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WIND, PHOTOVOLTAIC, FUEL CELL HYBRID ENERGY SYSTEM

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ABSTRACT

The load demand increases day by day due to increase in population and life styles of the people. It is not possible to generate more power from the conventional sources. In order to full fill the load demand, it is better if we go for Non conventional energy sources. These are gaining more importance in the present scenario. Lot of development has been done in the last few decades in this field. The sun and wind energy are available abundantly, but these vary with time and often the pattern does not actually follow the consumer load. In order to avoid this, we prefer a combination of these systems that means hybridization. In addition, fuel cells can also be added to solar and wind energy systems, thereby a "wind, photovoltaic, fuel cell hybrid energy systems" is formed. Relevant data is collected from the Kappathagudda and Mundaragi sites. A simulation model is developed using Matlab/Simulink.

Keywords: Wind Energy, Photovoltaic, Fuel-Cell, Hybrid Energy Systems and MATLAB Simulink.

I. INTRODUCTION

Supplying energy needs for the 21st century's life style is biggest challenge. The energy crisis experienced in 1973 has brought the fact that fossil fuel resources would be running out. Various problems are caused by fossil fuel sources such as global warming, fossil fuels, acid rain, pollution and ozone layer depletion. But the greater concern is about global warming, air pollution and energy crisis. This is leading in a transition from fossil fuel resources to renewable energy sources [1].

Energy production in any country represents the development. There are two methods to develop the country by its energy production. First approach is improving the energy production efficiency. Which is nothing but improvement of energy input to energy output ratio and second approach is to find substitutions. Renewable energy sources should be involved in power generation rather than fossil fuels. Conversion of energy is main cause for the environment pollution. Hence if the renewable energy resources are used as main resources, most of the environmental problems would be solved.

Increasing energy demand, cost and the fossil fuel scaring have been made search for the choice of sources to meet the current energy need. In addition to this, most of the world's population is located in rural areas which are far away from the substations and power generation centres [2]. Also energy needs in such areas are very small compared to the large cities. Because of the above stated problems many rural places are not linked to the power grid. Hence feasible as well as efficient techniques should be found out to electrify the rural areas.

1.1 Alternate Sources of Renewable Energy

1.1.1 Solar Energy

Solar panels are used to converts the solar energy into the electrical energy. Normally solar panels are used for power conversion directly or for the indirect mode such as to hest the water with the energy induced. Solar cells are also called as photovoltaic cells, which are made up of various semiconductor devices. When sun light falls on the panel electrons are emitted from the outer most shell of the semiconductor device. This process of release of electrons activates the currents. The process in which the beam of light is absorbed by panel and electricity produced is known as photovoltaic [3].

1.1.2 Wind Energy

For the conversion of energy associated with the wind power to electricity, wind turbines are used. The kinetic energy which is present in the wind can be converted into rotational energy by using wind turbines. The mechanical output which is obtained from the turbine is converted to electrical energy by the wind generator. The range of available wind turbine system is from 600KW to 5MW. The generated energy from the wind turbine depends upon wind velocity which is acting on turbine. The wind power is the best means to generate the electrical power in rural areas in order to meet the energy demand. Based on their physical construction such as dimensions, no of blades, axes, power generated wind turbines are classified. For example: based upon the axes structure horizontal and vertical plane turbines. Classification based on number of blades: single blade, two blade and three blade turbine. Classification based on power generation capacity: small power system, moderate power system and big power system.

1.2 Benefits of Hybrid Renewable Energy Systems

1. Decrease environmental pollution due to reduction in emission.
2. Energy saving due to reduces in production and purchase of fossil fuels.
3. Abatement of global warming due to CO_2 and other green house gases are not produced.
4. Fuel supply diversity.
5. Distributed power generation is reduces the necessity for transmission lines within the power grid [4].

