Figure 6: Solar Power output

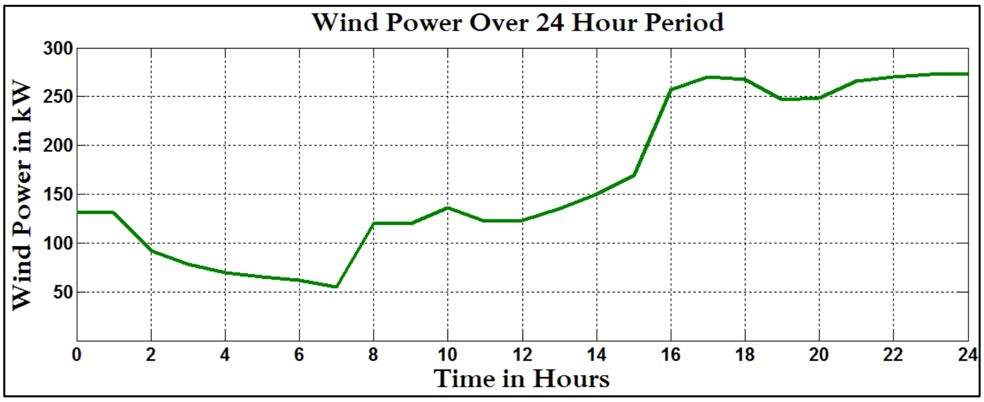

Figure 7: Wind Power Output

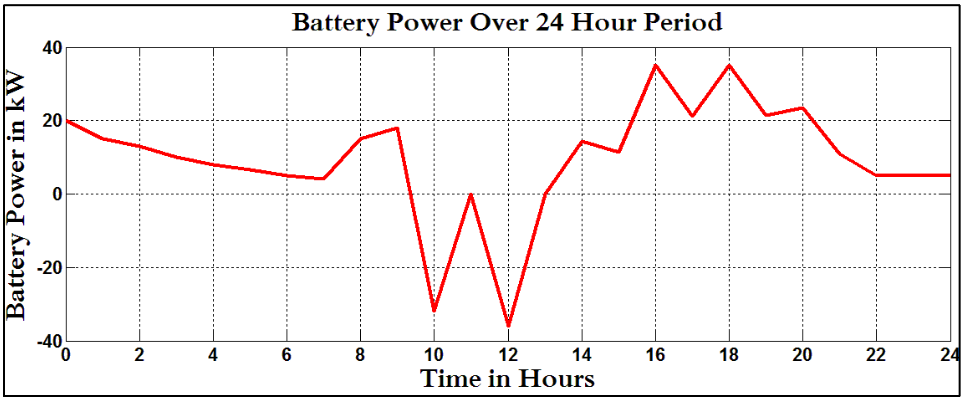

Figure 8: Battery Power

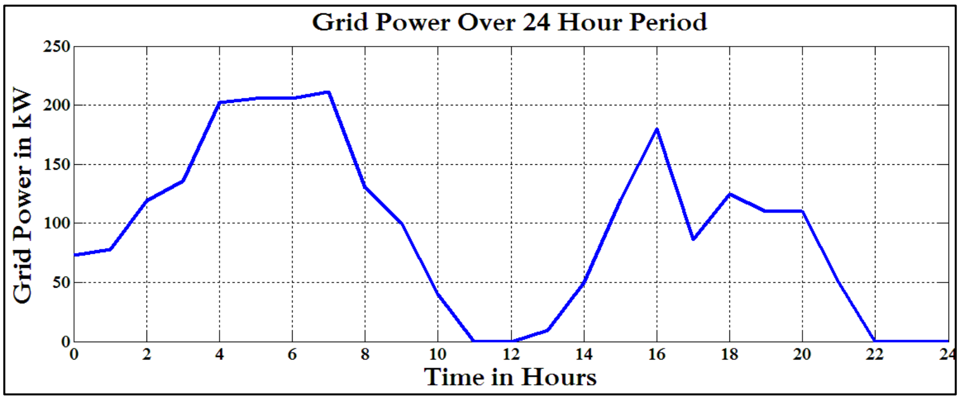

Figure 9: Grid Power

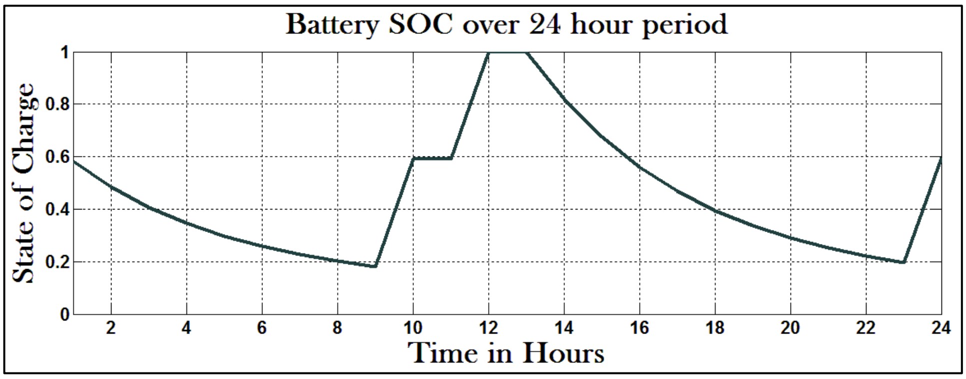

Figure 10: Battery SOC

5.Conclusion

In this paper power management of renewable energy (PV/wind) based hybrid power system is investigated using genetic algorithm. The performance of the proposed power management strategy is tested practical weather and load conditions using MTLAB. The proposed PMS shows good performance under all varying weather and load conditions

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