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Design and Analysis of Hybrid Power Plant Using Matlab

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ABSTRACT: Due to development in renewable energy technologies and continued rise in prices of petroleum products hybrid renewable energy systems are gaining more importance for supplying the power to meet the today's increasing energy demands either as a stand-alone system or as a grid connected system. In this paper a model of grid connected hybrid system consists of wind and solar (photovoltaic) system is studied and implemented in Simulink. The proposed system consists of a wind turbine, a PV solar cell array, boost converter, and an inverter to convert DC to AC of grid frequency. A relative study of hybrid model solar/wind system has been made. This Paper illustrates wind and solar hybrid system for supplying electricity to the power grid.

KEYWORDS: Hybrid Power Plant Design, MATLAB Schematic Model, Hybrid Power System Simulation Result

I.INTRODUCTION

In the last few years, because of high depletion of conventional energy resources and environment concerns, the renewable energy resources are becoming more important all over the world. Among different renewable energy sources, wind and solar energy sources are most promising. Since the oil crisis of the early 1970s, the utilization of solar and wind power has become increasingly noteworthy, popular and cost-effective. But the main disadvantage of solar and wind energy system is that it depends on seasonal variation and it is unpredictable in nature. As both wind and solar energy sources are not consistent and non-stable in nature. A hybrid system of wind and PV power sources provides a stable form of power generation. Hybrid energy systems are cost effective energy solutions with high reliability and power quality. Individual photovoltaic (PV) or wind energy system, do not generate utilizable energy for a large portion of time during the year. This is because of dependency on variable sunshine hours in PV system and on relatively high cut-in wind speeds. In this paper individual modeling of PV and wind energy system is done and studied in Matlab/Simulink software. A Hybrid model of PV and Wind system is also implemented and studied.

II.EXPERIMENTAL SETUP

The PV and Wind energy systems are modeled in Matlab/Simulink software using the Simulink blocks. To start with a Simulink model first the Matlab/Simulink software is started. Open a new Simulink file and the file is saved. Using the block sets from library, these blocks are added to the file, then blocks are connected, initiate the blocks by adding values and thereby model is created. Further updates in the model is done, initiated the model. Then the model is simulated. The simulation output is viewed.

