Hybrid Energy System Modelling for a Battery Operated Vehicle

Allam Venkata Surendra Babu, S. Pradeepa, Siva Subba Rao Patange

Department of Power Electronics (EEE), BMS College of Engineering, Bangalore, India

Abstract

Over the past few years there has been enormous increase in the consumption of the Electrical Energy, major part of which is extracted from the conventional way of Power Generation using fossil fuels, due to which the resource of the fossil fuels are draining, results of the some surveys shows that the fossil fuel reserves may last only few decades. Hence utilization of the energy generated from the Renewable Energy resources like Solar, Wind, Bio-Mass, etc. has to be encouraged to save the atmosphere and as an alternative fuel for the energy generation.

Among the Renewable Energy resources Solar and Wind power generation have been increasing significantly due to the availability of the resources, ease of the generation, etc. so in this study we proposed a Hybrid Energy System which combines both the Solar Power and Wind power Generation . A control strategy has been proposed to track the operating point at which maximum power can be extracted from the Solar PV system and Wind Turbine Generator under certain environmental conditions. The detailed description of the entire hybrid system had been given along with the comprehensive simulation results. A software model is developed in Matlab/ Simulink.

1. Introduction

In the recent years after the evolution of the energy extraction from the renewable energy resources like Solar, Wind, Bio-mass etc. the world started motivating towards the utilization of the renewable energy, as the energy obtained is clean, harmless to the environment etc. Solar energy is obtained due to the irradiation of the sunlight, solar cell is a p-n junction diode in which when sunlight falls on the cell the photons in it flows from the n-junction to the p-junction due to which the electric current flows, hence the solar energy is created.

Wind is also a form of solar energy which is caused due to the uneven heating caused in the atmosphere, which flows from the higher altitude to the lower altitudes. And the wind flow pattern depends on many parameters like season, water bodies, earth terrain, vegetation and geography. And wind turbine converts the kinetic energy of the wind to mechanical energy which is connected to separately excited DC Generator which converts the mechanical energy to electrical energy.

As transportation is also a major part in the utilization of the fossil fuel hence to reduce the consumption the fossil fuel usage, as a part of contribution here a hybrid energy system had been modelled. Were the project is all about a hybrid energy system modelling integrating both solar power and the wind power for hybrid vehicles operated using battery.

The paper is organized as follows In chapter 1 the introduction of the project had been discussed, along brief explanation of hybrid energy system, motivation and the objectives of project is also deliberated, chapter 2 is about the literature survey which explains about the work done in the earlier stages, chapter 3 deliberates the design of solar P-V module and the design of wind turbine, chapter 4 explains how the hybrid energy system is modelled in the

Corresponding Author,
E-mail address: surendrallam@hotmail.com

Matlab/Simulink, chapter 5 is about the testing and the simulation of the hybrid energy model, chapter 6 is about the conclusion and the future scope of the project, and the references are deliberated at last.

2. Design of the Energy System

A. Solar P-V Module

P-V array is formed by connecting modules in series and parallel, the diode equivalent of the P-V module is shown below in Fig 3.1. And the solar P-V module is modeled below.
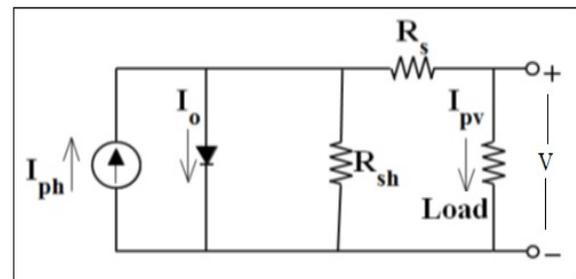

Fig: 1. Diode equivalent of P-V Module

Photo-current of the P-V module:

$$I_{ph} = \left\{ \left[I_{SCr} + (T - 298) \right] * \frac{\lambda}{1000} \right\}$$

