New Method for Controlling of Solar-Wind System

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Abstract

This article offerings the simulation and investigation and control of a hybrid system centered on solar and wind system engaging a dc-dc boost converter and permanent magnet synchronous generator. Maximum power point tracking controllers of solar PV and wind system are functioning on perturb and perceive method that extract the maximum power from solar and wind springs. It needs the knowing of dc voltage and current output of solar PV and the rectified output voltage of PMSG motivated by a wind turbine. We implemented load leveling through battery means that the solar–wind hybrid structure equips with the battery to supply the load demand. We developed the modeling of the system in MATLAB and MPPT control is considered during changing solar irradiance and wind speeds.

Keywords: Hybrid control systems, Solar panels, Renewable energy

INTRODUCTION

In the modern world majority of the world's energy sources are from the conventional sources (non renewable)-fossil fuels such as coal, natural gases and oil. These fuels are often termed non-renewable energy sources, as they cannot be renewed at the rate of its consumption. With growing concern of global warming and the reduction of fossil fuel reserves, many are look at sustainable energy solution to preserve the earth for the future generations. Hence the importance of renewable energy is dominant. Renewable energy sources which are also called as non-conventional type of energy are the sources which are continuously renewed by natural process. The majority of the renewable energy comes either directly or indirectly from sun and wind and can never be exhausted, and so they are called renewable energy [1-2].

Wind and photovoltaic energy holds the most potential to meet our energy demands. Alone, wind energy is capable of supplying large amounts of power but its presence is highly unpredictable as it can be here one moment and gone in another. Similarly, solar energy is present throughout the day but the solar irradiation levels vary due to sun intensity and unpredictable shadows cast by clouds, birds, trees, etc. [3].

Solar energy and wind energy match with each other at changed seasons and climate conditions, as a result independent wind-solar hybrid power system is expected to obtain better performance. Therefore, the hybrid energy source based on solar-PV and WECS are highly being a focus of research. It can provide high-quality power and also reduce the overall cost of power generation and greater balance in power supply. As a result, the important potential of renewable energy can is fully developed [4].

The systems with only solar or wind power generation are productive but there are problems linked with both of them. The solar power is not available for 24 hours and wind is not continuous all the time. So a hybrid system containing solar and wind has been designed to overcome these shortcomings. A system has been designed which utilizes both solar and wind power generation systems with the storage batteries for continuous power. Recent researches in the field of renewable resources shows that the solar and wind hybrid power generation system can work with increased outputs and increased practicality [5-6].

I-Solar PV-Wind Hybrid System

In this paper, a solar photovoltaic-wind hybrid power generation system model is studied and simulated. A hybrid system is more advantageous as individual power generation system is not completely reliable. When any one of the system is shutdown the other can supply power. A block diagram of entire hybrid system is shown below [7].

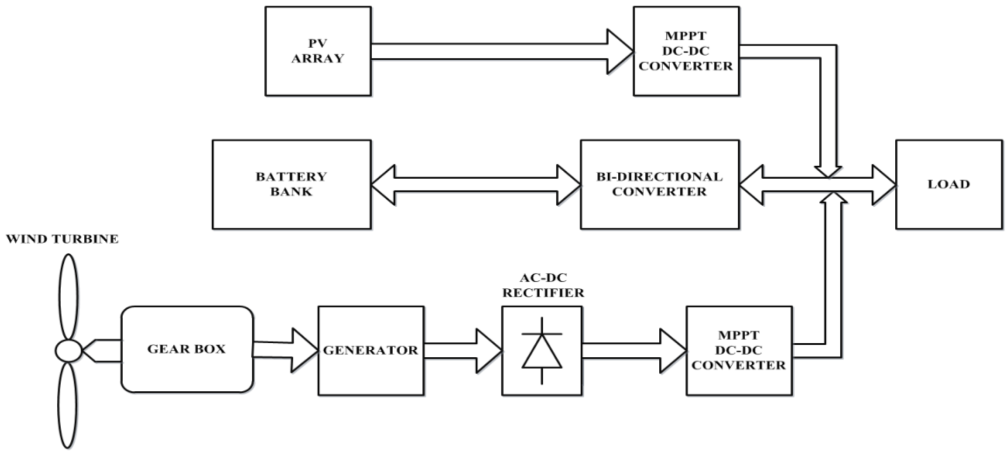

Figure 1: Proposed Schematic Diagram of Hybrid System [7]

The proposed hybrid power generation system is comprised of PV modules, storage battery and wind turbine generator. In recent times, the issues of how power fluctuations in solar PV and wind power generation are to be smoothed have attracted widespread interest and attention. And even as this issues is being resolved, another one, that of the application of an energy storage system such as Battery, has arisen.

Hybrid generation systems that use more than a single power source can greatly enhance the certainty of load demands all the time. Even higher generating capacities can be achieved by hybrid system. Surplus energy of solar power system and wind power system is stored in battery bank through bidirectional converter when power generation is higher than load demand.

- **Advantages of a Hybrid System**

1. To maintain the continuity of the energy and to maintain it at a level required by the load, a modified configuration including a source other than PV is essential means solar system is hybridized with the wind power generation system because both are in complement to with each other.
2. Another significant advantage of hybrid system is the flexibility it provides in terms of the effective utilization of the PV array means if PV generates more power than that demanded by the load, surplus power can be stored into the storage batteries.
3. A hybrid system can use of a complementary nature of the solar and wind sources, which helps in reducing the power oscillations or power outs.
4. Hence, combining a PV source with a wind generator can reduce the zero power intervals.
5. Environmental friendly especially in terms of CO_2 emission reduction.
6. Low cost – wind energy, and also solar energy can be competitive with oil, nuclear, coal and gas energy and Costs are predictable.
7. In a hybrid system, the various sources can be controlled to have a better efficiency of the individual sources. In addition, it gives more flexibility in terms of space and location required for the installation.