1.3 Challenges Associated with Hybrid Renewable Energy

The continuous increase of energy consumption, fossil fuel is exhaustible in nature, and polluting global environment had increase the interest in renewable with non renewable energy sources which contribute for the green environment. Two most important renewable energy sources are wind and solar. The growth in the photovoltaic and wind system has optimised the estimation. Because of the many merits associated with the fuel cells such as flexible structure, high efficiency, low emission from pollutant gases fuel cells are contributing to the green environment system. But each of these technologies is associated with their demerits. For example solar and wind system depends on the environmental conditions such as wind availability and intensity of sun radiations. Also fuel cells need the fuel which has rich hydrogen. But various power sources can be used as alternative to each other with a proper control system can provide the more reliable power supply to the consumers than the single system. Because of the above said features hybrid systems are becoming the most important aspect for the research.

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II. METHODOLOGY

Figure 2.1 shows the System configuration of Wind-PV-FC Hybrid Energy Power Plant

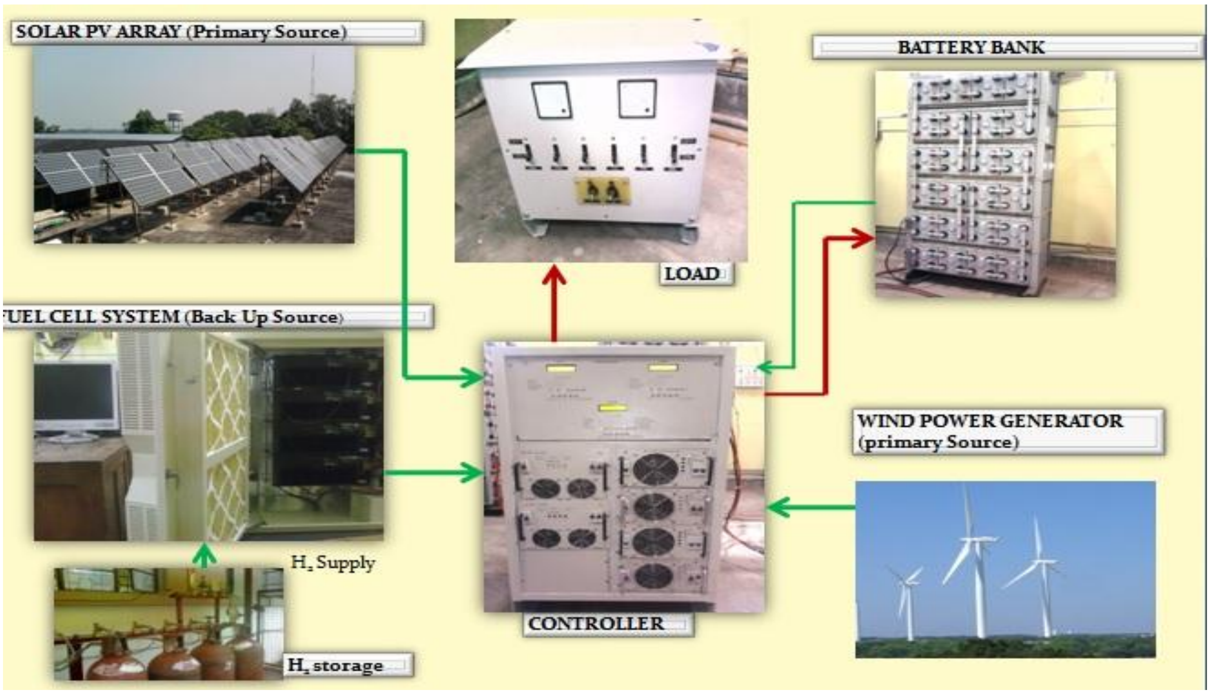

Figure 2.1 System Configuration of Wind-PV-FC Hybrid Energy Power Plant [6].