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III.PV SIMULINK MODEL

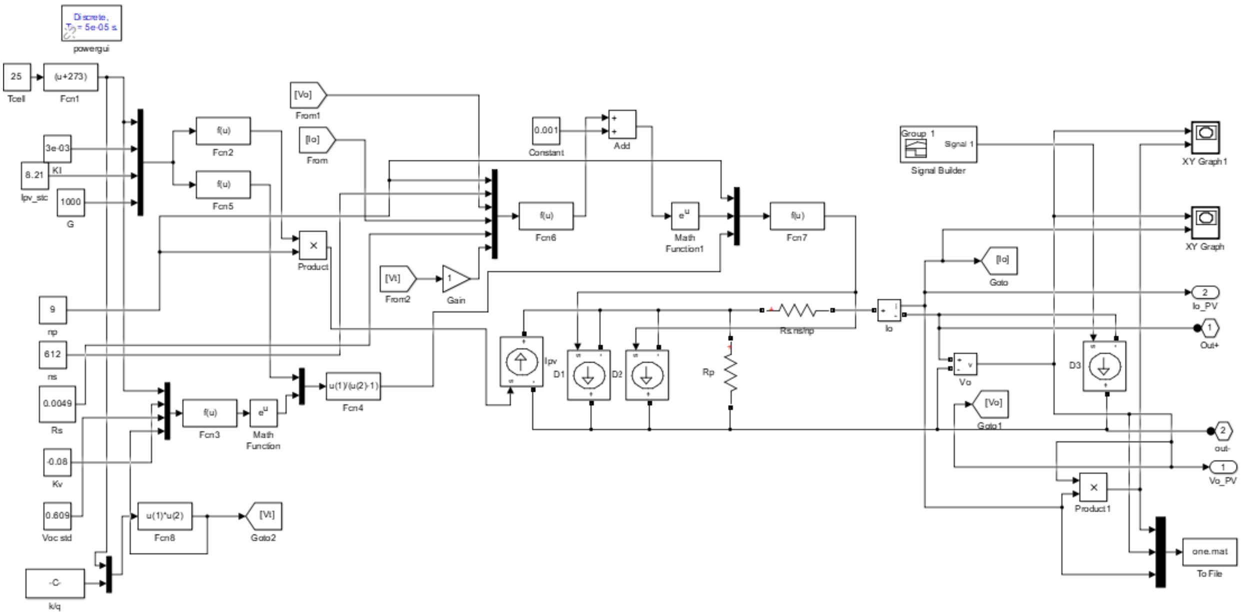

Fig. 1 PV Simulink Model

The above Figure 1 is the PV Matlab model[1]. The model is created based on the basic equivalent circuit diagram for a solar cell. In this model an extra diode is added to the equivalent circuit to improve the accuracy of the I-V characteristics. The diode is attached in parallel with the first diode in the circuit. As discussed earlier the model is designed using the theoretical equivalent circuit equations. Comparing with the single diode model the accuracy with two diode models is better. Using a two diode model makes the circuit more complex in work therefore a single diode model is preferred due to its simple performance. Therefore, the basic equation for a two-diode circuit is given by

$$I=I_{PV}-I_{D1}-I_{D2} \quad (1)$$

$$I_{D1}=I_{o1} * \left[exp\left(\frac{V}{A_1 * V_T}\right)-1\right] \quad (2)$$

$$I_{D2}=I_{o2} * \left[exp\left(\frac{V}{A_2 * V_T}\right)-1\right] \quad (3)$$

Substituting the equations 2 and 3 in equation 1 along with addition of series and shunt resistance to the circuit gives an overall equation of

$$I=I_{PV}-I_{o1} * \left[exp\left(\frac{V}{A_1 * V_T}\right)-1\right] - I_{o2} * \left[exp\left(\frac{V}{A_2 * V_T}\right)-1\right] - \left[\frac{V+R_S*1}{R_{SH}}\right] \quad (4)$$

In equation 4 I_{o1} is the reverse saturation current by diffusion and I_{o2} is the reverse saturation current due to recombination. A_1 is the diode reality factor of diode 1 and A_2 is the diode reality factor diode 2.

The light incident on the PV as photon current which is influenced by the temperature and solar irradiance is given by

$$I_{PV}=\left(I_{PV,N}+K_I * [?][?][?]T\right) * \frac{G}{G_n} \quad (5)$$

$I_{PV,n}$ is the light incident on solar panel under standard test conditions(STC)

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The diode reverse saturation current equation is given by

$$I_o = I_{o,n} * [\frac{T_n}{T}]^3 \exp exp\, [\frac{q_{Eg}}{AK}(\frac{1}{T_n} - \frac{1}{T})] \quad (6)$$

The improved nominal saturation current equation for a single diode model is given by

$$I_{o,n} = \frac{I_{sc,n} + K_i*[?][?][?]T}{[(\frac{V_{oc,n} + K_v*[?][?][?]T}{A*V_{T,n}}) - 1]} \quad (7)$$

K_i and K_v represents the short circuit temperature coefficient and $I_{sc,\ n}$ is the short circuit current, $V_{oc,\ n}$ is the open circuit voltage, G_n is the irradiance, T_n all these parameters under standard test conditions. Based on the above equations the PV design is modelled in the Matlab software.