A. Modeling of Solar PV system

Solar Photovoltaic (PV) systems convert the solar energy directly into electric energy. In general, an element that converts sunlight into electricity is called a PV device. The vital component in a solar PV system is the Solar Cell, while a set of connected solar cells form a panel or module. As an array either a module or a set of modules can be considered [8].

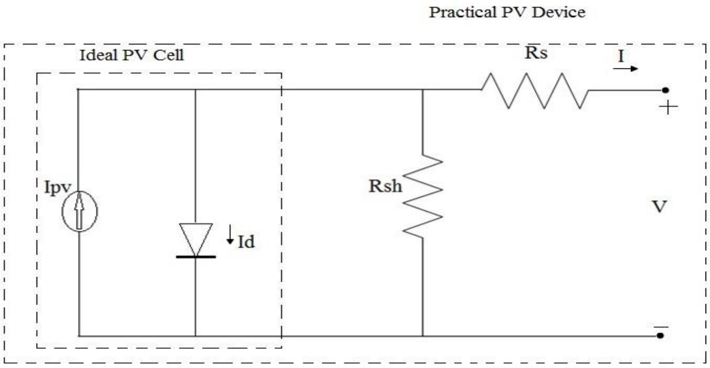

Figure 2: Equivalent circuit of a practical PV device [8]

A PV cell can be represented by the equivalent electric circuit shown in figure 2. An ideal PV cell is modelled by a current source in parallel with diode. But practically no solar cells are ideal and thereby shunt and series resistances are added to model as shown in Fig 2. This circuit consists of a diode which represents the PN junction of the cell and a constant current source whose current amplitude depends on the intensity of the radiation. The series resistance Rs represents the various contact resistance and the resistance of the semiconductor whose value is very small, R_P is the equivalent shunt resistance which has a very high value, hence they may be neglected to simplify the analysis. With such an equivalent electrical circuit, one can obtain the following mathematical model of the PV cell.

The equation based on the theory of semiconductors that mathematically describes the I-V characteristics of an ideal PV cell is the following equation:

$$I = I_{pv} - I_d - I_{Rsh} \tag{1}$$

$$I = I_{pv} - I_0 \left[exp\left(\frac{V+IRs}{a}\right) - 1\right] - \left(\frac{V+IRs}{Rp}\right) \tag{2}$$

Where, $a = \frac{N_S.A.K.T_c}{q} = N_s.A.V_T$

I_{pv} = Current generated by the incident light and is directly proportional to the solar irradiance [A].

I_d = Diode current.

I_0 = Leakage current or saturation current of the diode [A].

q = Electron charge ($1.602x10^{-19}$ C).

K = Boltzmann constant ($1.3806x10^{-23}$ J/K).

T = Temperature of the p-n junction [K].

A = Diode ideality constant.

V_T = Thermal Voltage [V].

N_s = Number of PV cells connected in series.

T_c = Actual cell temperature [K].

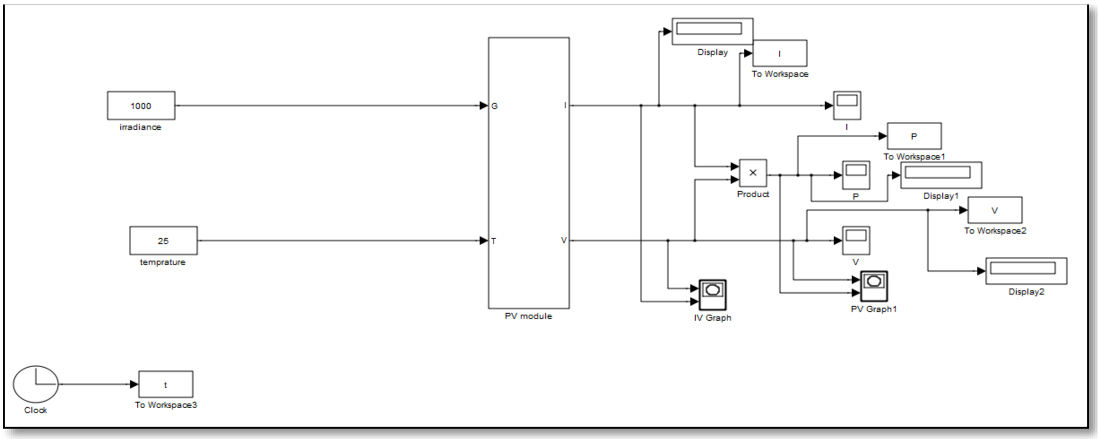

Figure 3: Simulink model of a PV device

The light generated current of the solar cell is mainly depends on the solar irradiation level and its working temperature, which is expressed as :

$$I_{pv} = I_{sc} + K_i(T_c - T_{cref}).\frac{G}{1000} \quad (3)$$

Where,

I_{sc} = Short circuit current of cell at 25^0C and $1000 W/m^2$.

K_i = short circuit temperature coefficient of cell.

T_{cref} = Reference temperature of cell.

The diode saturation current of the cell varies with the cell temperature, which expressed as :

$$I_0 = I_{0,ref}\left(\frac{T_c}{T_{cref}}\right)^3 exp\left[\frac{qE_g}{AK}\left(\frac{1}{T_{cref}} - \frac{1}{T_c}\right)\right] \quad (4)$$

Where,

$I_{0,ref}$ = Reverse saturation current of a cell at a reference temperature and a solar irradiation.