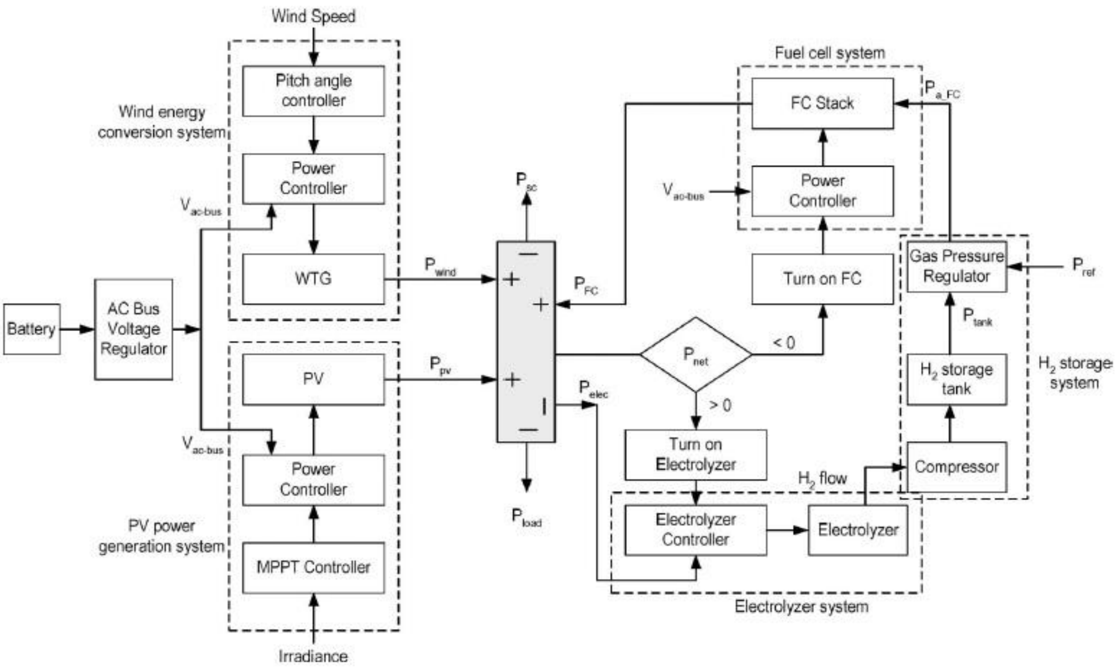

Figure 2.2 Block Diagram of the Overall Control Scheme for the Proposed Hybrid Energy System.

In this work, renewable energy sources such as wind and photovoltaic systems are considered as a primary source, fuel cell are used as back up purpose in order to meet the load demand under varying generation output from the solar and wind energy system. This system can be abbreviated as "complete green system" for the generation of power. This is because primary sources as well as back up storage source are free from the pollution and do not impact on the environment. If the generated energy does not meet the demanded load, fuel cell takes the hydrogen from the tank and fulfils the load demand. The battery backup is used into the system in order to supply the power during load spikes, transients and ripples. There are various methods adopted in order to configure the hybrid systems but every method is associated with several advantages and disadvantages. Depending upon requirements different configuration of hybrid systems can be preferred. Here MPPT control method is adopted for control strategy as shown in fig 2.2.

Central management which controls the overall power flow among various resources are needed. Figure shows the control strategies for whole hybrid system, which controls the power among various elements. The wind energy conversion system and photovoltaic system are the main sources of energy in this hybrid system [7]. The difference between the load demand and power generated is calculated as

$$P_{net} = P_{wind} + P_{pv} - P_{load} - P_{sc} \qquad (2.1)$$

Where, P_{wind} is the power generated by wind

P_{load} is the load demand

P_{sc} is the self-consumed power for hybrid system.

For example the power is required for the control units, gas compressor and cooling system. For simplicity, only the power consumed by compressor is considered. Hence equation is

$$P_{wind} + P_{PV} = P_{load} + P_{elec} + P_{comp}, \qquad P_{net} > 0 \qquad (2.2)$$

Electrolyser consumes the P_{elec} power to generate H_2

When the generated power is less than the demand, then fuel cell begins to produce energy.