IV.WIND ENERGY SIMULATION MODEL:

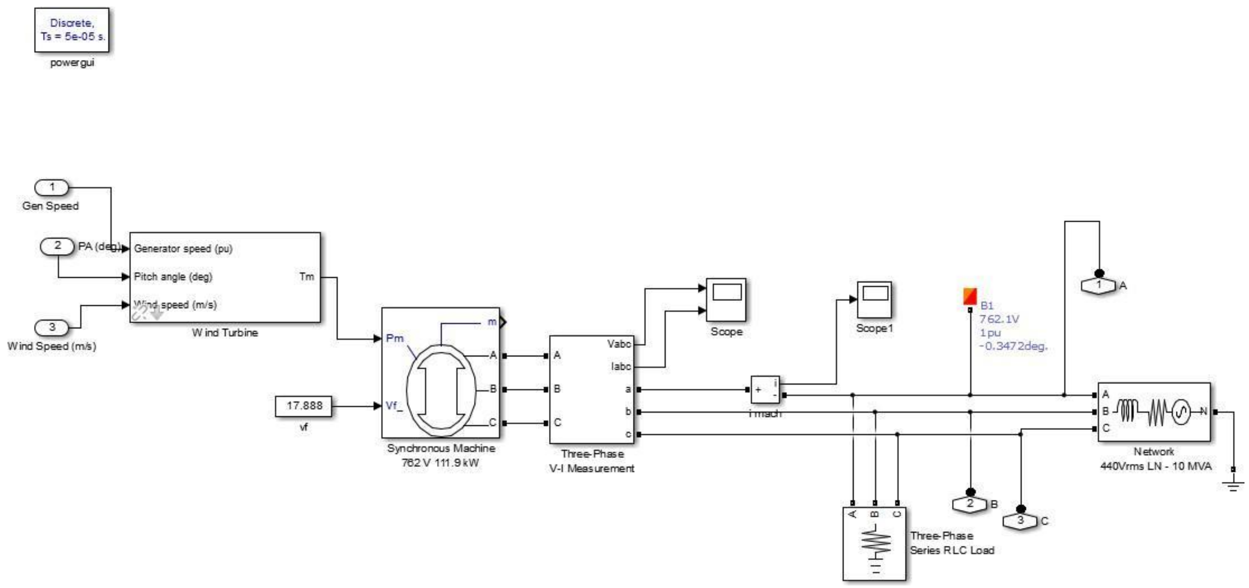

Fig. 2 Simulink Model of Wind Energy System

The above Figure 2 is the Simulink model of a wind energy system[2]. The wind turbine model as three inputs to the system generator speed, pitch angle and wind speed. The output from the wind turbine model is torque which is supplied to the generator shaft. The permanent magnet synchronous generator[6] (PMSG) converters the mechanical energy produced by the wind turbine into electrical energy. The electrical output from the generator is supplied to the grid or the load through the three phase V-I measurement block. The measurement block is always placed at output side to process the current and voltage sent from the generator. The synchronous generator is of 60kVA rating with 400V and 50Hz frequency. The input wind speed to the model is 12m/s, the blade pitch angle in degrees and the value is zero, the generator speed input in per units of the base rotational speed is 1.2. The model is designed to have a total output of 1.5MW therefore, 25 wind energy model having capacity rating of 60KW is combined. Then the combined output is supplied to grid through the measurement block.

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V.HYBRID PV-WIND ENERGY SIMULINK MODEL

The Figure 3 is the Hybrid PV-Wind energy system[3][4] modelled in Matlab/Simulink. The combination of two renewable inputs solar energy and wind energy forms the hybrid model.
The data from Kerala is shown as a reference to prove that the place is feasible for an installation of hybrid power generation unit using sun and wind energy. Kerala has a high accessibility to sun and wind energy, combining these two resources will give maximum output for power generation. The hybrid model using solar and wind is developed modifying and improvising the base models. Further to trial-and-error method the hybrid system is simulated.