E_g = Band energy of the semiconductor used in the cell ($E_g \approx 1.12$ eV for polycrystalline Si) at 25^0C.

The reverse saturation current of a cell $I_{0,ref}$ is :

$$I_{0,ref} = \frac{I_{sc}}{exp\left(\frac{q}{AkT_cN_s}V_{oc}\right)-1} \quad (5)$$

Where,

V_{oc} = Open circuit voltage [V].

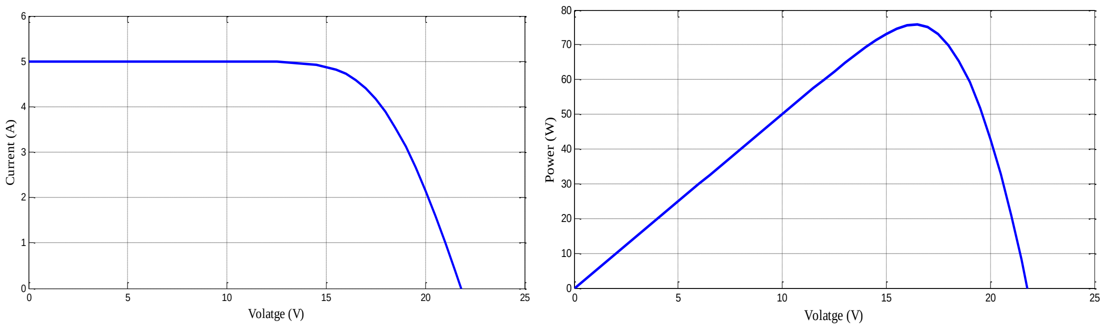

Figure 4: I-V and P-V characteristics of solar PV module at nominal condition

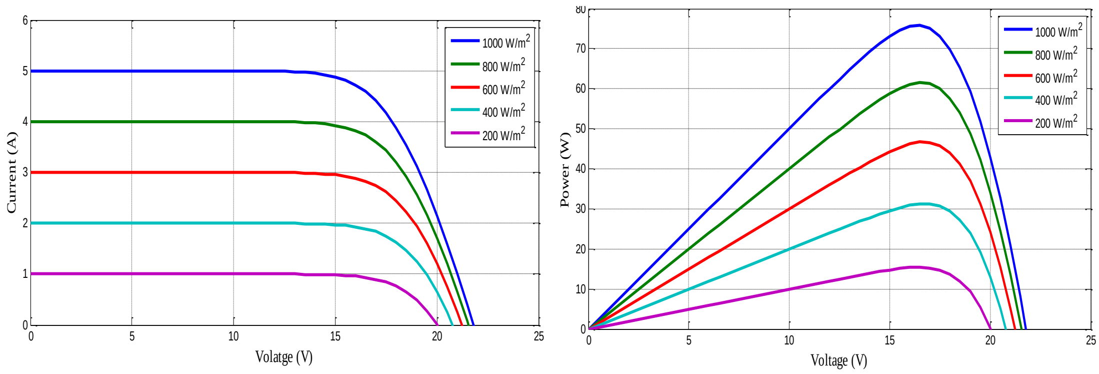

Figure 5: I-V and P-V characteristics of solar PV module at effects of variation of irradiation

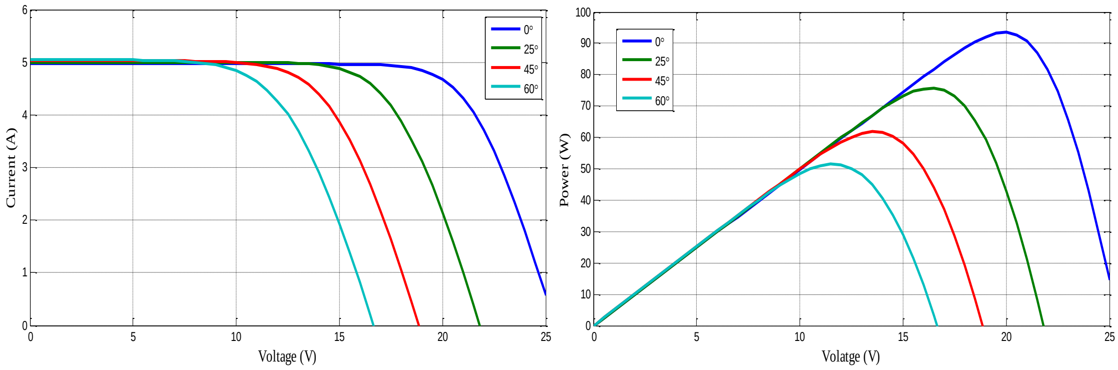

Figure 6: I-V and P-V characteristics of solar PV module at effects of variation of temperature

