# SIMULATION AND POWER MANAGEMENT OF STANDALONE SOLAR-WIND-FUEL CELL BASED HYBRID SYATEM

[1]Miss Parmar Hemlata, [2]Ms. Parevi Gandhi, [3]Mr. Mihir K. Patel,
[1]PG Scholar, [2, 3] Assistant Professor, Electrical Department, KITRC-Kalol, Gujarat, India.

## ABSTRACT

This Paper proposes of an A.C-linked hybrid wind/photovoltaic (PV)/fuel cell (FC) alternative energy system for stand-alone applications. Wind and PV are the primary power sources of the system, and an FC–electrolyser combination is used as a backup and a long- term storage system. An overall power management strategy is designed for the proposed system to manage power flows among the different energy sources and the storage unit in the system. A simulation model the hybrid energy system will be developed using MATLAB/Simulink. The system performance under different scenarios will be verified byCarrying out simulation studies using a practical load demand profile and real weather data.

Keywords:- PV, FC, BESS, Power Management, RES, etc.

## INTRODUCTION

There is no man who can live without energy; it is important aspect to everyone’s life no matter where and when they are. In today’s fast growing world this is true, where people want to live higher quality of life. Among all the different types of energy, electrical energy is one of the most important that people need every day. In this chapter an overview is given on the world energy demand and their development trends in near feature and also the motivation for the research work and scope of research work is proposed.

### World Energy Demand

Ever and ever increasing demand of HI profile life of people the world energy consumption is expected to grow about 58-60% in the next 20 years. An average growth rate of 1.6% and more then 2/3 of growth in world energy is used will come from developing country where economy and population is highest. Fig 1 shows the world energy consumption of 1990-2040.

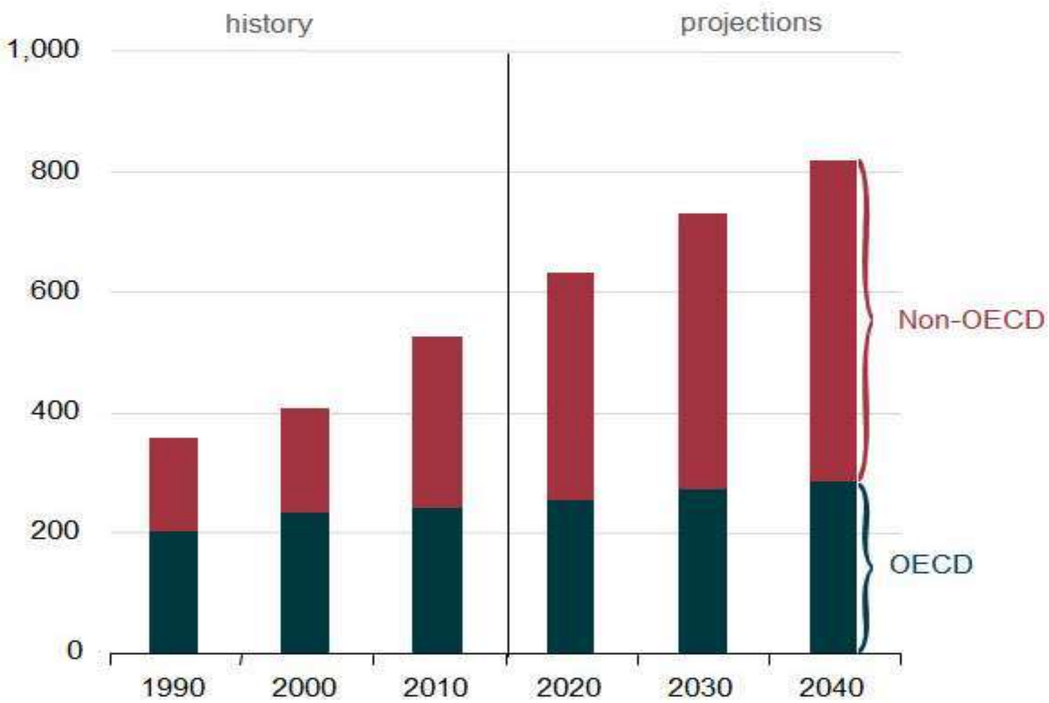


Fig.1 World Energy Demand

**Advantages of Renewable Energy Sources**

- They do not support global warming.
- These energy sources are available for free.
- These sources produce minimal toxic waste and hence do not pollute the environment in a negative way. They are a clean source of energy since they do not contribute to air pollution.
- Renewable power plants are located far away from the suburbs in cities which brings economic benefits in many regional places.
- Operational cost of the power plants are less since the source of energy is acquired in a natural way. Because of which the maintenance cost is also reduced.

**Wind energy**

Today, people are realizing that wind power "is one of the most promising new energy sources" that can serve as an alternative to fossil fuel-generated electricity. The cost of wind has dropped by 15% with each doubling of installed capacity worldwide, and capacity has doubled three times during the 1990s and 2000's.As of 1999, global wind energy capacity topped 10,000 megawatts, which is approximately 16 billion kilowatt-hours of electricity. That's enough to serve over 5 cities the size of Miami, according to the American Wind Energy Association. Five Miami may not seem significant, but if we make the predicted strides in the near future, wind power could be one of our main sources of electricity.

**Photovoltaic Energy**

From an environmental perspective, solar power is the best thing going. A 1.5 kilowatt PV system will keep more than 110,000 pounds of carbon dioxide, the chief greenhouse gas, out of the atmosphere over the next 25 years. The same solar system will also prevent the need to burn 60,000 pounds of coal. With solar, there's no acid rain, no urban smog, no pollution of any kind.