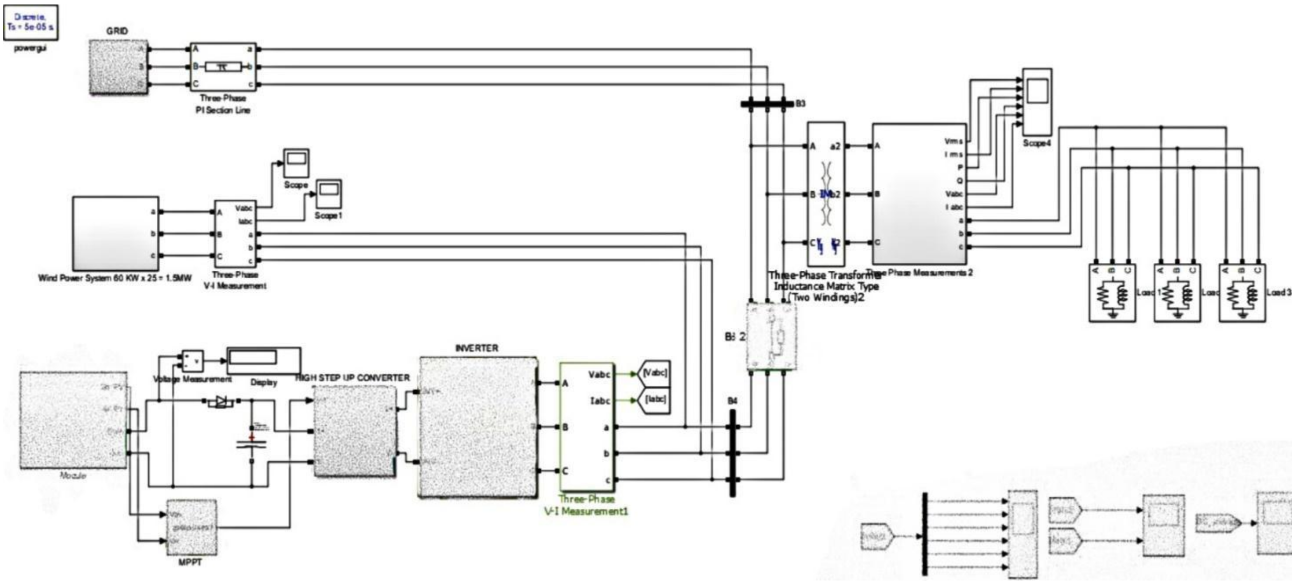

Fig. 3 Simulink Model of Hybrid PV-Wind Energy System

The bottom part of the Figure ure represents the solar energy system with a solar PV module producing IPV and VPV and with the MPPT[5] technique maximum energy tracked and send to the DC-DC converter switching pulses. The output from solar module is sent to the high step-up boost converter to produce a controlled DC output. The DC power is fed to inverter circuit to produce.

AC power. Then through the three phase V-I measurement the produced sinusoidal AC output is sent to the grid and the electrical loads.

To have a control over the grid side converters for PV and wind, a constant voltage link is maintained. The main aim is to maintain a DC link voltage constant by the grid side converters. To find a solution to this a voltage-based vector control method is suggested. Mathematical modelling methods are used for the control strategies and the PWM converter is based on current regulated having the direct axis current to regulate the DC link voltage and the quadrature axis current for the reactive power. the transfer of three phase quantities to two phases is done using the d-q theory. The control scheme utilizes the current control loop. The id and iq where id from the dc-link voltage error through the PI controller. For the control design there are two loops such as the inner current loop and outer voltage loop. The line resistance and reactance for the current loop and dc capacitor for the voltage loop.