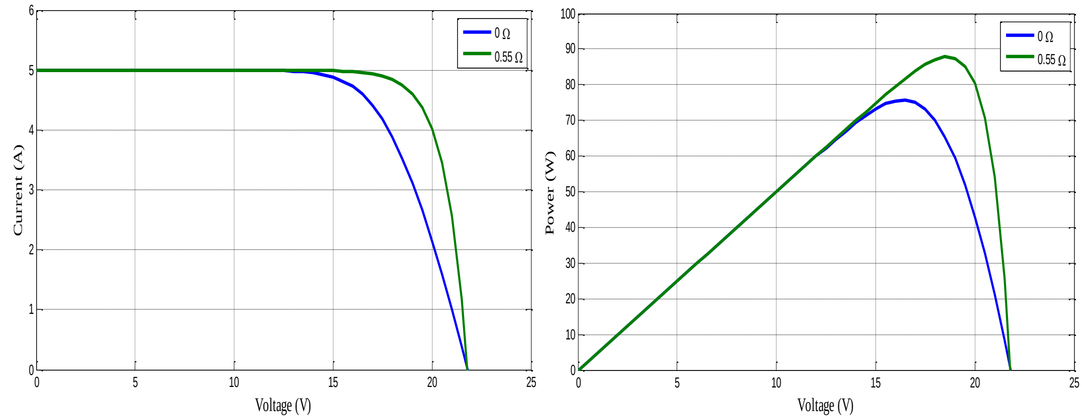

Figure 7: I-V and P-V characteristics of solar PV module at effects of variation of series resistance

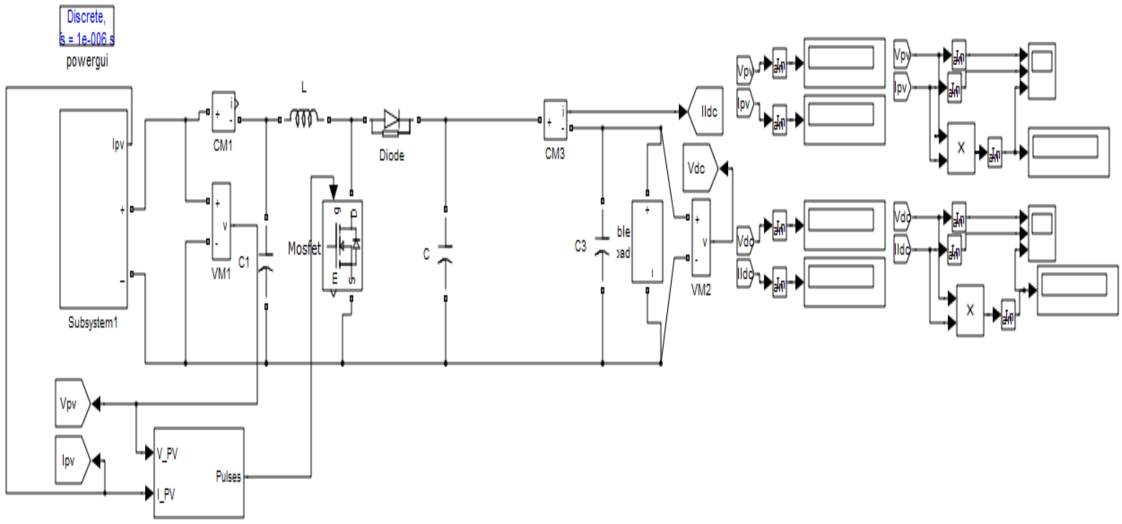

Figure 8: Simulink model of a solar PV panel connected to boost converter

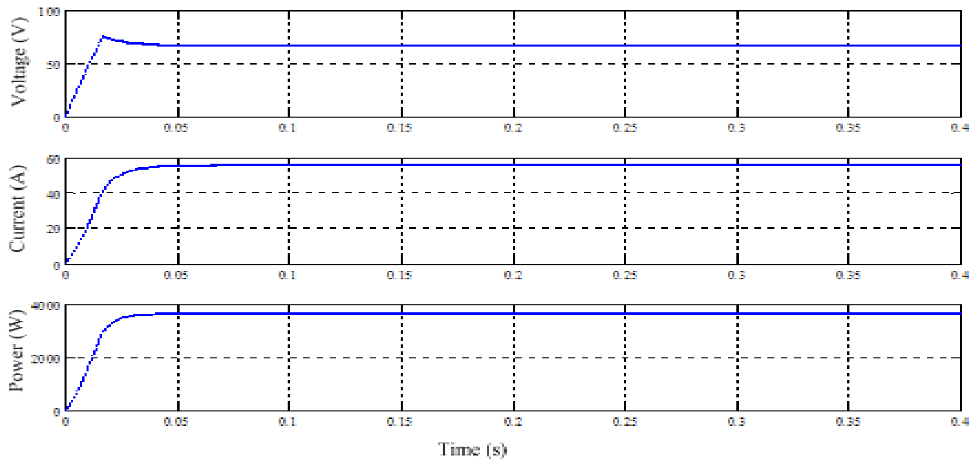

Figure 9: Output voltage, current and power of PV panel

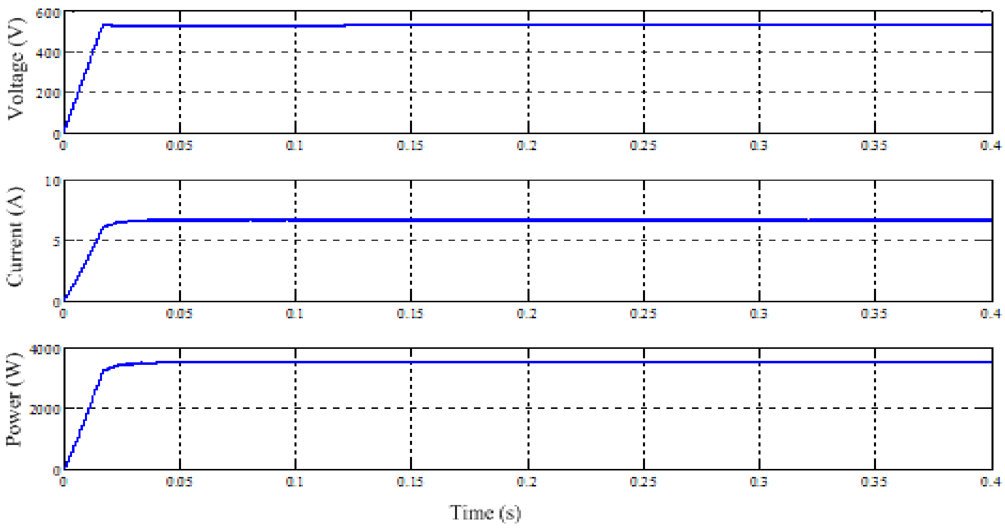

Figure 10: Output voltage, current and power of solar PV panel with boost converter

