International Journal of Engineering Research
Volume No.4, Issue No.4, pp : 178-183
ISSN:2319-6890)(online),2347-5013(print)
01 April 2015

Modeling and Simulation for Hybrid of PV-Wind system

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Abstract: The rising consumption rate of fossil fuels causes a significant pollution impact on the atmosphere, unwanted greenhouse gases has drawn worldwide attention towards renewable energy sources. Moreover, in recent year's generation of electricity using the different types of renewable sources are specifically evaluated in the economical performance of the overall equipment. This paper focuses on the modeling and analysis of a Standalone Photovoltaic (PV)-wind energy hybrid generation system under different conditions using MATLAB. The proposed system consists of two renewable sources i.e. wind and solar energy. Modeling of PV array and wind turbine is explained. The wind subsystem is equipped of an induction generator. In photovoltaic system, the variable DC output voltage is controlled using buck-boost converter for the MPPT. These two systems are combined to operate in parallel and the common bus collects the total energy from the wind and PV systems are uses it to the load and with change the load.

Keywords— PV, Wind system, DC-DC Converter, and Inverter

I. Introduction

Photovoltaic (PV) and wind energy are non-deflectable, site dependent, non-polluting, and potential sources of alternative energy options. Many countries are pursuing the option of wind energy conversion systems; in an effort to minimize their dependence on fossil-based nonrenewable fuels. In addition, presently thousands of PV deployments exist worldwide, providing power to small, remote, grid-independent or stand-alone applications. For both systems, variations in meteorological conditions (solar insolation and average annual wind conditions) are important. The performance of PV and wind energy systems is strongly dependent on the climatic conditions at the location. The power generated by a PV system is highly dependent on weather conditions, **[i-iv].**

In order to reduce conversion losses from sources to loads and improve energy efficiency, micro-grid (standalone) was proposed and had been an important research direction [ii]. All the energy sources are simulated using MATLAB/ SIMULINK as software tool to analyze their behavior. The simulation results prove the feasibility and reliability of the proposed system. In this paper, an isolated hybrid PV-Wind model which contains PV, wind turbines, and AC loads is constructed. The proposed system is shown in Fig.1.

II. Modeling of Power Sources

Combination of PV farms, wind units increases the overall reliability during different environmental conditions.

1. PV Unit Modeling:

The equivalent circuit of a solar cell is shown in Figure 2, [v].

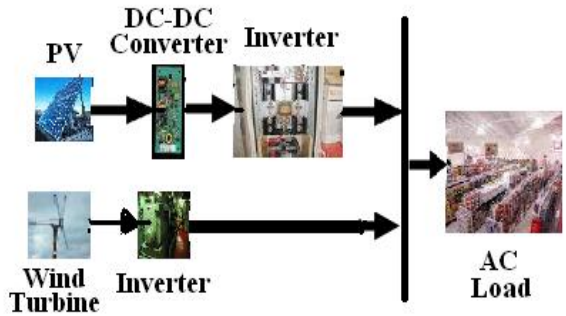

Fig. 1. Simplified layout of Stand-alone Hybrid PV-Wind System.

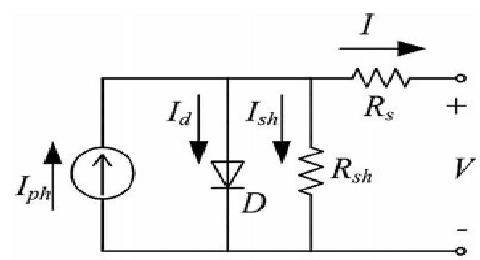

Fig. 2, PV Cell Equivalent Circuit**.**

$$I_D = I_O\{\exp[A_{PV}(V_{pv} + I_{pv}R_S)] - 1\} \quad (1)$$

Where:

1- The temperature is constant at 300^{o} K (i.e. 27^{o} C).