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VI.RESULT AND ANALYSIS

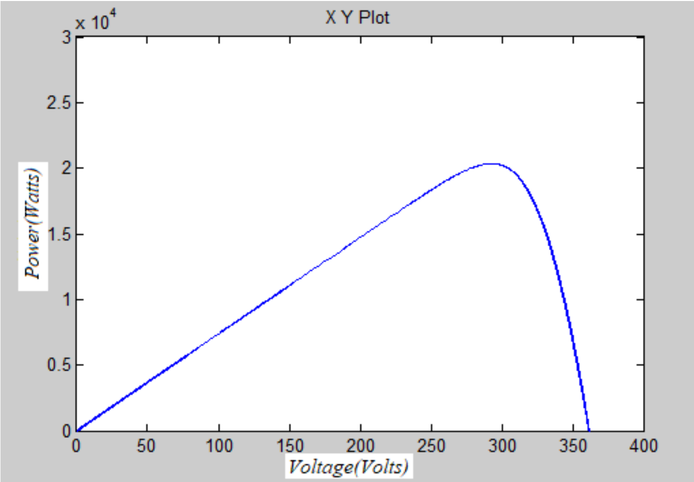

Fig. 4 P-V Curve of the PV Module

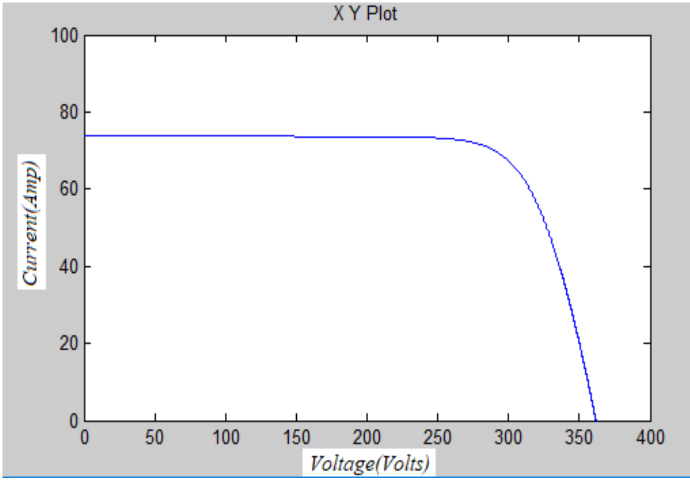

Fig. 5 I-V Curve of PV Module

The above two Figure 4 and 5 represents the P-V and I-V characteristics for a PV module at standard test conditions of temperature 25°C and solar irradiance of 1000W/m2. In the Figure ure
4 the x-axis indicates the voltage values in volts and y-axis indicates the power values in watts. While in Figure ure 5 the x-axis indicates the voltage values in volts and y-axis indicates the current values in amperes. From the Figure ure the short circuit current Isc is 74A and open circuit voltage Voc is 360V and the maximum power obtained is 20KW.
Observations were done on varying the solar irradiance values. The irradiance values are varied from 250W/m2 to 1000W/m2 at a temperature of 25°C. On varying the irradiance value keeping the temperature constant it is observed that the current increases. The solar irradiance has influence on the current value. The effect of solar irradiance on voltage is very minimal. As the irradiance value is increasing the power also increases. Power is increased because of the increment in current value.
Observations are done on varying the temperature value. The temperature values are varied from 25°C to 100°C keeping the irradiance value at 1000W/m2. On varying the temperature value keeping the irradiance same it is observed that the value of voltage decreases, and the current value remains somewhat same. Temperature variation has much more effect on voltage. As the temperature value increases the power value decreases. Power is decreased because of the decrement in the voltage value.

VII.SIMULATION RESULT OF INVERTER OUTPUT OF PV

The Figure below 6 is the simulation output for an inverter circuit.The PV module input in DC form is stepped up in boost converter and fed to inverter to form an AC output. The graph is of two parts with upper portion representing the AC voltage in volts and bottom portion representing the AC current in amperes. The x-axis indicates the time while y-axis represents the voltage and current. The converter DC power of a PV panel to AC power by the inverter circuit is shown in the graph. The Figure ure and represents the output waveforms of wind power systems. The Figure ure 7 is the output graph of voltage and the Figure ure 8 is the output graph of current. The x-axis indicates the time and the y-axis is the voltage and current.