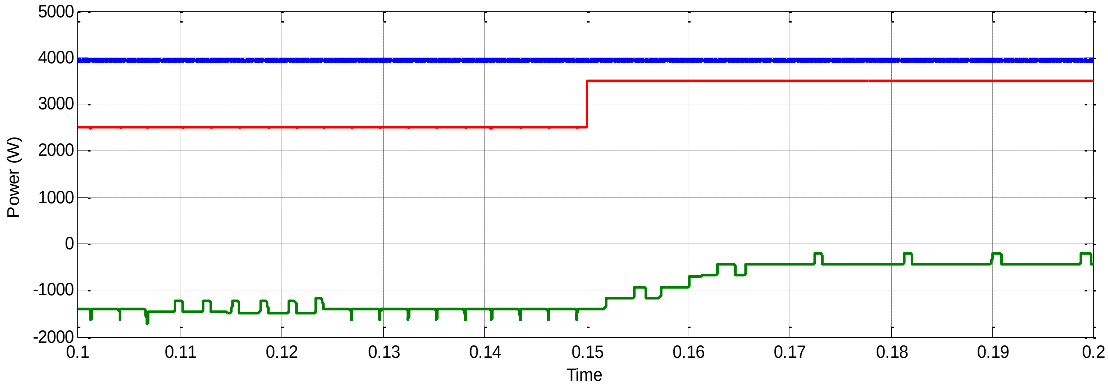

Figure 11: Output power of PV panel, load and battery

B. Modeling of Wind system

Wind system consists of the PMSG based variable speed wind turbine along with rectifier, dc-dc boost converter.

The amount of mechanical power captured by the wind turbine is given by :

$$P = \frac{1}{2} C_p(\lambda, \beta)\rho A V_w^2 \qquad (6)$$

Where, the air density ρ is 1.22. The area of rotor (A) is calculated as (πr^2) 32 m^2. The value of power coefficient C is function of blade pitch angle (ß) and tip speed ratio (λ), is obtained as [9] :

$$C_p(\lambda, \beta) = 0.5176\left(\frac{116}{\lambda i} - 0.4\lambda - 5\right) e^{\left(\frac{-21}{\lambda i}\right)} + 0.0068\lambda$$

$$\lambda i = \frac{1}{\lambda + 0.08\beta} - \frac{0.0035}{\beta^3 + 1} \qquad (7)$$

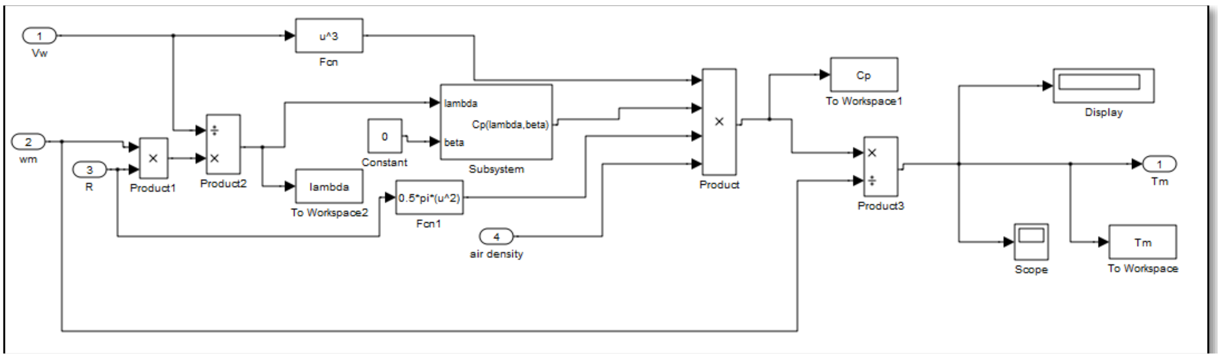

Figure 12: Simulink model of a Wind turbine

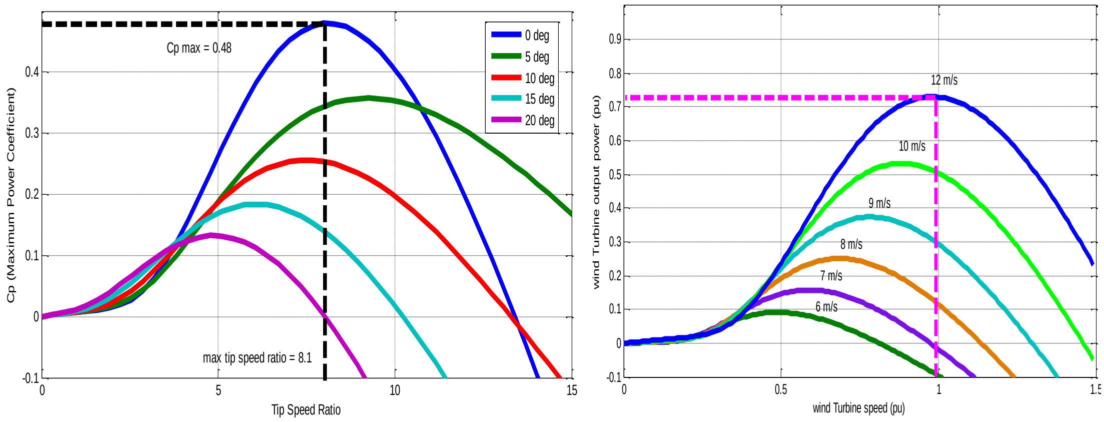

Figure 13: T_m-ω and C_p-λ characteristics of wind turbine

PMSG offers many advantages but not limited to self excitation capability which allows operation at a high power factor and improved efficiency, gear less transmission, high reliability, good control performance, low noise emissions, MPPT capability.