Mankind has been crazy to have not bothered to harness the sun's energy until now. Think about this. Go outside on a sunny day. The light falling on your face left the Sun just 8 minutes go. In those 8 minutes it traveled 93 million miles. Those photons are hauling and when they strike your PV module you can convert that motion to electricity. As technology, photovoltaic are not as glitzy as that new sport utility vehicle the television tells us to crave. But in many ways PV is a much more elegant and sophisticated technology. Whether it be for your business or for your home, why not invest in Solar Panels. Today's solar panels are bombproof and often come with a 25 year warranty or more. Your solar panels may outlive you. They are also modular—you can start with a small system and expand it over time. Solar panels are light (weighing about 20 pounds), so if you move you can take the system with you.

**Fuel Cells**

Fuel cells (FCs) are static energy conversion devices that convert the chemical energy of fuel directly into DC electrical energy. Fuel cells have a wide variety of potential applications including micro-power, auxiliary power, transportation power, stationary power for buildings and other distributed generation applications, and central power. Among different types of fuel cells, polymer electrolyte membrane fuel cells (PEMFC) and solid oxide fuel cells (SOFC) both show great potentials in transportation. Compared with conventional power plants, these fuel cell systems have many advantages such as high efficiency, zero or low emission (of pollutant gases) and flexible modular structure. Fuel cells can be strategically placed at any site in a power system (normally at the distribution level) for grid reinforcement, deferring or eliminating the need for system upgrades, and improving system integrity, reliability and efficiency. Moreover, as a byproduct, high-temperature fuel cells also generate heat that makes them suitable for residential, commercial, or industrial applications, where electricity and heat are needed simultaneously.

**Scope of Research Work**

Although there are many types of alternative/renewable resources, the alternative sources in this paper are confined to wind, PV and fuel cells for the research on the proposed hybrid alternative energy systems. Wind and PV are the primary power sources of the system to take full advantage of renewable energy, and the FC–electrolyzer combination is used as a backup and a long-term storage system. A Battery is also used in the system for short-time backup to supply transient power. The different energy/storage sources in the proposed system are integrated through an Ac link bus. The details of the system configuration, system unit-sizing, and the characteristics of the major system components are also discussed in later chapters. SOFC fuel cell will be modelled and used in the paper. The ultimate goal of this paper is to model a multi-source alternative system consisting of wind turbine(s), PV arrays, fuel cells and electrolyzer, and to manage the power flows among the different energy resources in the system.

**Research Objectives**

(1) An autonomous renewable energy micro-grid system consists of a wind turbine, a photovoltaic array, a fuel cell, an electrolyzer, a Battery and a load of 100 households' electrolyzer will be proposed.

(2) Wind and PV will be the primary power sources of the system to take full advantage of renewable energy, and the FC–electrolyzer combination will be used as a backup and a long term storage system.

(3) A Battery will be used in the system for short-time backup to supply transient power.

(4) The details of the system configuration, system unit-sizing, and the characteristics of the major system components will also discussed in the work.

(5) An overall power management strategy will be designed for the system to coordinate the power flows among the different energy sources.

(6) Simulation studies have been carried out to verify the system performance under different scenarios using practical load profile and real weather data.

## The Proposed System Configuration

A multi-source hybrid alternative distributed generation system consisting of wind, PV, fuel cell, and electrolyzer is discussed. Wind and PV are the primary power sources of the system to take full advantage of the available renewable energy. The FC-electrolyzer combination is used as a backup and long-term storage system. For stand-alone applications, a battery is also used in the system for short -term energy storage to supply fast transient and ripple power.