2- The shunt resistance is too high, and consequently I_{sh} may neglected.

$$I_{R_{sh}} = \frac{V_{PV} + I_{PV} R_s}{R_{sh}} \quad (2)$$

$$I_{pv} = I_{Ph} - I_D - I_{R_{Sh}} \quad (3)$$

The parameter values of a PV module (neglect the change of temperature) are:

I_O = 2.35E-8 Amp,

R_S = 0.411383 ohms,

A_g = 0.86948 1/volts at 300^{o} K (i.e. 27^{o} C),

I_{ph} = 4.682355 Amp at 100% insolation.

$$V_{pv} = -0.411383 I_{pv} + \frac{1}{0.86949} Ln\left(1 + \frac{4.682355 * \Phi - I_{pv}}{2.35E-8}\right) \quad (4)$$

ISSN:2319-6890)(online),2347-5013(print)
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The PV system is highly non-linear as can be evident from its current vs. voltage (I–V) characteristics shown in Fig. 3. While, the voltage-power (V-P) curves are shown in Fig. 4, at different level insolation.

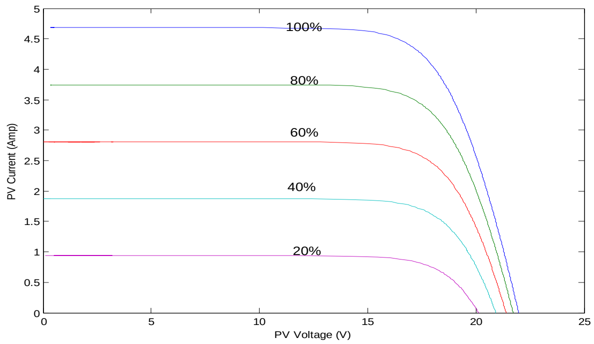

Fig. 3, V-I characteristic of PV module at different insolation.

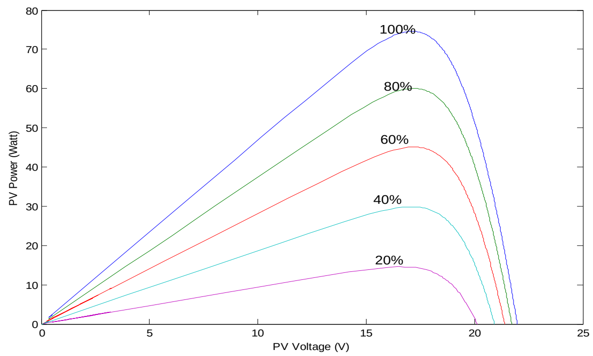

Fig. 4, V-P characteristic of PV module at different insolation.

2. Buck-Boost Converter

An ideal Buck-Boost converter is used to interface the PV array source to the inverter. The PI control is used to control of the value of duty cycle (D) depend on calculate of voltage at maximum power point. With the assumption of ideal circuit elements, two switched models are shown in Fig. 5. State variables for this Buck-Boost converter are chosen as the inductor current, $I_L \equiv X_1$, and the capacitor voltage, $V_c \equiv X_2$. State-space-averaged equations in matrix form are, [i]:

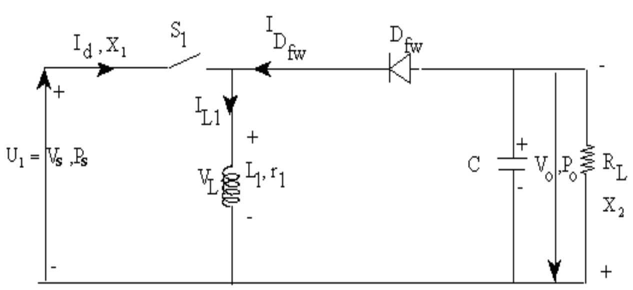

Fig. 5, Electronic Circuit for the ideal Buck-Boost converter.

$$\begin{bmatrix} \dot{X}_1 \\ \dot{X}_2 \end{bmatrix} = \begin{bmatrix} 0 & \frac{(1-D)}{L} \\ -\frac{(1-D)}{C} & -\frac{1}{RC} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} \frac{D}{L} \\ 0 \end{bmatrix} [U_1] \quad (5)$$

The simulink model of buck boost converter from equation (5) is shown in Fig. 6.