The electromagnetic torque developed by a PMSG is given by,

$$\varphi i_q + (L_d - L_q) i_d i_q$$
$$T_e = 1.5p \qquad (8)$$

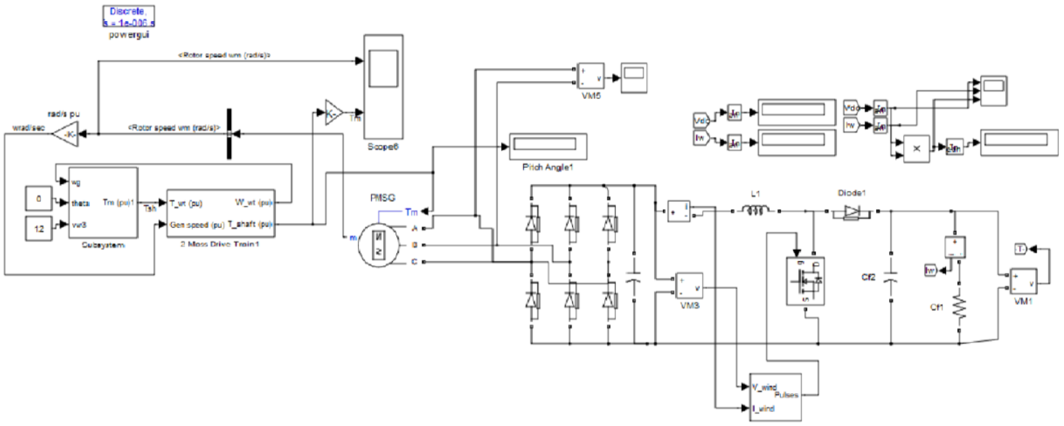

Figure 14: Simulink model of a Wind turbine using PMSG

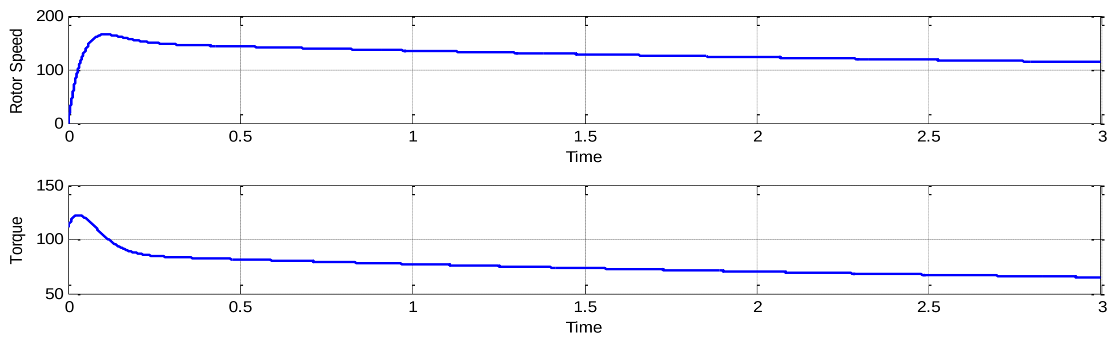

Figure 15: Generator speed in rad/sec and torque of the wind turbine

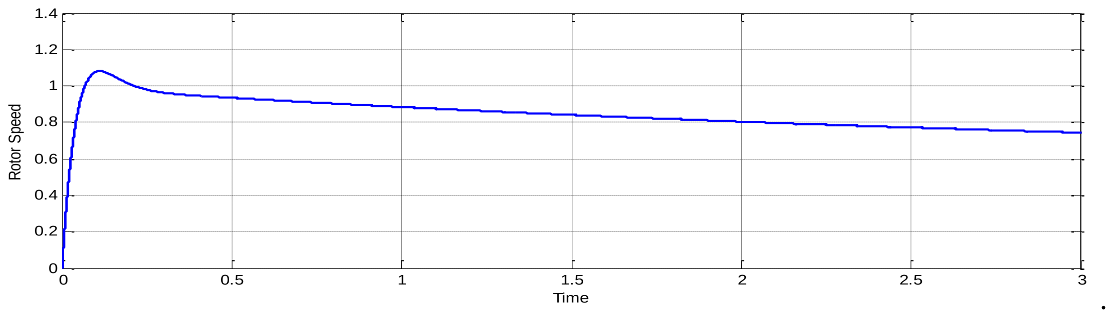

Figure 16: Generator speed of wind turbine in pu

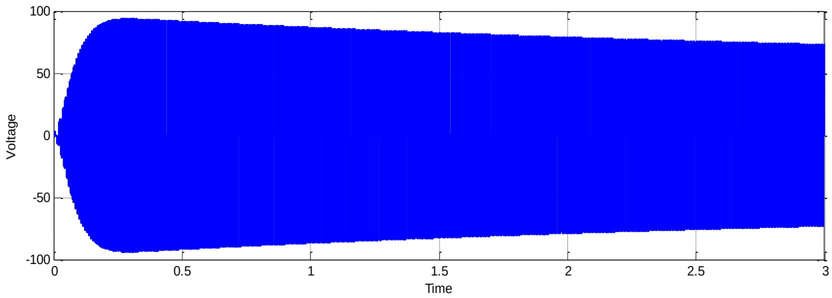

Figure 17: Output AC voltage of wind turbine using PMSG