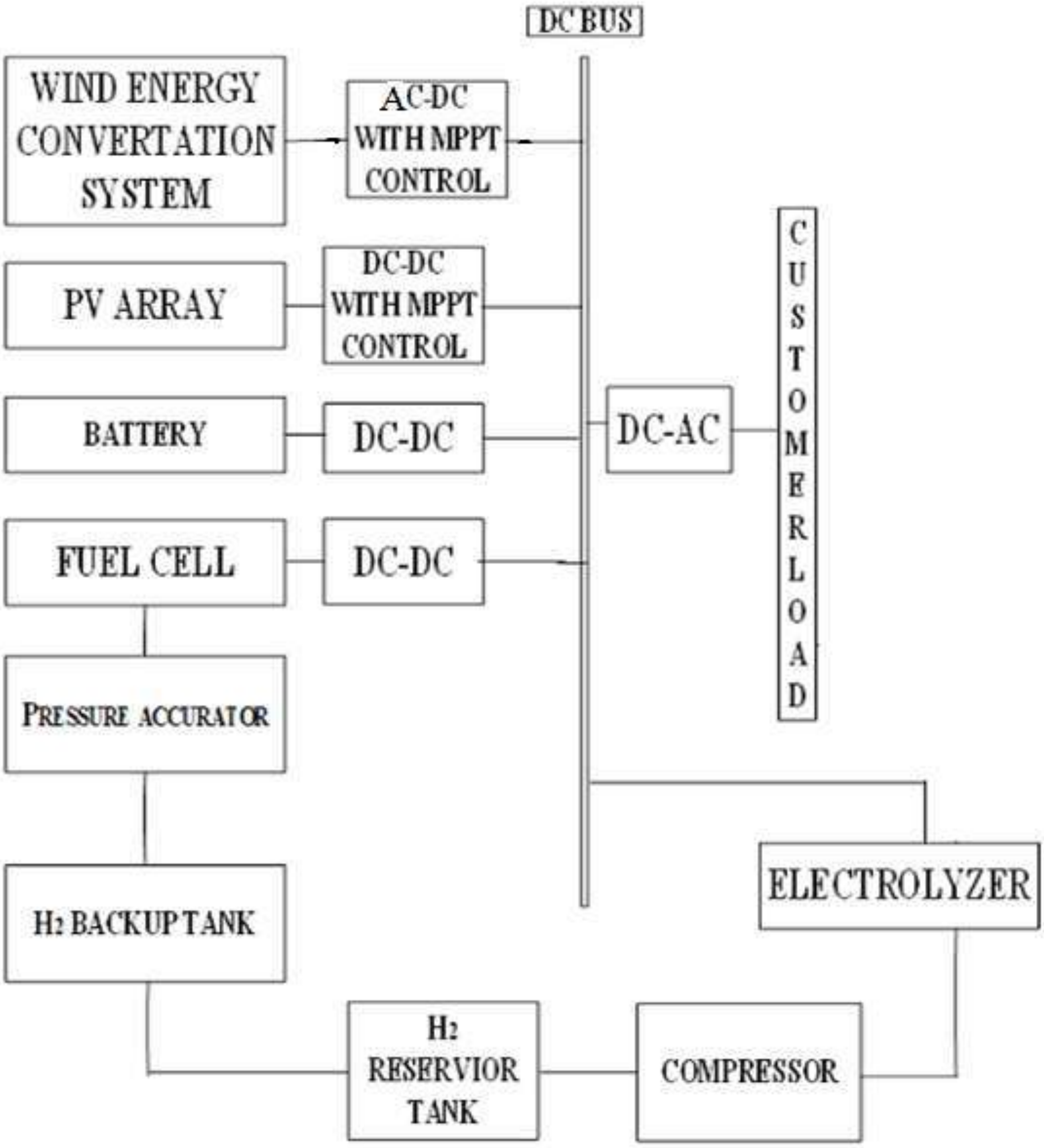


Fig. 2 System configuration of the multisource alternative hybrid energy system

The different energy sources in the system are integrated through an dc link bus. A power management strategy is designed for the system to coordinate power flows among the different energy sources. The details of the system configuration, power management strategy, unit sizing, maximum operation of the power generation units involved, and simulation results are given in this section.[6]

**System Configuration**

Figure 2 shows the system configuration for an ac-coupled hybrid wind-PV- FC system. In the system, the renewable wind and solar power are the primary power source, while the FC-electrolyzer combination is used as a backup and storage system. This system can be considered as a "green" power generation system because the main energy sources and storage system are all environmental friendly; the system can operate in stand-alone or grid-connected mode. When there is excess wind and/or solar generation available, the electrolyzer turns on to begin producing hydrogen, which is delivered to the hydrogen storage tanks. If the H2 storage tanks become full, the excess power will have to be diverted to other dump loads, not shown in Fig.2

When there is a deficit in power generation, the fuel cell stack will begin to produce energy using hydrogen from the reservoir tanks, or in case they are empty, from the backup H2 tanks. The battery bank is used only for supplying transient power to fast load transients, ripples and spikes in stand-alone applications. In grid connected applications, the battery bank can be taken out from the system; the utility grid will take care of transient power. The different energy sources are connected to a 50 Hz ac bus through appropriate power electronic interfacing circuits. The system can be easily expended, that is, future energy sources can be integrated into the system as desired, as shown in Fig. 2

**Overall Power Management Strategy**

An overall control strategy for power management among different energy sources in a multisource energy system is needed. Fig.3 Shows the block diagram of the overall control strategy for the proposed hybrid alternative energy system. The WECS, controlled by a pitch angle controller, and a PV electricity generation unit, controlled by a maximum power point tracking (MPPT) controller are the main energy sources of the system.

The power difference between the generation sources and the load demand is calculated as