Therefore

$$P_{wind} + P_{PV} + P_{FC} = P_{load} \qquad P_{net} < 0 \qquad (2.3)$$

III. SIMULATION MODELS

Simulation of the hybrid wind and PV system is discussed in this chapter which is done in Matlab/Simulink environment. In Hybrid Wind/PV/Fuel cell energy System, Wind and PV system act as a main source. In Wind Energy conversion system, wind speed is varied continuously. Using the proposed Wind, Photovoltaic, Fuel cell energy system has been developed using Matlab/Simulink. In order to verify the system performance under different situations, simulation studies have been carried out using practical load demand data and real weather data (wind speed, solar irradiance). The weather data are collected from the wind and solar power plants. Simulation studies are carried out for power management during a typical winter days and a summer days. The load demand is kept the same for the two cases. Simulation results for the winter and summer scenarios are given and discussed in the following section.

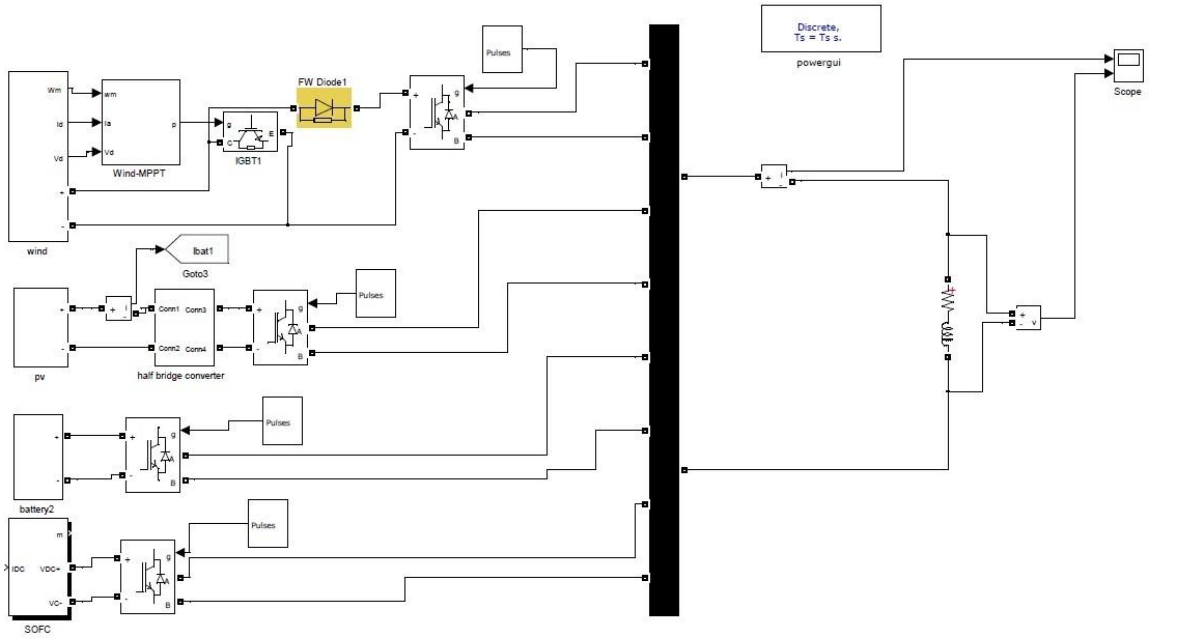

Figure 3.1 Simulink model of hybrid energy system.