3. Wind Unit Modeling

Wind energy systems convert kinetic energy of wind into electrical energy or use it to do other work, [vi]. The kinetic energy of air of mass m moving at speed v can be expressed as

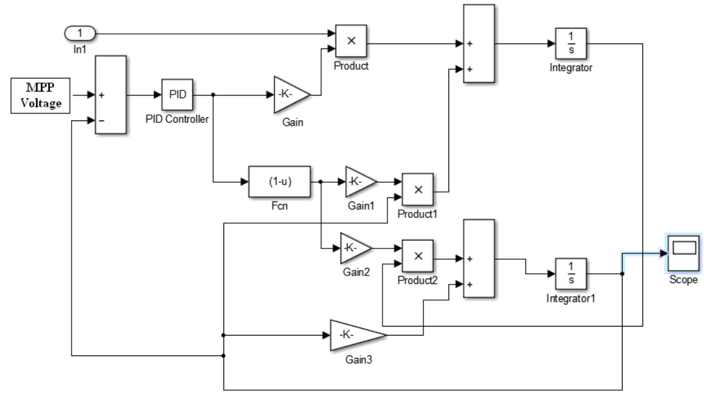

Fig. 6, Simulink model of buck-boost converter

$$E = \frac{1}{2} m v^2 \quad (6)$$

$$m = \rho A v t \quad (7)$$

The power of wind

$$P_w = \frac{1}{2} \rho A v^3 \quad (8)$$

The specific power or power density of a wind site is given as

$$P_{den} = \frac{1}{2} \rho v^3 \quad (9)$$

Where, ρ: Air density.
A: Rotor swept area.
d: Distance (m).
m: mass of air =air density*volume
= ρ*A*d.
v: Distance/time (m/s).

The actual power extracted by the rotor blades from wind is the difference between the upstream and the downstream wind powers, [vii]:

$$P_w = \frac{1}{2} * K_m (V^2 - V_0{}^2) \quad (10)$$

Where V is the upstream wind velocity at the entrance of the rotor blades, V_0 is the downstream wind velocity at the exit of the rotor blades. Km is the mass flow rate, which can be expressed as

$$K_m = \rho A \frac{v + v_0}{2} \quad (11)$$

$$P = \frac{1}{2} [\rho A \frac{v + v_0}{2}] (v^2 - v_0{}^2) \quad (12)$$

Let

$$C_p = \frac{1}{2} (1 + \frac{v_0}{v}) [1 - (1 - \frac{v_0}{v})^2] \quad (13)$$

ISSN:2319-6890)(online),2347-5013(print)
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$$P = \frac{1}{2}\rho A v^3 C_p$$

Cp is called the power coefficient of the rotor or the rotor efficiency.

$$P_m = .5\rho A C_p(\lambda, \beta)v^3 \quad (14)$$

λ: The tip speed ratio and β: Pitch angle.

$$T_m = \frac{P_m}{\omega_r} \quad (15)$$

A Matlab/Simulink model, based on the equations mentioned above, was developed for the wind generator module. This model is shown in Figure 7.

Wind Turbine model shown in Fig. 8. The three inputs are the generator speed (ωr_pu) in pu of the nominal speed of the generator, the pitch angle in degrees and the wind speed in m/s. The output is the torque applied to the generator shaft.

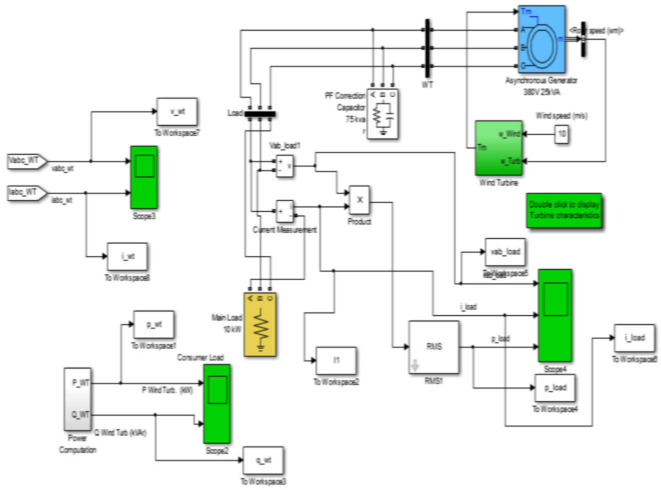

Fig. 7, Simulink diagram of IG wind turbine.