$$Pnet = Pwind + PPV - Pload - Psc \qquad 1$$

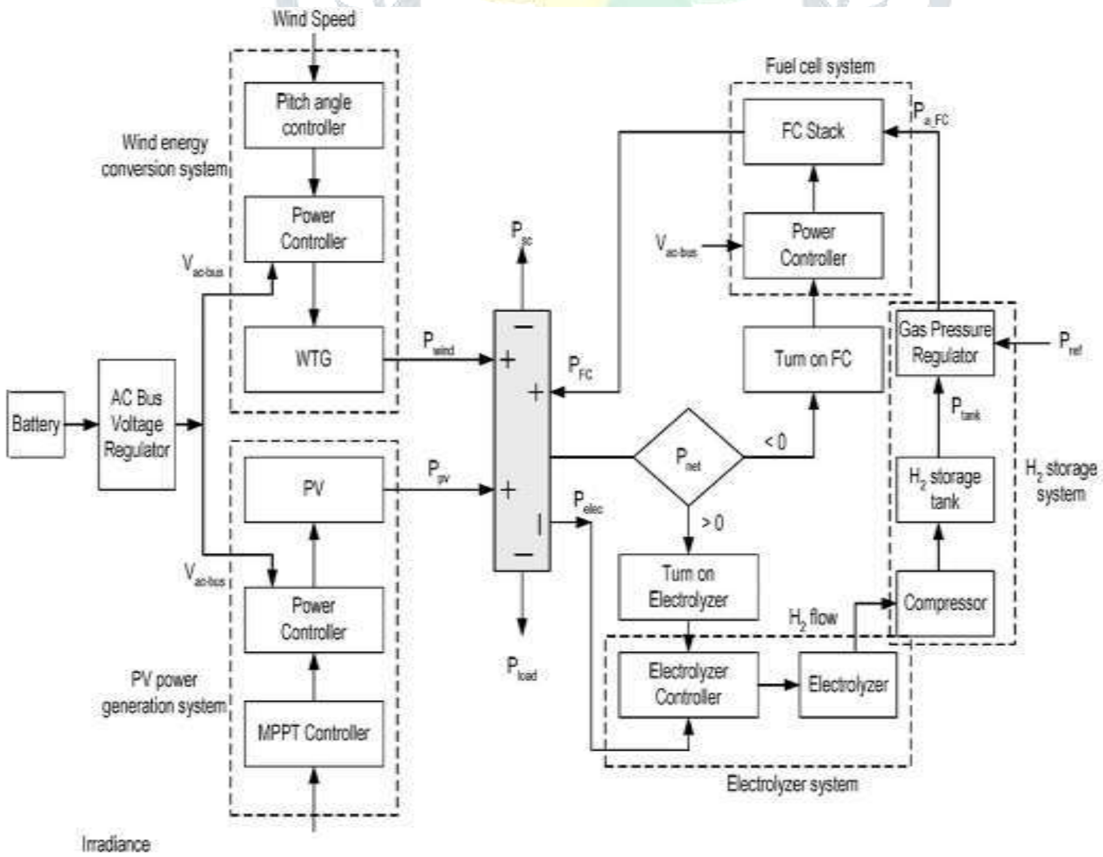


Figure 3 Overall Power Management Strategy

Where Pwind is the power generated by the WECS, PPV is the power generated by the PV energy conversion system, Pload is the load demand, and Psc is the self-consumed power for operating the system. The system self-consumed power is the power consumed by the auxiliary system components to keep it running, for example, the power needed for running the cooling systems, the control units, and the gas compressor. For the purpose of simplification, only the power consumed by the compressor (Pcomp) is considered in this study.

The governing control strategy is that, at any given time, any excess wind and PV-generated power (Pnet > 0) is supplied to the electrolyzer to generate hydrogen that is delivered to the hydrogen storage tanks through a gas compressor. Therefore, the power balance equation can be written as

$$Pwind + PPV = Pload + Pelec + Pcomp,\ Pnet > 0 \qquad 2$$

Where Pelec is the power consumed by the electrolyzer to generate H2 and Pcomp is the power consumed by the gas compressor. When there is a deficit in power generation (Pnet < 0), the FC stack begins to produce energy for the load using hydrogen from the storage tanks. Therefore, the power balance equation for this situation can be written as

$$Pwind + PPV + PFC = Pload,\ Pnet < 0 \qquad 3$$

Where PFC is the power generated by the FC stack.

## SIMULATIONS AND RESULTS

**Overall system simulation**

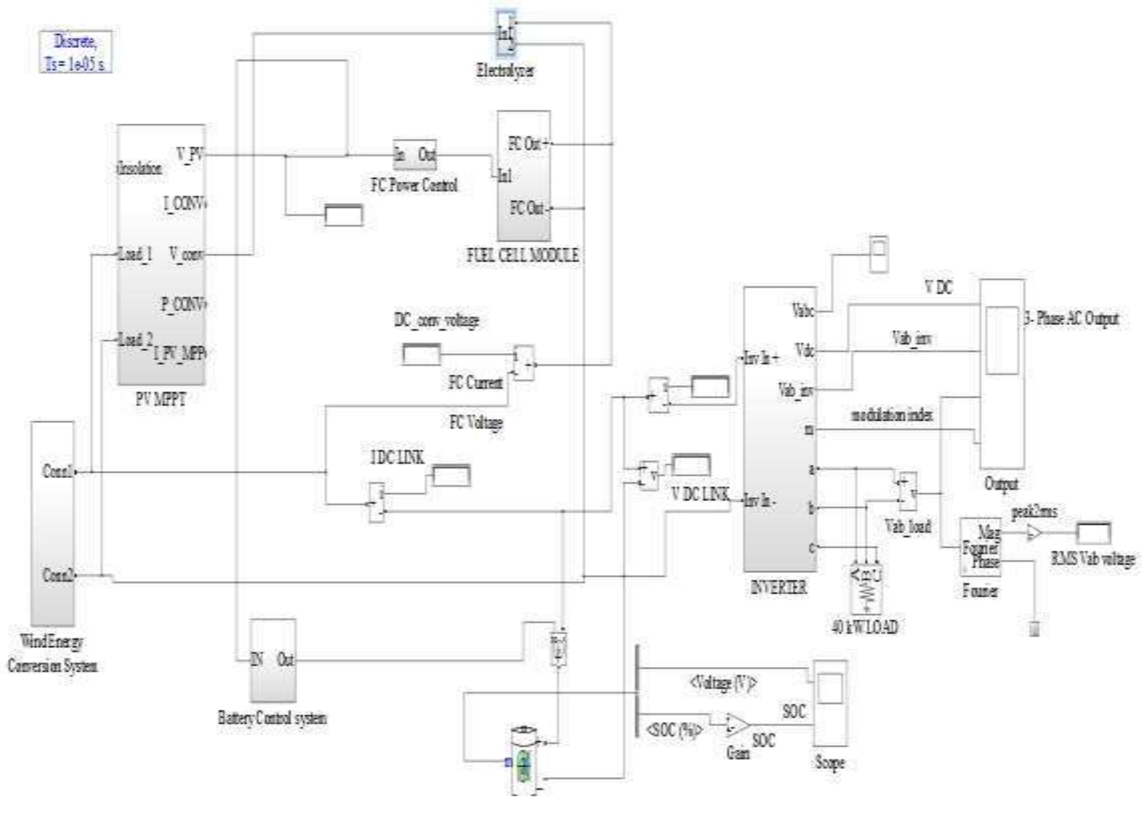


Figure 4 Overall system simulation

Figure.4 shows the simulation of overall completed system. In which there are five main system first one is PV array with MPPT control, Second is Wind Turbine, Third one is Fuel Cell system, Fourth one is Electrolyzer and Fifth is Battery for the storage purpose. Also there is three mode for it when there is maximum Power generated is more then load at that time Battery is charged. When irradiance is less then the limit(< 750) Power generated is less then load then Battery will discharge. When Battery will fully discharge and load demand is more then generation at that time Electrolyzer will turn on and supply Fuel cell. Then Fuel cell will in action and give supply to load.