IV. RESULTS AND DISCUSSIONS

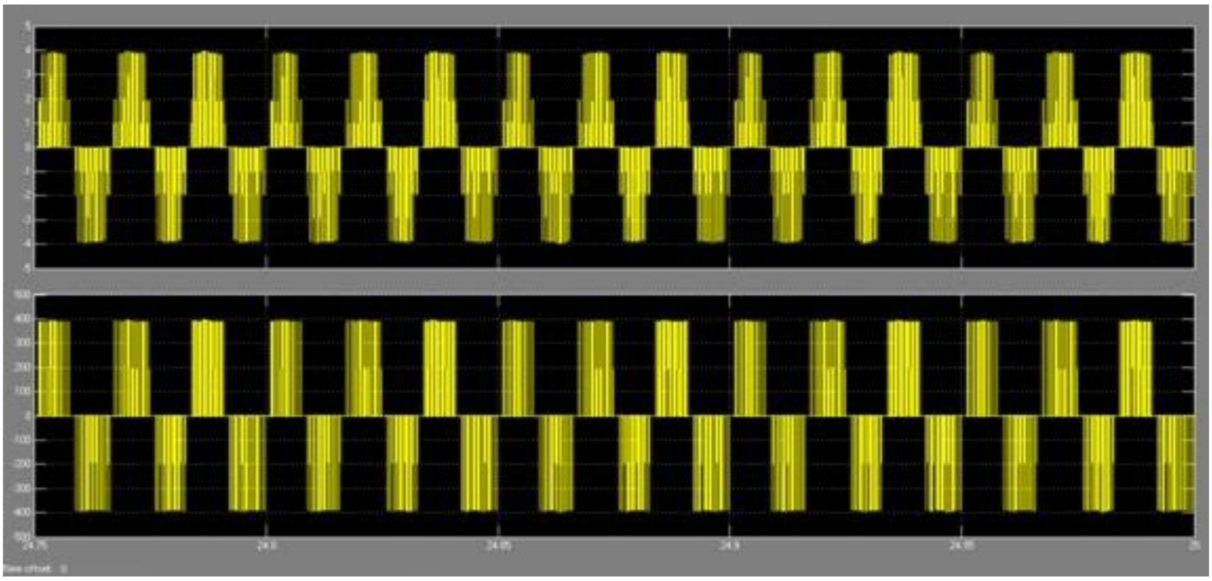

Figure 4.1 Current and voltage wave form of hybrid system

Figure 4.1 represents the voltage and waveform of the hybrid fuel cell, wind and photovoltaic system

4.1 Winter Scenario

(i) Data of Weather:

The data of weather is obtained on December 2014 and simulated. The wind data were collected is using the below equation [8]:

$$WS1 = Ws0\left(\frac{H_1}{H_0}\right)^{\alpha} \quad (4.1)$$

Ws0= Speed of the wind at a height of H_0 (meters), expressed in m/s.

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Ws1 = Speed of the wind at a height of H_1 (meters), expressed in m/s.

α = wind speed correction exponent, considered as 0.13 for this study.

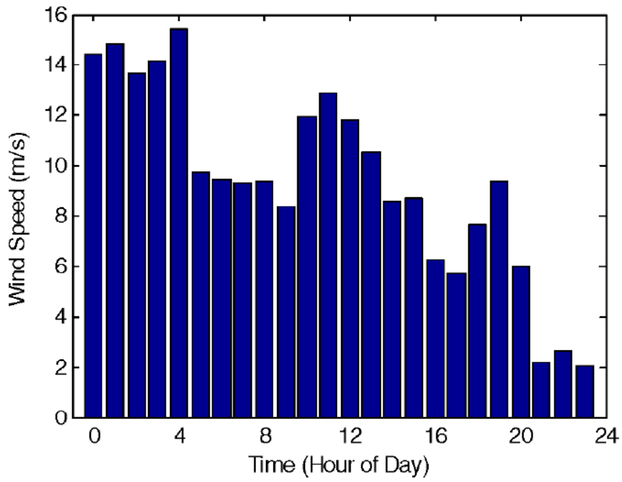

Figure 4.2 Wind Speed Data for the Winter Scenario Simulation Study.

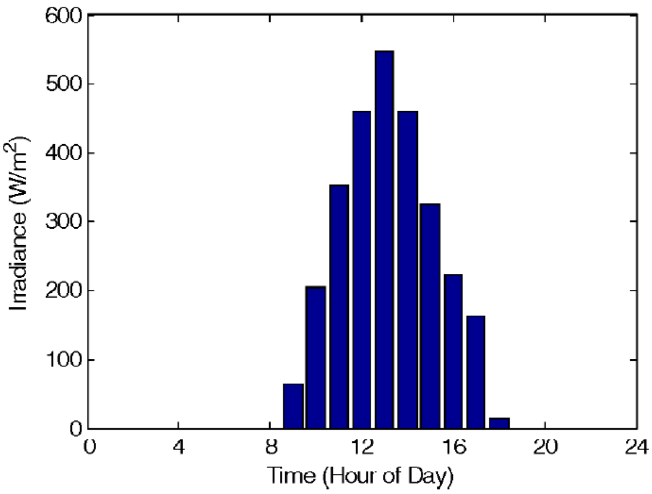

Figure 4.3 Solar Irradiance Data for the Winter Scenario Simulation Study.