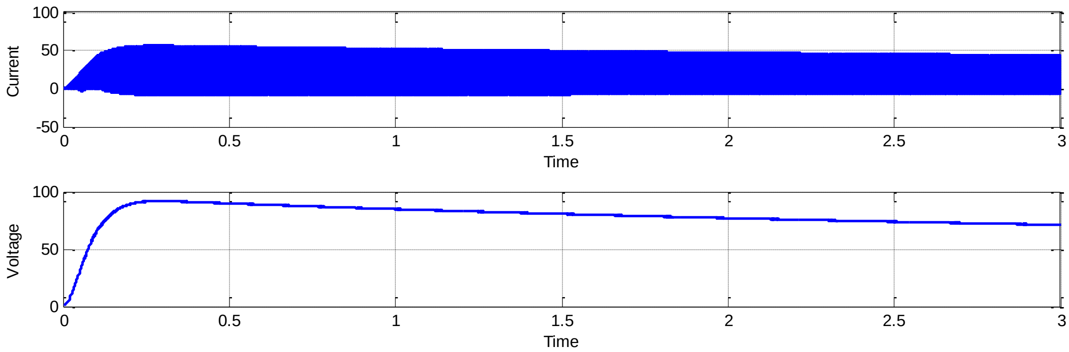

Figure 18: Output current and Voltage of rectifier

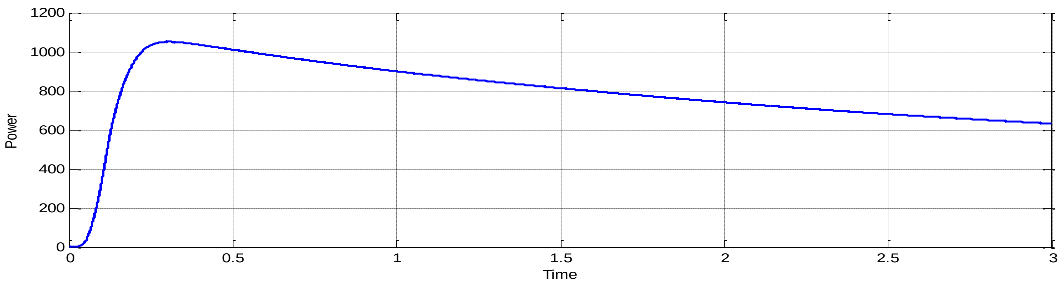

Figure 19: Output power of boost converter

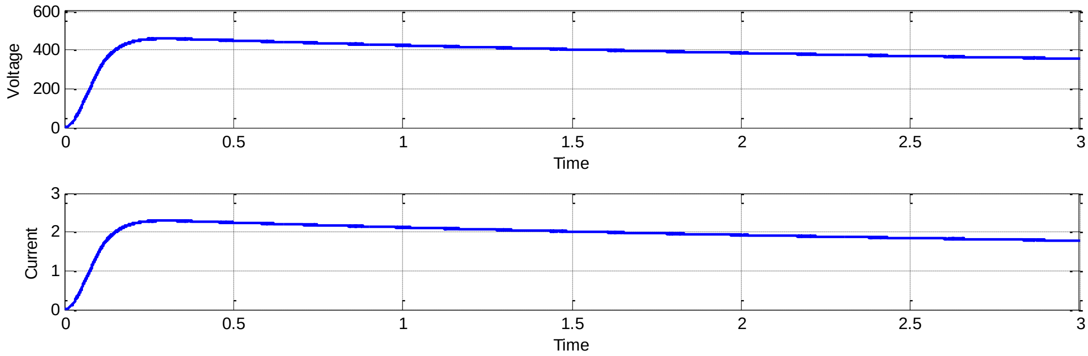

Figure 20: Output voltage and current of load

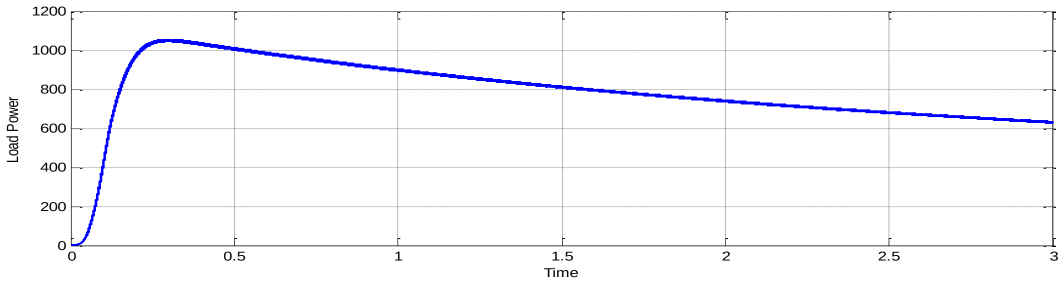

Figure 21: Output power of load

C. Modeling of Hybrid system

Hybrid system consists of a solar PV conversion and wind energy conversion system with battery bank[9].