**PV Array with MPPT And Dc-Dc Converter**

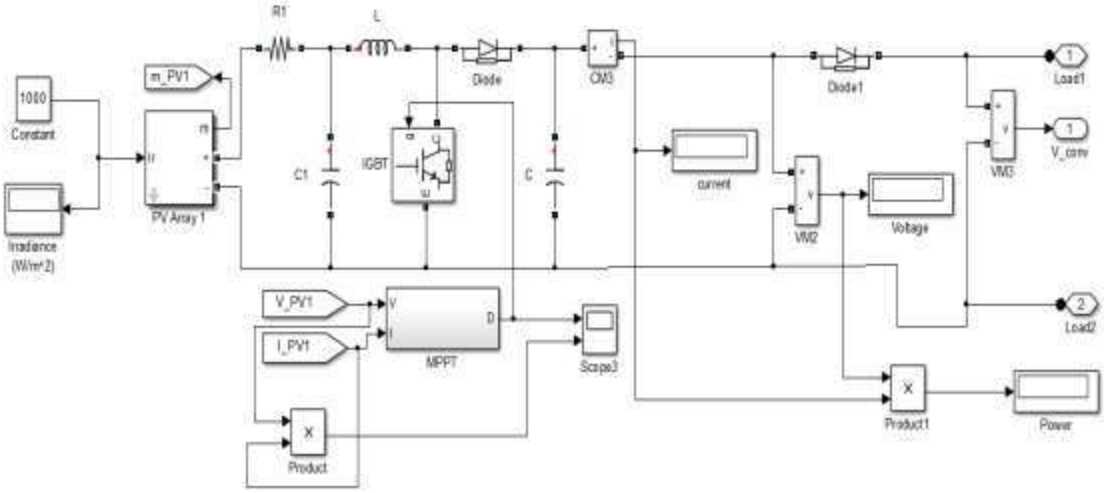


Figure 5 PV Array with MPPT and Dc-Dc Converter

A typical solar panel converts only 30 to 40 per cent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solar panel. According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the source impedance matches with the load impedance. In the source side a boost converter is connected to a solar panel in order to enhance the output voltage. By changing the duty cycle of the boost converter appropriately the source impedance is matched with that of the load impedance.

**Fuel Cell Control System**

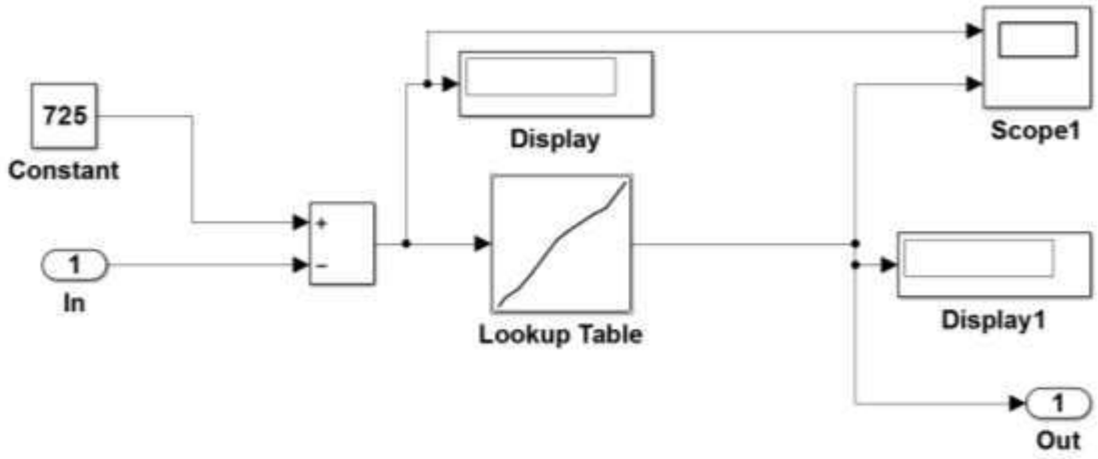


Figure 6 Fuel Cell Control Systems

Fig.6 shows the fuel cell control system in which output of PV is compared with the constant value and according to lookup table the fuel cell will be operate. Here the output voltage of PV is less than 725 and battery is fully discharge then fuel cell will operate.

**Simulation of Battery Control System**

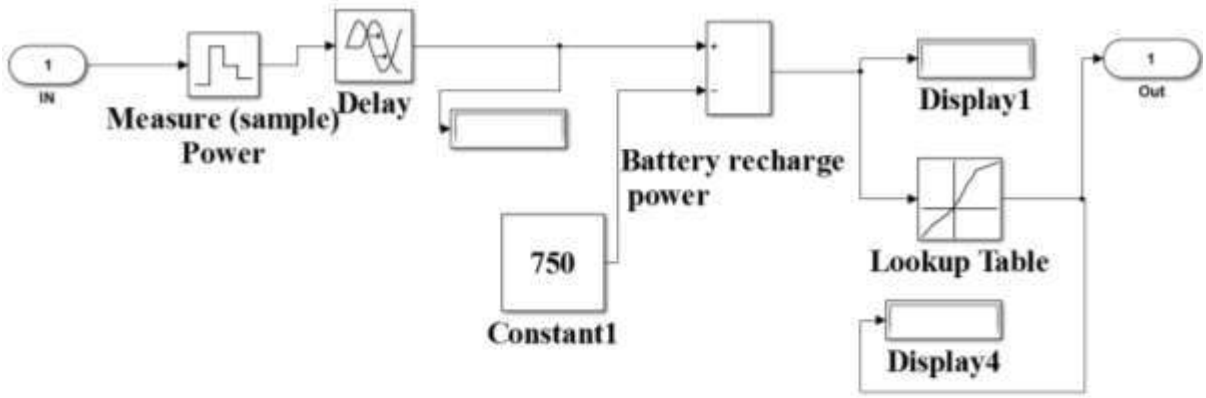


Figure 7 Simulation of Battery Control System

Fig. 7 shows the Battery control system in which the output of PV is compared with some constant value at which battery will come in to action. And according to lookup table battery will charge or discharge. Here voltage greater than
750V battery will be in charging mode and voltage less than 750V battery will be in discharging mode.