Reverses saturation current of the P-V module:

$$I_{rs} = I_{SCr} \Big/ \left[exp\left(\frac{qV_{oc}}{N_s kAT} \right) - 1 \right]$$

Saturation current of the module:

$$I_o = I_{rs} \left[\frac{T}{T_r} \right]^3 exp\left[\frac{q*E_{go}}{Bk} \left\{ \frac{1}{T_r} - \frac{1}{T} \right\} \right]$$

The current output of P-V module:

$$I_{pv} = N_p * I_{ph} - N_p * I_o \left[\exp\left\{ \frac{q*(V_{pv}+I_{pv}R_s)}{N_s kAT} \right\} - 1 \right]$$

The Voltage Output of the P-V module:

$$V_{pv} = \frac{AkT_r}{q} \ln\left[\frac{I_{ph}+I_o-I_{pv}}{I_o} \right] - R_s I_{pv}$$

This equations are used to simulate in mat lab/Simulink and the result shows the nonlinear characteristics of photovoltaic array at different irradiations and temperature.

Table: 1. Solar Module (300W) Specification

Rating	305.5W
Current at Peak	5.58A
Voltage at Peak	54.7V
Short circuit current	5.96 A
Open circuit voltage	64.2 V

B. Modelling of Wind turbine

Wind turbine converts the Kinetic energy of the wind to mechanical energy, this conversion depends on many parameters like velocity of the wind, pitch angle of the blade, tip speed ratio, performance coefficient of the turbine swept area of the turbine, and air density etc. Output of the wind turbine is the wind power

$$P_0 = \frac{1}{2}(Air\ mass\ per\ unit)(Wind\ Velocity)^2$$

$$P_0 = \frac{1}{2}(\rho A V_w)(V_w)^2$$

$$P_0 = \frac{1}{2}(\rho A V_w^3)$$

The above equation clearly states the power available in the wind, but the mechanical power obtained from the turbine is different from each turbine as it depends on the performance of the turbine. Hence the aerodynamic power generated from the wind is given by

$$P_m = \frac{1}{2}(\rho A C_p V_w^3)$$

Where ρ = air density (kg/m^2);

A= swept area of turbine;

C_p = performance coefficient;

V_w = wind velocity (m/s).

$$C_p(\lambda,\beta) = C_1\left(\frac{C_2}{\lambda_i} - C_3\beta - C_4 \right) exp^{\frac{C_5}{\lambda_i}} + C_6\lambda$$

$$\frac{1}{\lambda_i} = \left(\frac{1}{\lambda+0.08\beta} - \frac{0.035}{\beta^3+1} \right)$$

Where C1=0.5176, C$_2$=116, C$_3$=0.4, C$_4$=10, C$_5$=21, C$_6$=0.0068.

    λ = Tip speed ratio,
    β = pitch angle.

Power coefficient (C_p) is the function of tip speed ratio (λ) and pitch angle (β). The characteristics curve shows the detailed behavior of mechanical power extracted from the wind at different wind speed. And the power coefficient reaches maximum of 0.48 for maximum tip speed ratio of 0.81. The mechanical power obtained from the turbine has to be converted to torque, the mechanical torque is the ratio of the power obtained from the turbine to

$$T_m = \frac{P_m}{\omega}$$

$$T_m = \frac{1}{2}(\rho A C_M R V_w^2)$$

$$C_M = \frac{C_p}{\lambda}$$

The above equation of torque defines the amount of torque delivered by the turbine to the connected generator shaft, it clearly states that torque is directly proportional to the square of the wind speed.

The wind turbine specifications are tabulated in table.3.1.

Table: 2. Wind Turbine Specifications

Rating	1.8KW
Cut-in Speed of wind	3m/s
Cut-out Speed of wind	25m/s
Rated wind Speed	12m/s
Air-Density	1.255kg/m^3

3. Implementation in Matlab/Simulink

The model is developed using Matlab/Simulink, the main block diagram of the Hybrid Energy System is shown in the Fig.1 it shows the Solar Energy System, Wind Energy System, Energy monitoring System and Battery storage device.