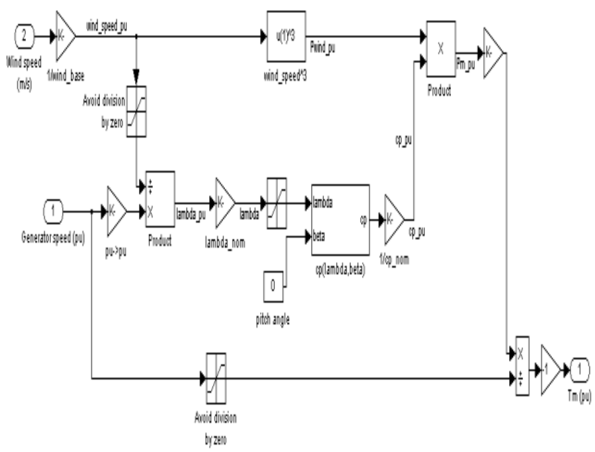

Fig. 8. Simulink diagram of wind turbine.

4. PWM Inverter

The DC power available at the DC-DC converter output is filtered and converted to AC power using a PWM inverter employing double edge sinusoidal modulation. The output consists of a sinusoidal modulated train of carrier pulses, both edges of which are modulated such that the average voltage difference between any two of the output three phases varies sinusoidal, [viii]. The MATLAB/Simulation diagram of inverter with LC filter is shown in Fig. 9.

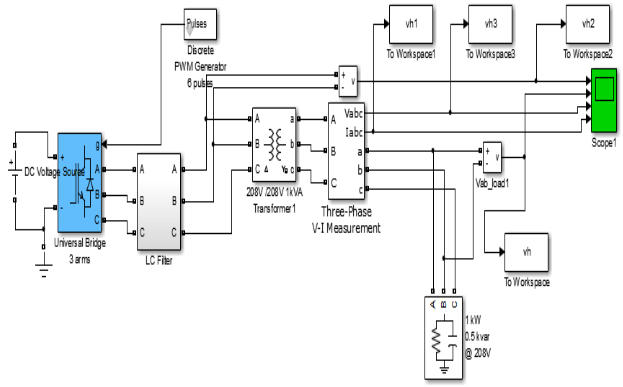

Fig. 9, the simulation of PWM inverter.

III. Simulation and Results System

In the Fig. 10, the simulation system contains power generation blocks from renewable energy sources such as PV and wind turbine blocks and energy consumer block. For the simulation, the data solar irradiance and wind speed are used. The data will be the input of the PV and Wind energy generation system. Figure's shown below show the waveform of the output of the solar and wind energy generation system.

In Fig. 11, the insolation changed at time 0.2 sec from 40% to 80% then changed again to 50% at t=0.4 sec then changed to 100% at t=0.6 sec.

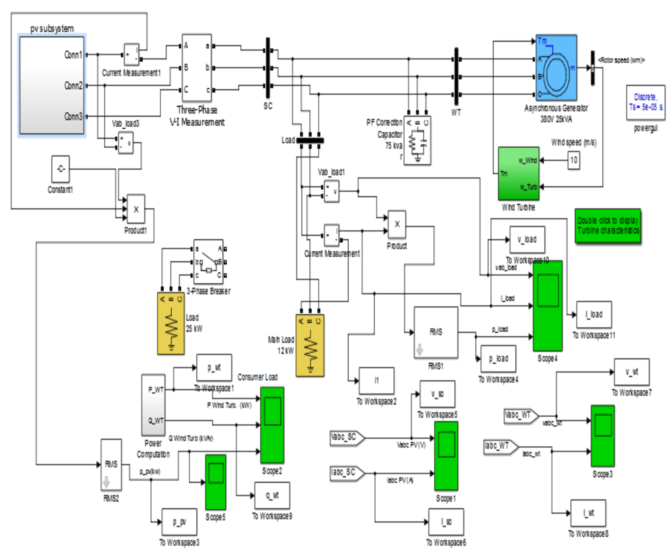

Fig. 10, the modeling of PV-wind hybrid power generation system.

At t=0.2sec the active power start increasing from 5 KW to reach 7.5 KW where at t= 0.4sec the out power starts to decrease to reach 6 KW and then increase again at t=0.6sec to reach 8KW.

The output voltage changed at MPP from 340 V to 385 V at t=0.2m/sec and decreased at t= 0.4 to 350 V and then at t=0.6sec the voltage increased again to reach 390V.