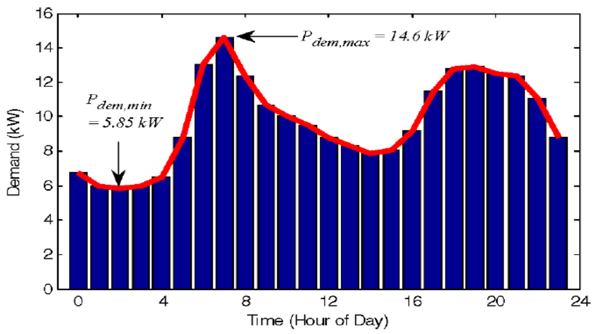

Figure 4.4 Hourly Average Load Demand

The performance of the system under load is given by the Figure. 4.1, 4.2 and 4.3. The power output obtained from the wind system in the hybrid unit is simulated over 24 hours. The output power is restricted to 50kW when the wind speed is 14 m/s or above. This is achieved by pitch angle controller. There will be power generation,when the wind speed is below cut-in speed that is 3 m/s. output obtained from PV array is also simulated over the period of 24hours. MPPT controller controls the output of photovoltaic array. This is employed in order to achieve maximum power generation for different radiations of solar. In photovoltaic array, tempreture plays an important role. There two important factors which affects the tempreture of photovoltaic array. One is surrounding air tempreture and second is solar radiations. It can be noted that maximum power output is reduced, as the tempreture is increased [9]. For H_2 generation,there will be availibility of excess power when Pnet > 0.

If Pnet < 0,the power generated from solar and wind power plant will not be sufficient to supply the load demand. Under such conditions, fuel cell be turned on to supply for power shortage.

The simulation results for the above wind and solar irradiation data aare as shown in Figure 4.5 and 4.6. and corresponding fuel cell performance for the winter scenario are as shown in Figure 4.7. It acts only when the generated energy is less than the consumer load demand. And its performance are plotted.