The brief explanation of the each block is given below. Solar energy system and wind energy system generates power depending on the conditions in the input side which is given to the energy monitoring system for monitoring the input energy and in take depending on the requirement of voltage condition of the battery.
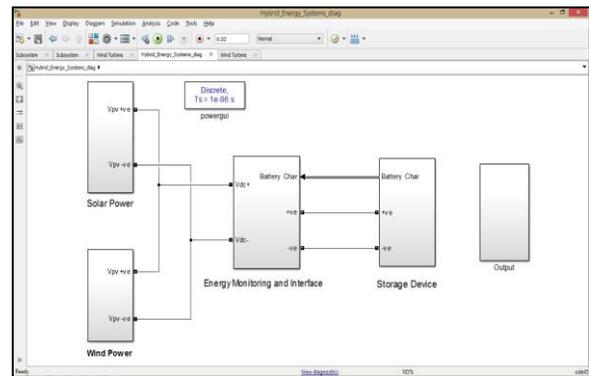

Fig: 2. Complete Simulation of the Hybrid Energy System

The Fig.2 shows the internal circuitry of Solar Energy System. In which solar energy is extracted from the solar panel and is given to boost converter for DC power regulation. For the extraction of the maximum from the solar module an Incremental Conductance Maximum Power Point Tracking Algorithm had been designed with which maximum power is been extracted from the solar module by tracing the maximum point of power in the solar module characteristics. The output power depends on two parameters of the solar module Irradiation and temperature of the module. The changes occurred in the solar module creates the change in output power from the solar module, which is given to the MPPT algorithm technique which monitors the changes and generates the pulses for triggering the gate of IGBT for regulating the output power to be in defined limit. These changes are made as per the duty cycle of the gate drive of IGBT. Triggering pulses are generated using the Pulse width modulation according to the changes in the duty cycle of gate drive of IGBT.
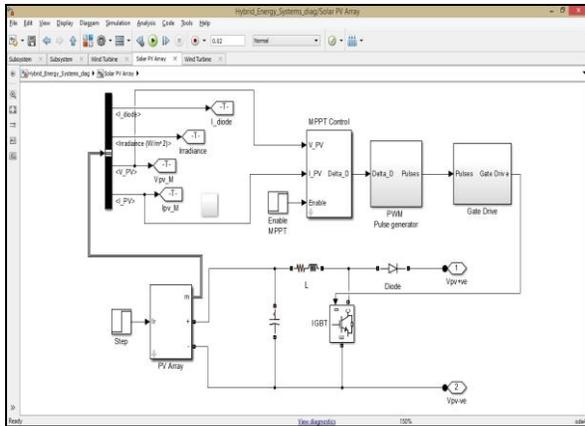

Fig: 3. Design of Solar energy system.

Fig.3 shows the design of Wind Energy System in which is been designed using wind turbine connected to the separately excited DC machine, and the output of the DC machine to be given to the Buck-Boost converter for the regulation. When their occurs the changes in the wind speed or in tip angle the torque obtained from the wind turbine changes which is connected to the shaft of the separately excited DC machine which generates the electricity from the input load torque.
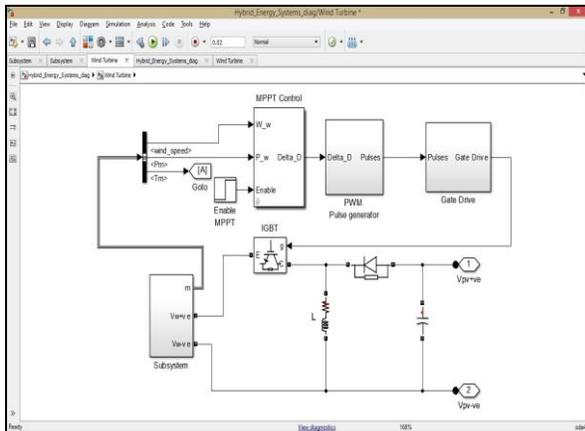