**Battery Specifications**

| | |
|---|---|
| Battery type | Nickel-Metal-Hybride |
| Nominal Voltage (v) | 700 |
| Rated Capacity (AH) | 50 |
| Initial State-of-charge (%) | 50 |
| Maximum Capacity (AH) | 53.7462 |

| | |
|---|---|
| Fully Charged Voltage (v) | 773.4746 |
| Nominal Discharge Current (A) | 10 |
| Internal Resistance (ohms) | 0.15 |
| Capacity (AH) @ Nominal Voltage | 47.0769 |
| Exponential Zone [Voltage (v), capacity (AH)] | [713.5593 10] |

Table:1 Battery Specifications

**Results of Battery Charging and Discharging**

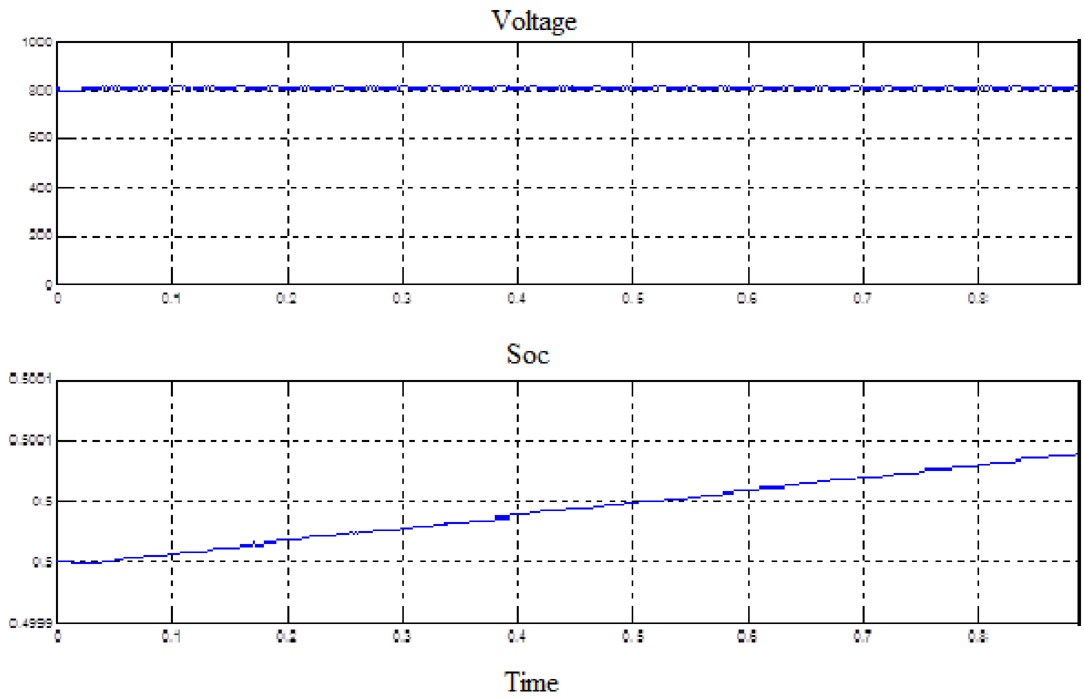


Figure 8 (A) Results When Battery Charging

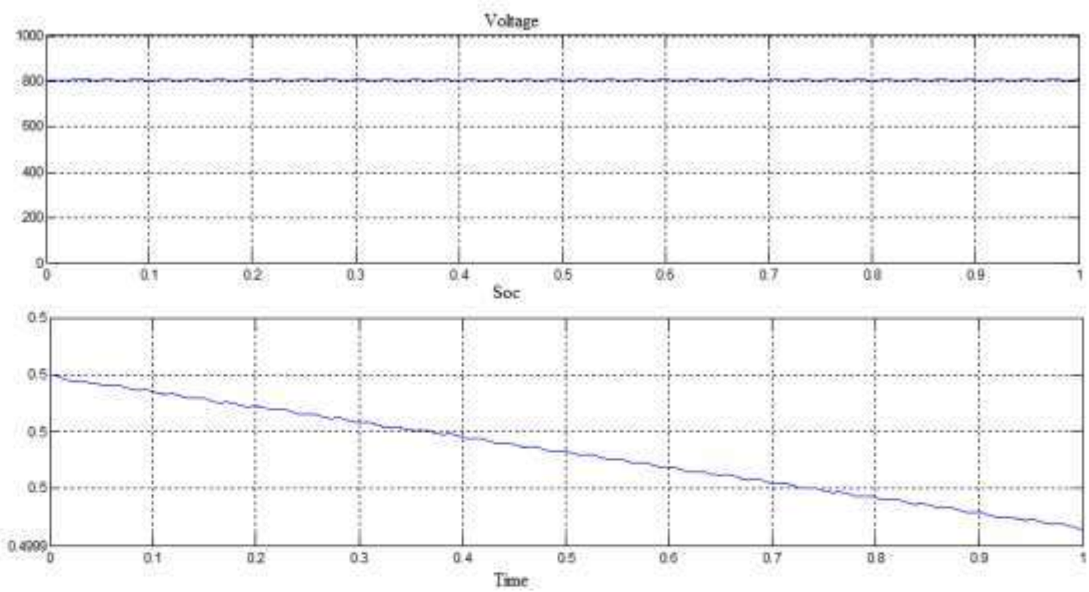


Figure 8 (B) Results When Battery Discharging

**Wind turbines With MPPT and DC-DC Converter**

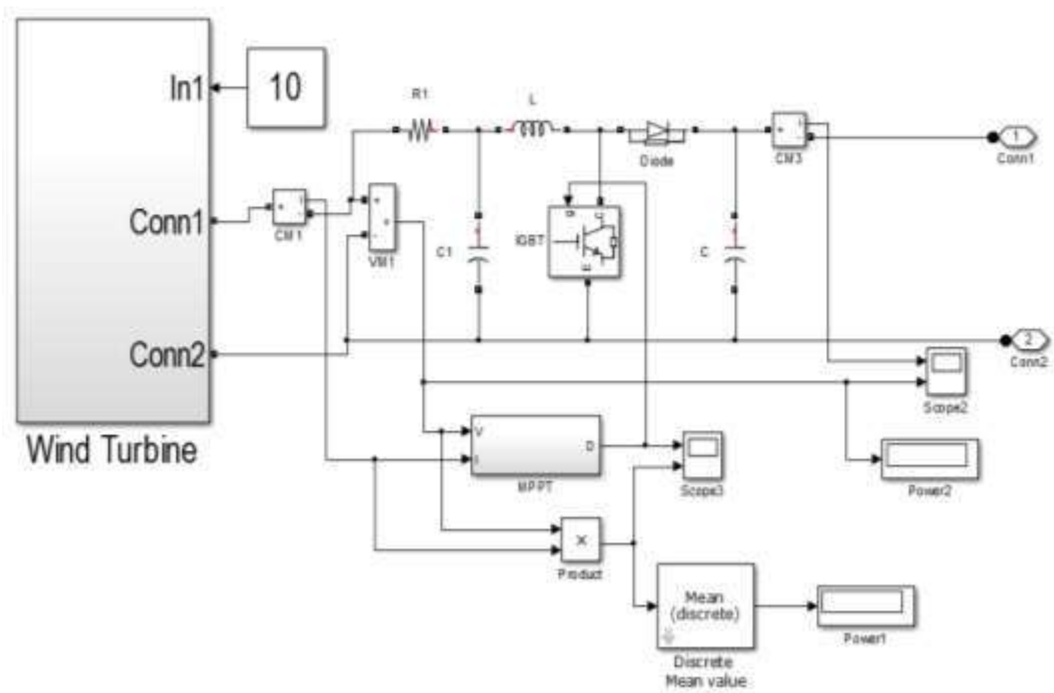


Figure 9 Wind turbines With MPPT and DC-DC Converter

Same as PV array the nature of wind turbine is intermediate so it cannot give constant output. So to constant out the output DC-DC converter is used. To reach at maximum output MPPT is used.