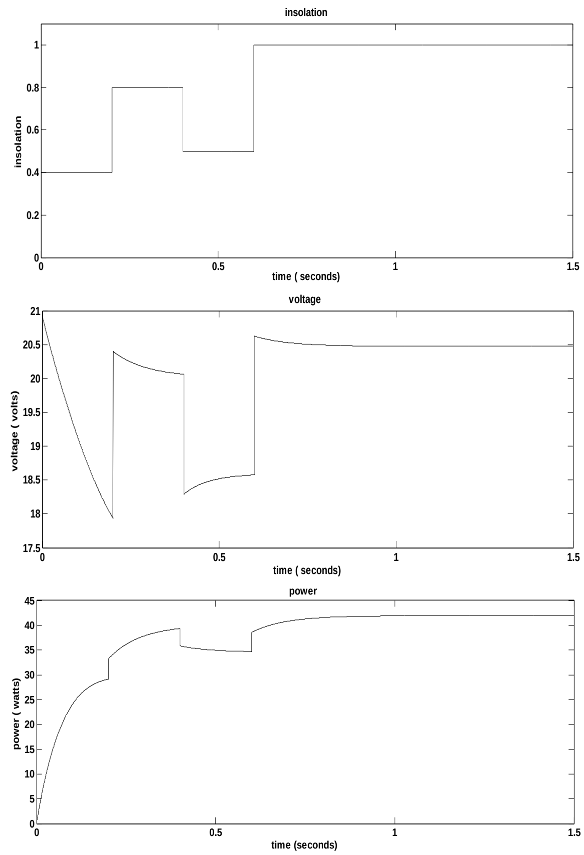

Fig. 11, Voltage and Power of PV at change in insolation.

The output line voltage of inverter after using LC filter and Fourier transfer are shown in Fig. 12 and Fig. 13. The value of harmonic to phase voltage is 2.02%. The three-phase ac output current (I_{abc}) after using LC filter and Fourier transfer are shown in Fig. 14 and Fig. 15 respectively. The value of harmonic to current is 3.48%.

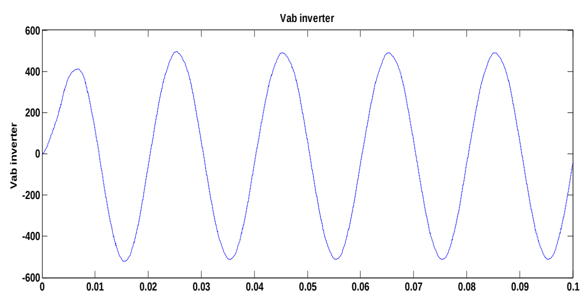

Fig. 12, line voltage of inverter after using LC filter.

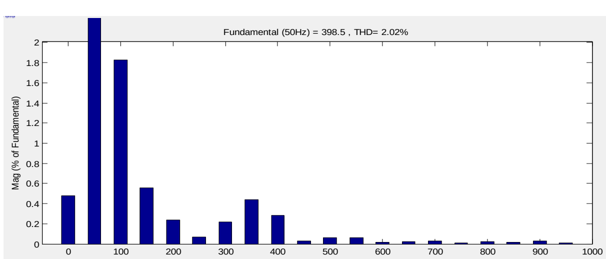

Fig. 13, Fourier transfer analysis of inverter the line voltage after using LC filter.

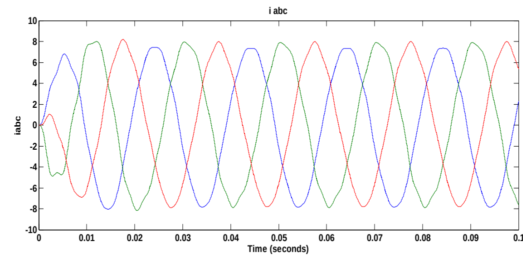

Fig. 14, three phase ac output current (I_{abc}) after using LC filter.

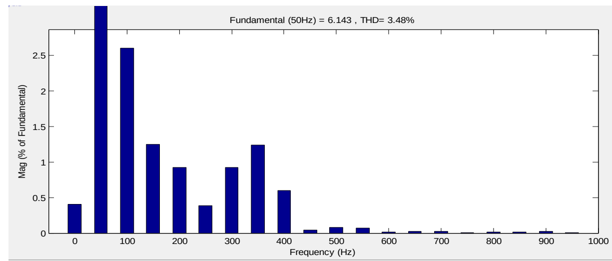

Fig. 15, Fourier transfer analysis of load phase current (I_{abc}) after using LC filter.