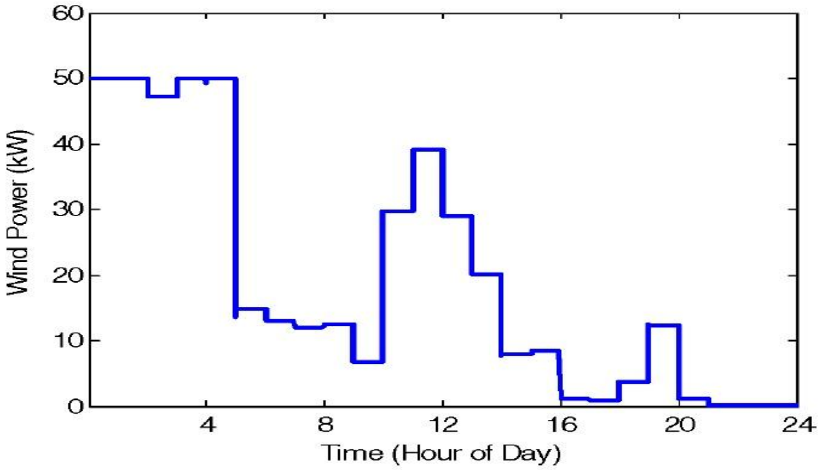

Figure 4.5 Output Power Wave Form of Wind Energy System at Winter Scenario

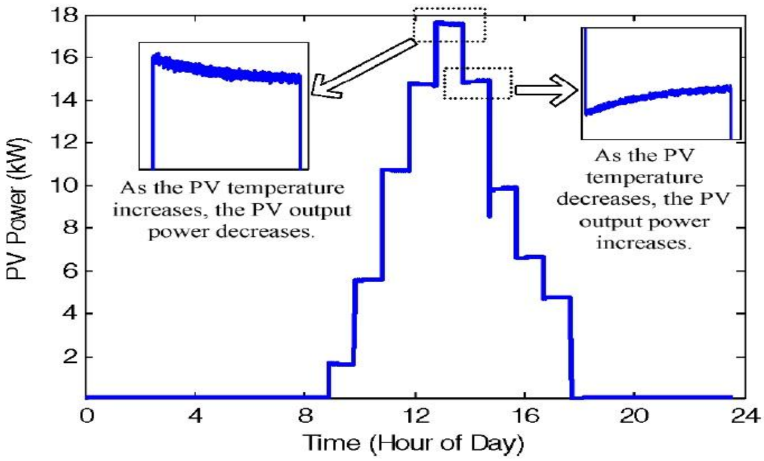

Figure 4.6 Output Power Wave form of PV System at Winter Scenario

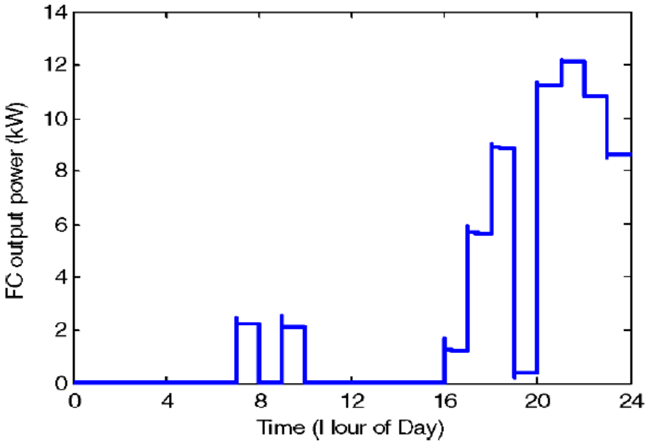

Figure 4.7 Power Supplied by the FC Stack the Winter Scenario Study.

4.2 Summer Scenario

(i) Weather Data

The weather data is collected of the year 2014 for the study of summer scenario. The collected wind speed data is as shown in Figure5.8. It is observed that solar energy available in the summer is wider than winter.

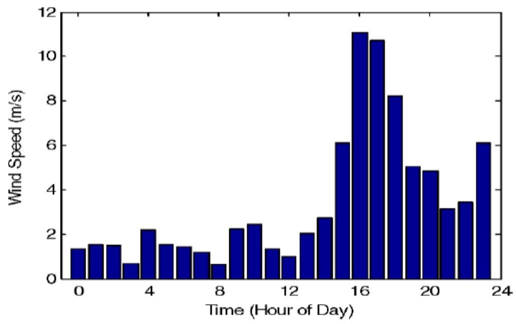

Figure 4.8 Wind Speed Data for the Summer Scenario Simulation Study.

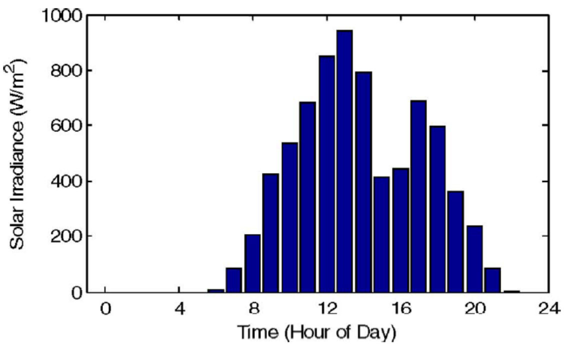

Figure 4.9 Irradiance Data for the Summer Scenario Simulation Study.

The data from photovoltaic and WECS is simulated for 24 hours. Figure 4.8 & 4.9 shows MPPT control which tries to control the output of the photovoltaic array.