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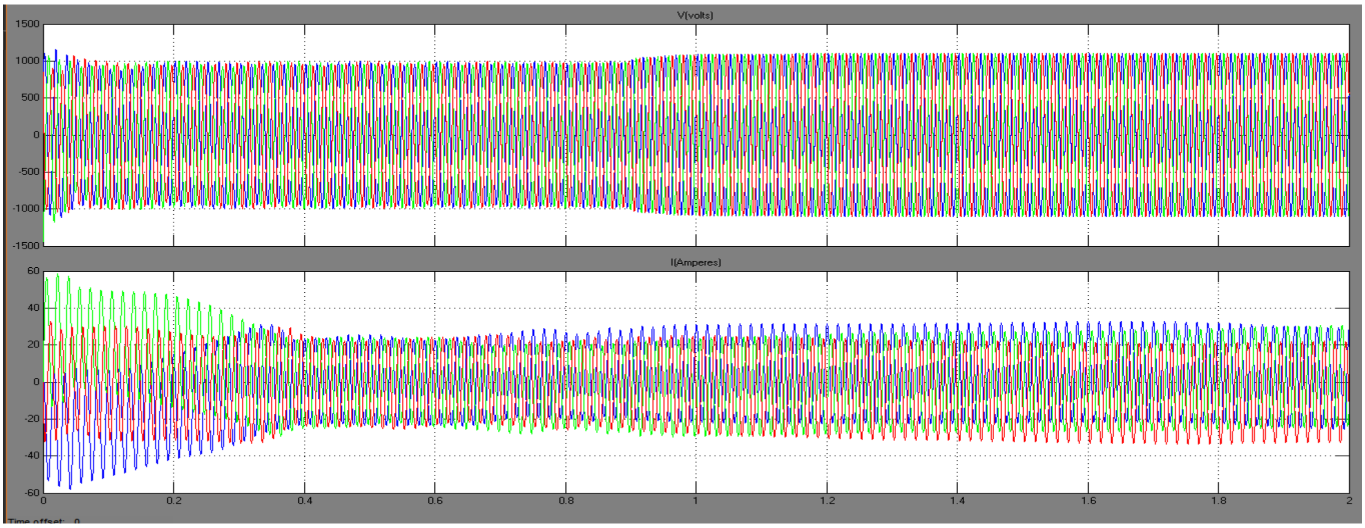