**Simulation of Wind Turbine Module with PMSG**

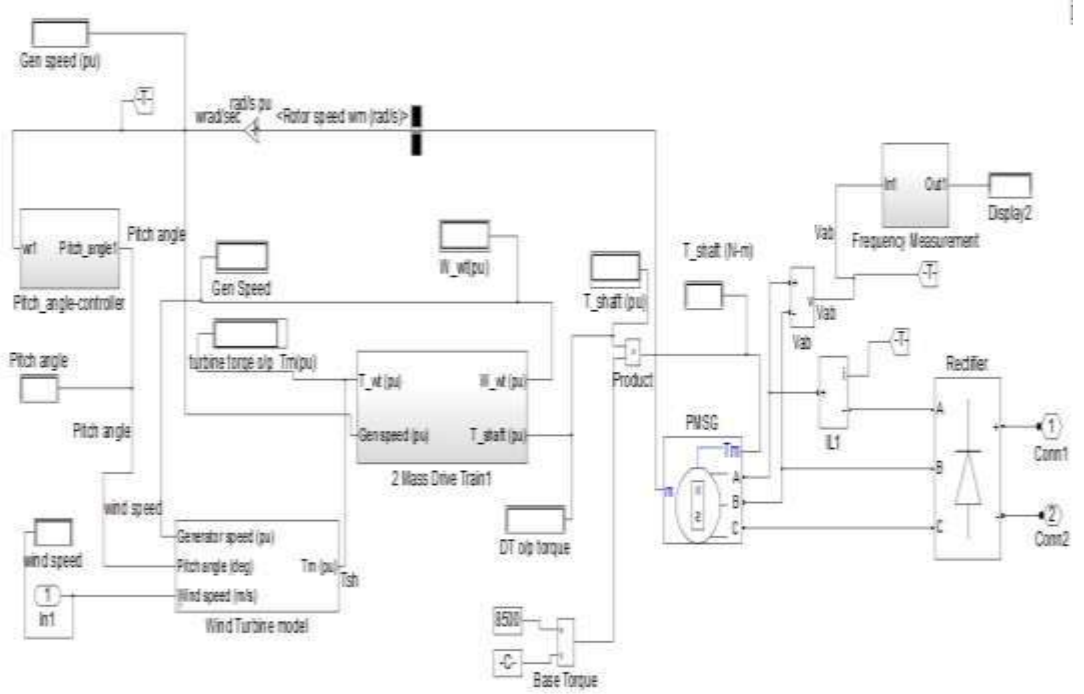


Figure 10 Simulation of Wind Turbine Module with PMSG

**Results Table**

| Insolation (w/m2) | Load (KW) | AC Voltage (rms) | DC Bus Voltage | PV I(A) | PV V(v) | PV P(w) | FC I(A) | FC V(v) | FC P(w) | Battery I (A) | Battery V (v) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1000 | 30 | 414.8 | 799.9 | 54.79 | 800.75 | 43870.93 | 0.00394 | 430.8 | 1.696 | 10 | 863.8 |
| 500 | 30 | 416.1 | 755.1 | 23.67 | 755.87 | 17892.87 | 0.00468 | 430.8 | 2.014 | 25 | 857.5 |
| 250 | 30 | 414.7 | 737.2 | 11.19 | 737.96 | 8259.26 | 0.00497 | 430.7 | 2.14 | 40 | 854.8 |
| 1000 | 40 | 414.6 | 784.4 | 51.49 | 785.2 | 40432.2 | 0.00419 | 430.8 | 1.806 | 10 | 860.2 |
| 500 | 40 | 415.2 | 718.2 | 25.63 | 718.86 | 18424.19 | 4.36 | 430 | 1875 | 40 | 856.7 |
| 250 | 40 | 416 | 686.2 | 7.36 | 686.94 | 5056.4 | 28.54 | 424.7 | 12120.9 | 40 | 854.7 |
| 1000 | 50 | 415.3 | 737.4 | 55.11 | 738.28 | 40684.58 | 0.00496 | 430.7 | 2.138 | 25 | 857.4 |
| 500 | 50 | 415.8 | 677.8 | 40.19 | 678.66 | 17277.06 | 37.77 | 422.8 | 15969.1 | 40 | 854.7 |
| 250 | 50 | 370.4 | 595.3 | 4.66 | 596.15 | 2777 | 40.36 | 422.2 | 17039.9 | 40 | 854.7 |

**Table 2: Results Table**

## CONCLUSION

A hybrid wind/PV/FC DG system is proposed in this paper. Wind and PV are the primary power sources of the system, and the combination of FC and electrolyzer is used as a backup and long term storage unit. The different energy sources in the system are integrated through an AC link bus. The system can be used as test-bed system for other related studies on hybrid alternative energy systems. Based on the dynamic component models, a simulation model for the proposed hybrid wind/PV/FC energy system has been developed successfully using MATLAB/Simulink. The overall power management strategy for coordinating the power flows among the different energy sources is presented in the paper. Simulation studies have been carried out to verify the system performance under different scenarios using practical load profile and real weather data. The results show that the overall power management strategy is effective and the power flows among the different energy sources and the load demand is balanced successfully.

## REFERENCES

**PAPERS**:

[1] M.MAHALAKSHMI, Dr.S.LATHA,"modeling, simulations and sizing of photovoltaic/wind/fuel cell hybrid generation system" International Journal of Engineering Science and Technology (IJEST), Vol. 4 No.05 May 2012

[2] M.M Hoque , I.K.A Bhuiyan , Rajib Ahmed, A.A .Farooque & S.K Aditya," Design, Analysis and Performance Study of a Hybrid PV Diesel - Wind System for a Village Gopal Nagar in Comilla",

Global Journal of Science Frontier Research Physics and Space Sciences Volume 12 Issue 5 Version 1.0 year 2012