There will be availibilty of excess power when Pnet > 0. If Pnet < 0,the power generated from photovoltaic and wind are not sufficient to meet the demand ,which is shwon in the Figure.5.10 and 4.11

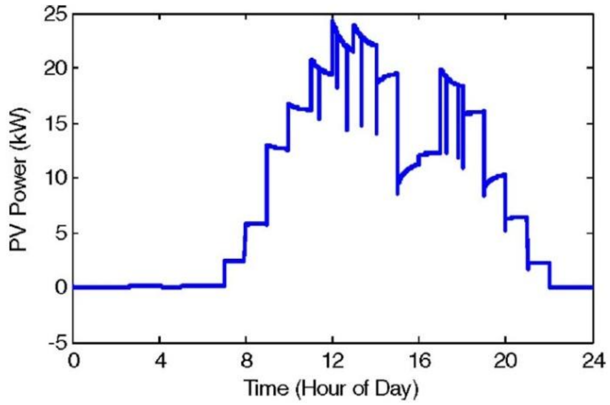

Figure 4.10 Output Power Wave Form of Solar Energy System at Summer Scenario

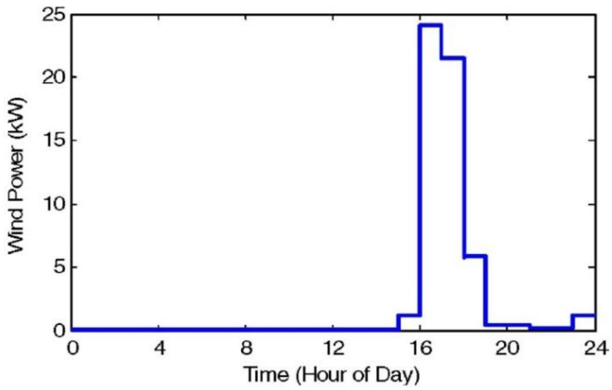

Figure 4.11 Output Power Wave Form of Wind Energy System at Summer Scenario

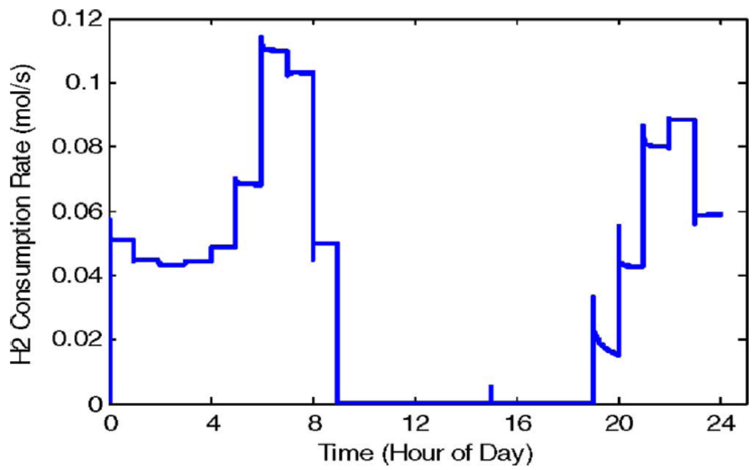

Figure 4.12 H_2 Consumption Rate for the Summer Scenario Study.

If Pnet<0,the power generated from solar and wind power plant will not be sufficient to supply the load demand. Under such conditions, fuel cell be turned on to supply for power shortage.

The simulation results for the above wind and solar irradiation data aare as shown in Figure 4.10 and 4.11. and corresponding fuel cell performance for the summer scenario are as shown in Figure 4.12. It acts only when the generated energy is less than the consumer load demand. And its performance are plotted.

V. CONCLUSION AND FUTURE SCOPE

The present work provides idea regarding the hybrid system and its necessary and about renewable hybrid system.

- The availability of wind as well as the solar irradiation is intermittent in nature.
- The data collection shows that in summer season the solar irradiation is more compared to wind speed data, so more power generation is from solar power plant only.
- Likewise in a rainy season the value of wind speeds is high and the solar irradiation is almost nil, so in this1case1the1maximum1power1can1be expected from the wind power itself.
- In the case of winter season the value of both wind speed as well as solar irradiation are average and we can expect power generation from both the power plants.
- If the load demand is not met by solar and wind, small amount of load demand can be met by fuel cell energy system.
- I have done this work by collecting data for one day in summer and winter seasons. This work can be extended by taking more number of days.

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