Fig: 4. Design of Wind Energy System

Fig.4 is shows energy monitring system in which the power obtained from the two sources is been monitered and will take energy from any one source or from the both as per the reuirement of battery charging. Here the controller is designed such the battery starts charging when the battery volatge is less than the certain limit and it will avoid the battery usage when the battery voltage is below certain limit. Hence the controller is bee designed.
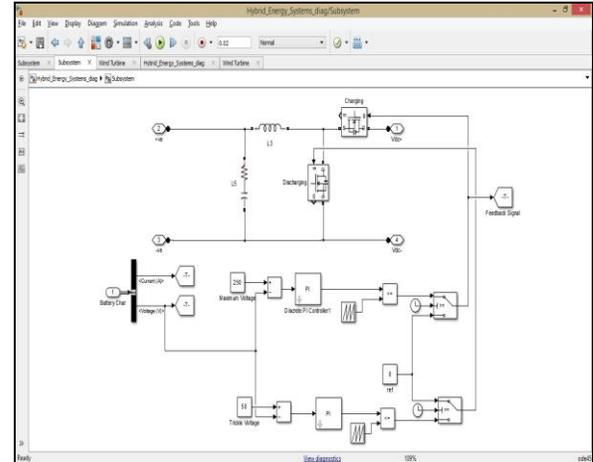

Fig: 5. Design of energy monitoring system

Fig.5 shows the battery storage device in which the energy from the source chosen by energy monitoring system is been connected to the battery to get it charged. The battery starts getting charged when the voltage of the battery is less than the 95% of its full charge and it will not allow the battery to get drained when the battery voltage goes below 15% of full charge.
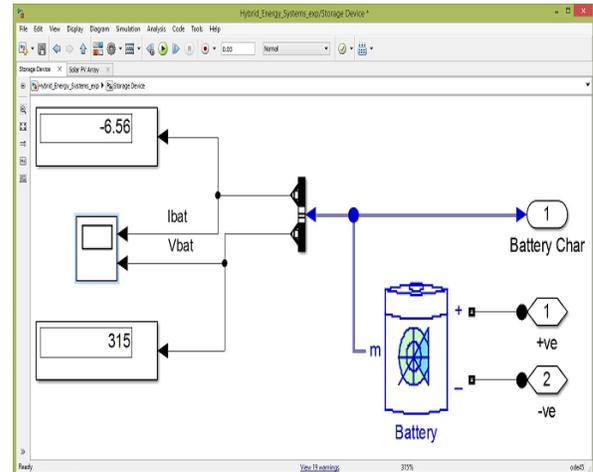

Fig: 6. Battery Storage Device

Hence modeling of the Hybrid Energy system is done using Matlab/Simulink and compiled. The results are obtained which is explained in the section VI.

4. Simulation Results

The model developed in the Matlab/Simulink is has compiled and the results are obtained as shown below. Here the output obtained at the output side of solar energy system, wind energy system and the battery characteristics.

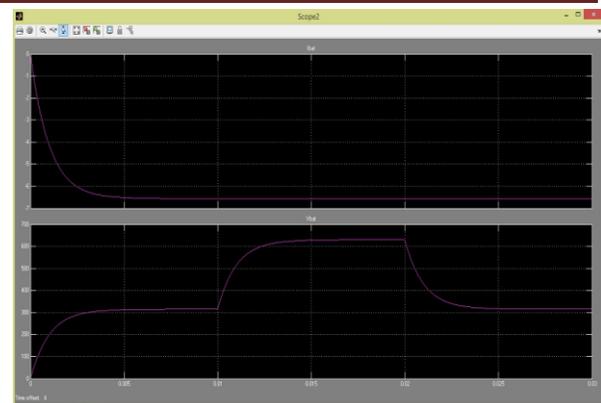**Fig: 7.** Voltage, Current and Power output waveforms of solar energy system