[3] Rosana Melendez1, Dr. Ali Zilouchian2 Dr. H. Abtahi3, Power Management System applied to Solar/Fuel Cell Hybrid Energy Systems, 8th Latin American and Caribbean Conference for Engineering and Technology, June 1-4, 2010

[4] Guiting Xue, Yan Zhang and Dakang Zhu, "Synthetically Control of a Hybrid PV/FC/SC Power System for Stand-Alone Applications" Research Journal of Applied Science, Engineering and Technology

[5] Esmaeil Alikhani, Mohammad Ahmadian, Ahmad Salemnia, Optimal Short-term Planning of a Stand-Alone Micro grid with Wind/PV/Fuel Cell/Diesel/Micro turbine, Canadian Journal on Electrical and Electronics Engineering Vol. 3, No. 3, March
2012.

[6] Caisheng Wang and M. Hashem Nehrir," Power Management of a Stand-Alone Wind/Photovoltaic/Fuel Cell Energy System" IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 23, NO. 3, SEPTEMBER 2008

[7] M. Hashem Nehrir and Caisheng Wang "Modelling and Control Of Fuel Cells Distributed Generation Application". International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering December 2013

[8] T.U. Townsend, A Method for Estimating the Long-Term Performance of Direct- Coupled Photovoltaic Systems, MS thesis, University Of Wisconsin – Madison, 1989. [9] Hohm, D. P. & M. E. Ropp "Comparative Study of Maximum Power Point Tracking Algorithms" Progress in Photovoltaic: Research and Applications November
2002, page 47-62

[10] Dezso Sera, Tamas Kerekes, Remus Teodorescu and Frede Blaabjerg" Improved
MPPT algorithms for rapidly changing environmental conditions".

[11] S.C. Singhal, "Advances in tubular solid oxide fuel cell technology," Solid State
Ionics, Vol. 135, pp.305-313, 2000.

[12]Miguel LópezJean-Claude Vannier, "Stand-Alone Wind Energy Conversion System With Maximum Power Transfer Control" Ingeniare. Revista chilena de ingeniería, vol. 17 Nº 3, 2009

[13] Mahmoud M. Hussein , Tomonobu Senjyu , Mohamed Orabi , Mohamed A. A. Wahab and Mohamed M. Hamada "Control of a Stand-Alone Variable Speed Wind Energy Supply System," Appl. Sci. 2013, 3, 437-456; doi:10.3390/app3020437

[14] Mohamed Hilmy, Mahrous E. Ahmed, Mohamed Orabi, and Mohamed ElNemr, "Modelling and Control of Direct Drive Variable Speed Stand-Alone Wind Energy Conversion Systems" Proceedings of the 14th International Middle East Power Systems Conference (MEPCON'10), Cairo University, Egypt, December 19-21,
2010, Paper ID 276.

[15] W. Kreuter and H. Hofmann, "Electrolysis: The Important Energy Transformer in a World of Sustainable Energy," Int. J. Hydrogen Energy, Vol. 23, No.8, pp. 661-
666, 1998.

[16] A.F.G Smith and M. New borough, "Low-Cost Polymer Electrolysers and Electrolyser Implementation Scenarios for Carbon Abatement," Report to the Carbon Trust and ITM-Power PLC, Nov. 2004.