The output voltage of IG wind turbine output and its Fourier transfer is shown in fig. 16 and fig. 17 respectively. While, the output current of IG wind turbine output and its Fourier transfer are shown in fig. 18 and fig. 19 respectively.

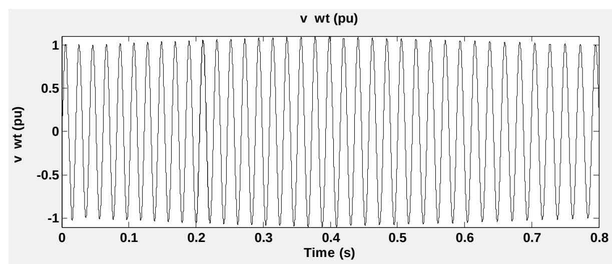

Fig. 16, output voltage of IG wind turbine at the hybrid system.

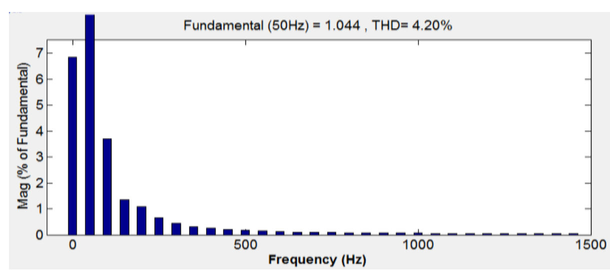

Fig. 17, Fourier transfer analysis of the output voltage of IG wind turbine at the hybrid system.

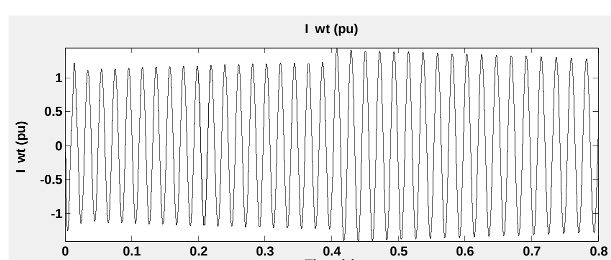

Fig. 18, output current of IG wind turbine at the hybrid system.

ISSN:2319-6890)(online),2347-5013(print)
01 April 2015

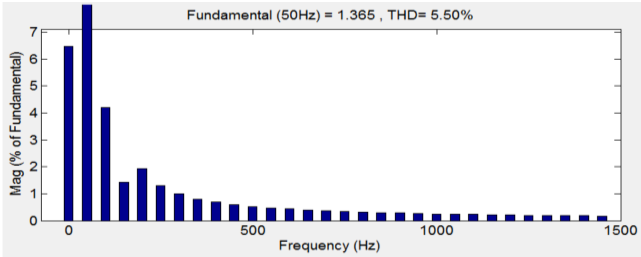

Fig. 19, Fourier transfer analysis of the output current of IG wind turbine at the hybrid system.

While Fig. 20 is shown the load, active and reactive power of wind at change in wind speed. Wind speed is changed at t= 0.3 sec from 10 m/s to be 5 m/s. When wind speed is 10 m/s we found that the output power is approximately 14 kw, where the reactive power is equal to 4kvar. Then at t= 0.3 sec power starts decreasing to 8kw and the reactive power equal 2kvar .The load power changed at t= 0.3sec from 6kw to 4kw. Fig. 21 is shown voltage, current and power when the connected load is change from 15 kw to 20 kw at time 0.4 sec.