Fig: 9. Voltage and Current waveforms of battery
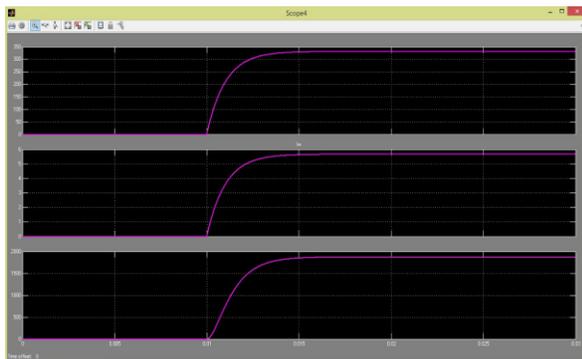

Fig: 8. Voltage, Current and Power output waveforms of wind energy system

References

[1] N. Pandaniarjan, Ranaganth Muth, Wrote a paper titled Mathematical Modeling of Photovoltaic Module with Simulink, International Conference on Electrical Energy Systems, 2011

[2] H. Altas, A. M. Sharaf, A Photovoltaic Array Simulation Model for Matlab-Simulink GUI Environment, IEEE conference on Solar Energy, 2007

[3] Turner, How Solar Photovoltaic cell converts solar energy to electrical energy, Monthly journal Trends in Solar Energy Systems, 23(4)

[4] S. Chowdary, S. P. Chowdary, G. A. Taylor, Y. H. Song, wrote a paper titled, Mathematical Modeling of a Stand-Alone Polycrystalline P-V Plant with MPPT Facility, IEEE conference on Advancements in solar energy on 2014

[5] R. II. Ovando, J. Aguayo, M. Cotorogea, Emulation of a Low Power Wind Turbine with a DC motor in Matlab/Simulink, published in IEEE conference on wind energy systems, 2007

[6] F. Boico, B. Lehman, Study of Different Implementation Approaches for a Maximum Power Point Tracker, IEEE COMPEL Wrokshop, Rensselaer Polytechnic Institute, Troy, 2006

[7] M. A. G. de Brit, Jr. L. Galoto, L. P. Sampio, G. de A. e Mel, C. A. Canesin, Evaluation of the Main MPPT Techniques for Photovoltaic Applications, IEEE transcations on Industrial Electronics, 60(3), 2013

[8] D. W. Hart, Power Electronics (Indian Edition), McGraw Hill Education (India) Private Limited, 2011 Edition, 2013

[9] Ned Mohan, Tore M. Undeland, William P. Robbins, Power Electronics, Converters, Applications, and Design, John Eiley and Sons INC, 3rd Edition, 2013

[10] R. M. Zavadil, wrote an article titled "Wind Generation Technical Characteristics for the NYSERDA Wind Impacts Study

[11] Judy Amanor-Boadu, Mohamed A. Abouzied, Salvador Carreon bautisa, Roland Rideiro, Xiaosen Liu, Edgar Sanchez-Sinencio, A Switched Mode Li-ion Battery Charger with multiple Energy Harvesting Systems Simultaneously used as Input sources, published in IEEE conference on renewable energy resources, 2014

[12] Cheng Zhang, Kang Li, Sean Mcloone, Zhile Yang, Battery Modelling Methods for Electric Vehicles - A Review, European control conference (ECC), 2014, France.

[13] Ugar Fesil, Rafi Bagir, Mahmut Ozer, Design and Implementation of a Domestic Solar-Wind Hybrid Energy System, IEEE conference of Electrical Energy Systems on 2013

[14] Ahmad Atieh, Samir Al Sharif, Khaleel Mohammed, Mahdi Alnakhli, Hybrid Wind/Electric Powered Vehicle, The fifth International Renewable Energy Congress IREC, 2014