Fig. 6 Simulation results of Inverter Output of PV

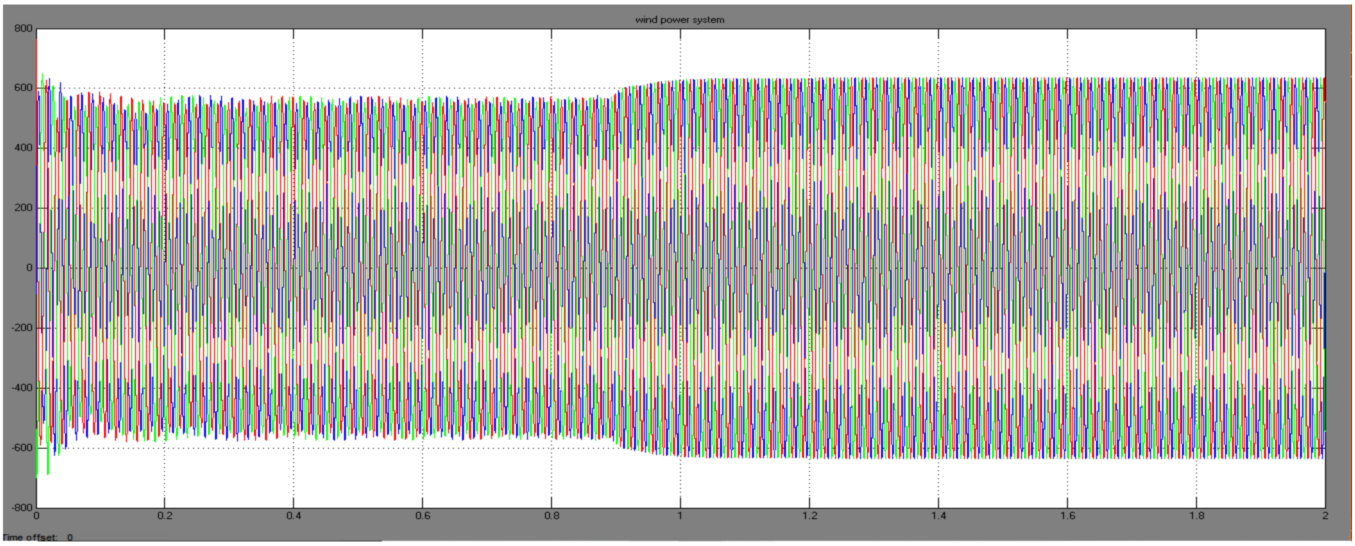

Fig. **7** Output Voltage of Wind Power System

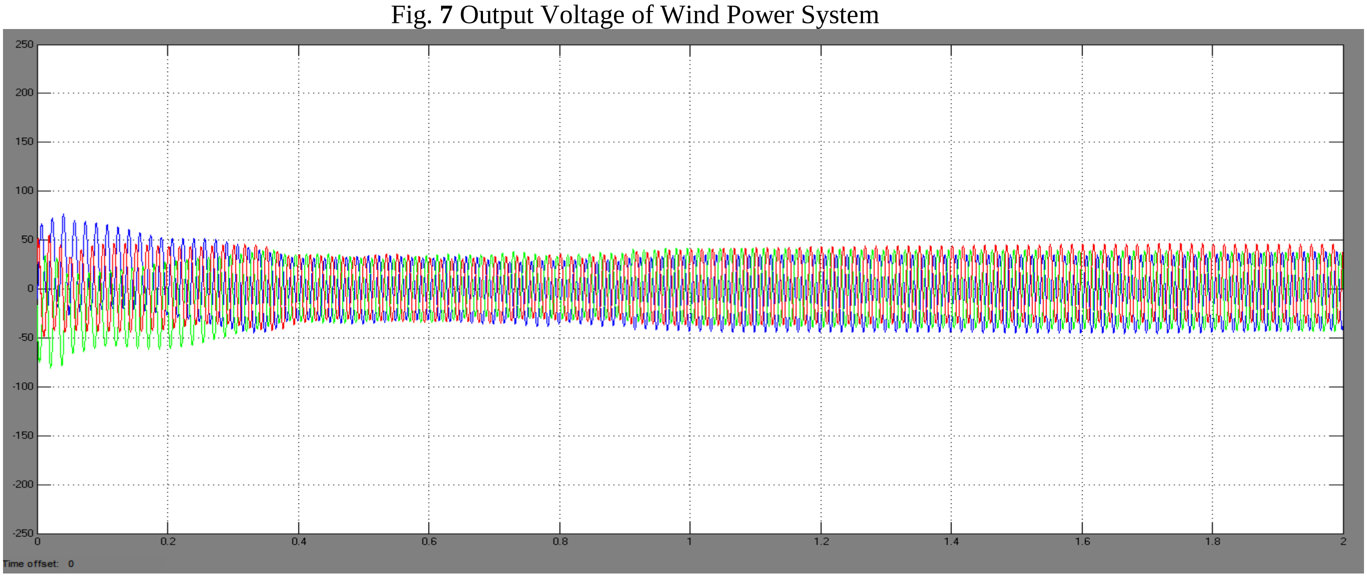

Fig. 8 Output Current of Wind Power System

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VIII.SIMULATION RESULT OF HYBRID POWER SYSTEM

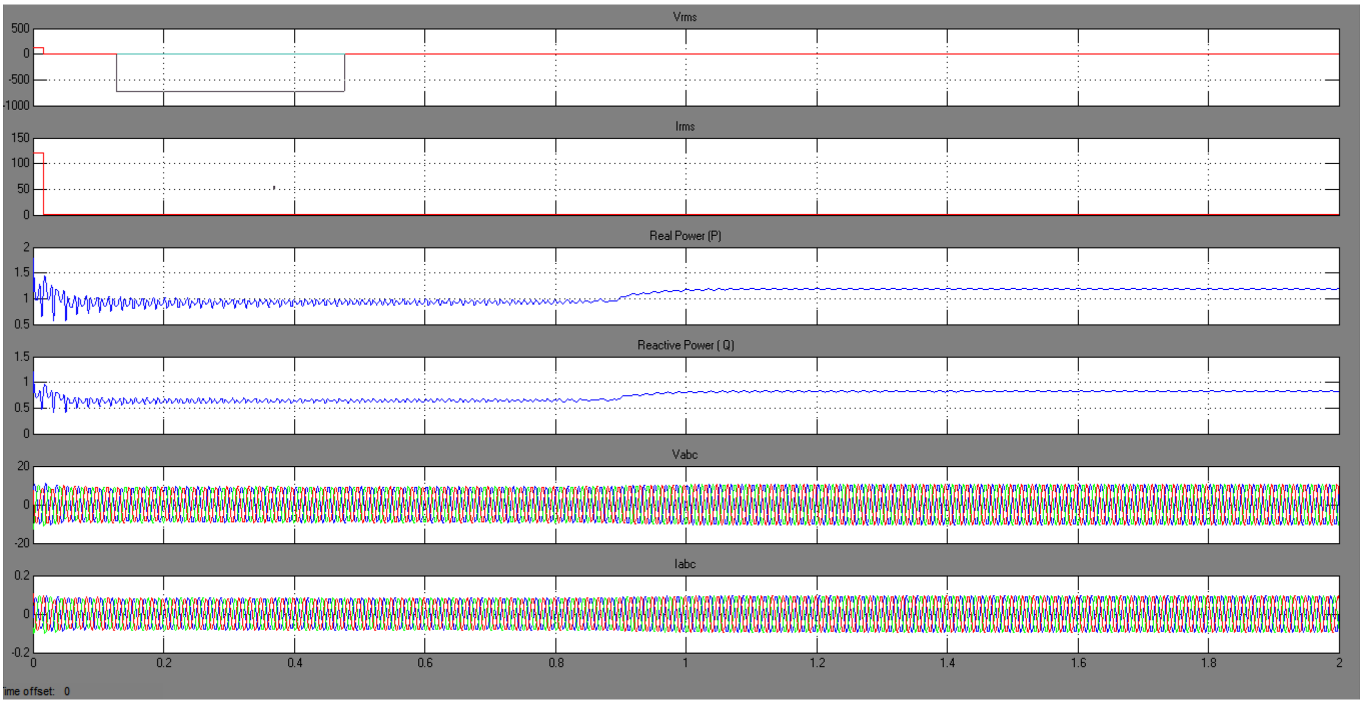

Fig. 9 Output of Hybrid Energy System

The above Figure ure 9 represents the output from the combined solar and wind energy system. the output for the hybrid system will be the combined solar energy plus the wind energy. The output from the hybrid model first two graphs is the output of Vrms and Irms which is the DC equivalent output waveforms. The middle two graphs represent the real power and reactive power of the power distribution of the hybrid energy system. The bottom graphs represent the sinusoidal voltage and current output from the hybrid energy system. From the hybrid system supply is fed to the load also and power remaining is supplied to the grid.

On combining the hybrid system using the solar and the wind energy to power the grid. The generated power from wind is connected parallel and shared with PV system. There is a difference in generation from wind and solar because sources depend on varying climatic conditions therefore, there is likely to be inequality in the measurement of power even though the two systems are connected in parallel to the grid.

IX.CONCLUSION

Individual modelling and simulation study of Wind and PV system has been carried out in Matlab/simulink. Then a hybrid model has been simulated by combining these energy resources with the help of converter and voltage regulator. The simulation result of implemented hybrid system shows the generated output voltages which can be supplied to the grid. This hybrid system is the most feasible economic solutions in lowering electricity bills; it also avoids the high costs encountered during extending grid power lines to remote areas and provides a clean renewable non-polluting source of electricity.

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