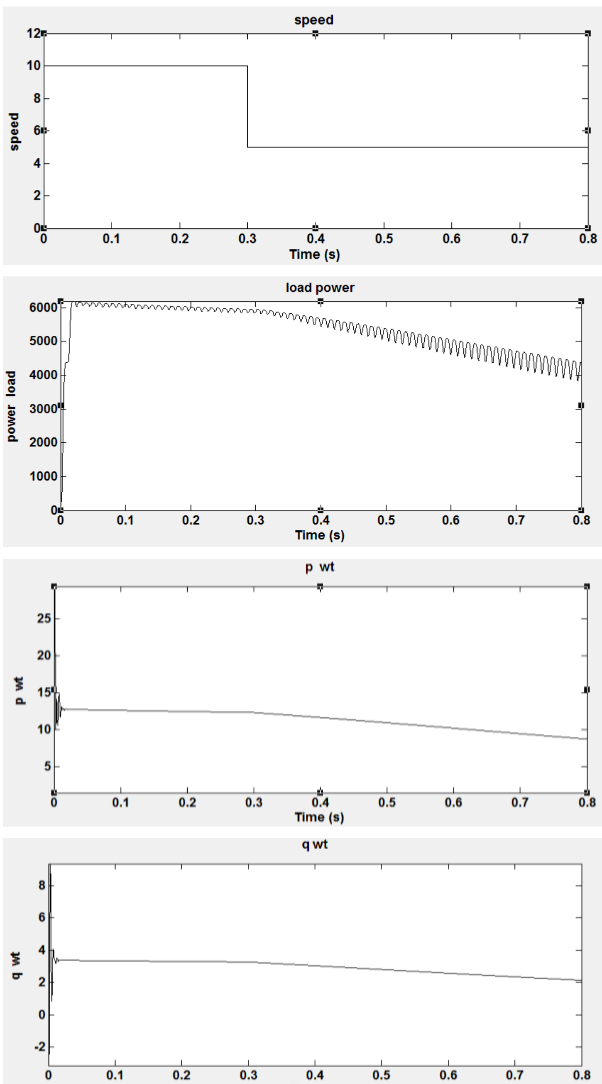

Fig. 20. Output power of load, active and reactive power of wind turbine for step change in wind speed.

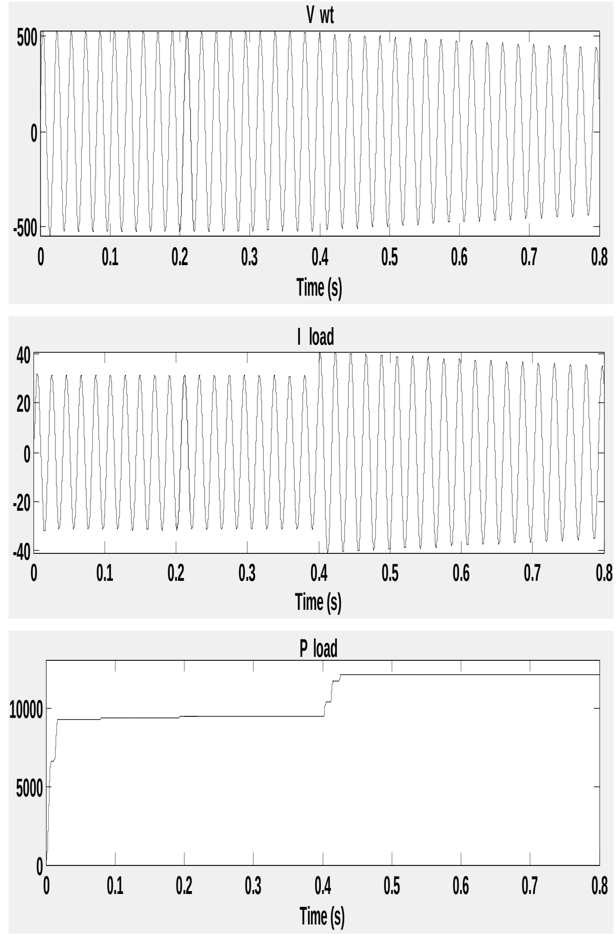

Fig. 21. Output voltage, current and power of load at step change in load value.

IV. Conclusion

The promotion of energy production from renewable resources represents an imperative objective in present times justified by environment protection, the increase of energetic independence by supplying sources diversity and, of course, economic and social cohesion reasons.

This paper modeling and simulation of hybrid PV/wind isolated system. The system is simulated in the Matlab/Simulink. The individual system performance of the wind and PV systems are studied through simulation for varying wind velocities and solar intensities respectively. The system is tested under different conditions at different level of insolation and different wind speed with change in load value. The proposed hybrid system performs well under different loading conditions. It was study voltage and current harmonic of the system.

Acknowledgment

All authors would like to thank Electrical Engineering Department at Benha Faculty of Engineering. In addition, special thanks to Electronics Research Institute, Cairo, Egypt http://eri.sci.eg and Benha University, Qalubia, Egypt. http://www.bu.edu.eg/en/

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