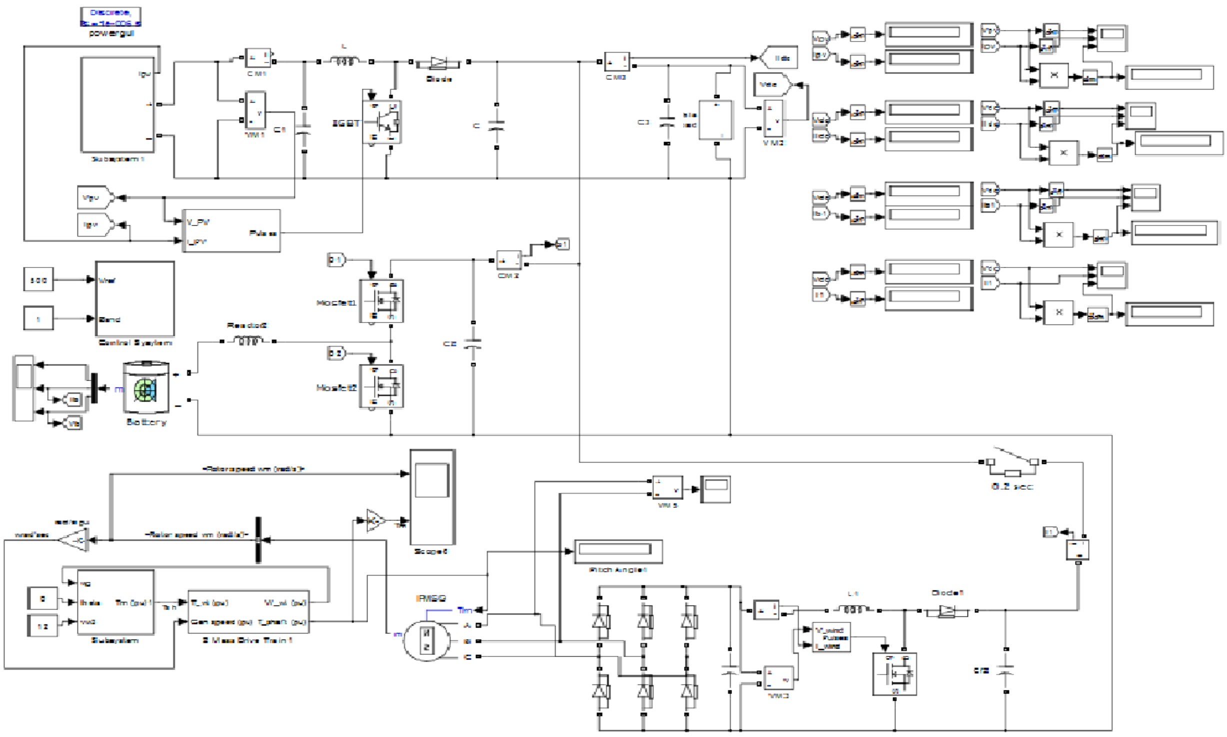

Figure 22: Simulink model of hybrid power generation system

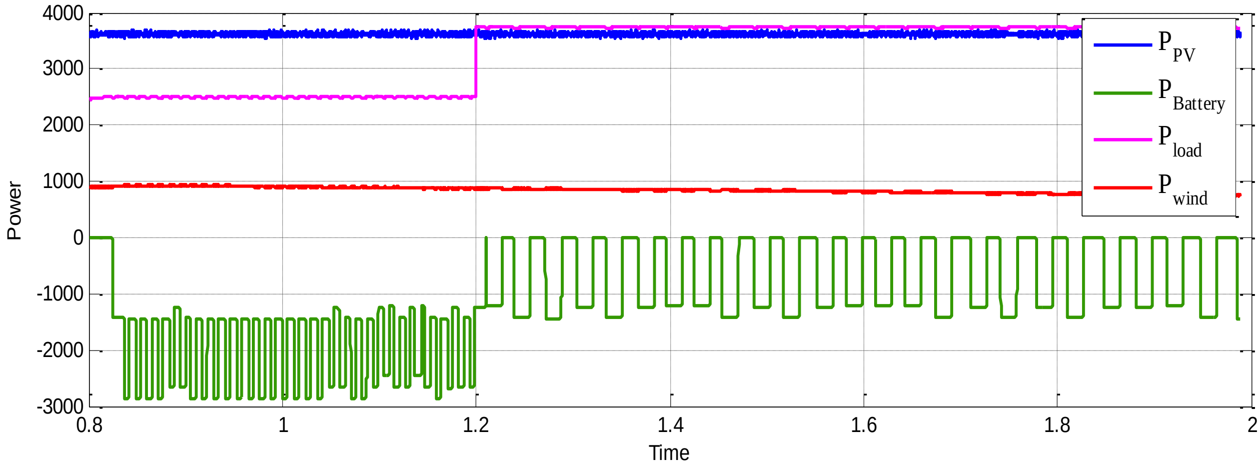

Figure 23: Output power of PV system, battery, load and wind system in hybrid system

CONCLUSION :

The objectives of this paper are to develop and simulate a hybrid power generation system that combines the solar PV model and wind model. Then develop a battery energy storage system and simulate together with the solar-wind hybrid energy system and effect of varying environmental conditions on their characteristics is studied. Maximum power is tracked for both systems using incremental conductance method. Simulation results show that the hybrid energy system has greater reliability compared to standalone energy system because it is based on more than one type of electric renewable power generation source. When either one of the renewable energy generation system does not operate at its full capacity due to inconsistence energy source at that time another system will operate to compensate the peak load demand. In addition, the hybrid system also able to produce a greater output voltage compared to standalone system and hybrid system is used for battery charging and discharging.

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