VOL. 7, NO. 9, SEPTEMBER 2012 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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MODELING OF GRID CONNECTED HYBRID WIND/PV GENERATION SYSTEM USING MATLAB

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ABSTRACT

This paper presents the modeling of grid connected hybrid wind-solar photovoltaic (PV) system. The proposed system consists of wind generator, wind-side converter, solar PV array, dc-dc converter, and grid interface inverter. Maximum Power Point Tracking (MPPT) is important in solar PV system, because they maximize the output power from the PV system so that effective PV array utilization. The power extracted from hybrid wind-solar power system is transferred to the grid interface inverter by keeping common dc voltage constant. Sinusoidal Pulse Width Modulation (SPWM) technique is used for generating pulses for inverter. The simulation study is carried out using MATLAB and results are presented.

Keywords: wind power generation system, solar PV system, grid interface inverter, MPPT, MATLAB.

INTRODUCTION

In order to reduce the greenhouse gas emission from electric power generation system and for the growing demand of electricity, the environmental issues has led to one of the new trends of integration of renewable energy resources and energy storage systems. In particular, advantages in wind and PV energy technologies have increased their use in hybrid configurations, because of being emission-free and no cost of energy. Hybrid Wind/PV systems are one of the most efficient solution to supply power either directly to a utility grid or to an isolated load.

A wind turbine which converts kinetic energy into mechanical energy drives the wind generator to generate ac electric power, and it is converted into dc power to form the common dc link. Solar PV panel is a non linear power source, where the panel output power varies with temperature and insolation. Due to the low voltage of an individual solar cell (typically 0.6V), several cells are combined into photovoltaic modules, which are in turn connected together into an array. The output voltage from the array is low when compared to the dc link. To raise the output voltage of the array, dc-dc converter is used. In this paper buck-boost converter is used. MPPT controller is used to track the peak power from SPV module. The power extracted from the hybrid wind/PV system is transferred to the grid through a three - phase inverter at synchronized grid frequency.

PROBLEM FORMULATION

Modeling of solar PV system

The standard one diode or 5 parameter model used to represent the SPV module is shown in Figure-1. It consists of a current source in parallel with a diode, a shunt resistance and a series resistance. The modeling equations are:

$$I_{pv} = I_{ph}(G,T) - I_D - v_d/R_{sh} \tag{1}$$

$$I_D = I_R\left(e^{\frac{V_d}{V_t}} - 1\right) \tag{2}$$

$$V_t = \frac{nkT}{q} \tag{3}$$

$$V_d = V_{pv} + I_{pv}R_{se} \tag{4}$$

Figure-2 shows the current-voltage and power-voltage characteristics obtained by simulating (1) to (4) through MATLAB M-file coding at STC, that is at G=1000W/m^2 and T=25^{o}C.

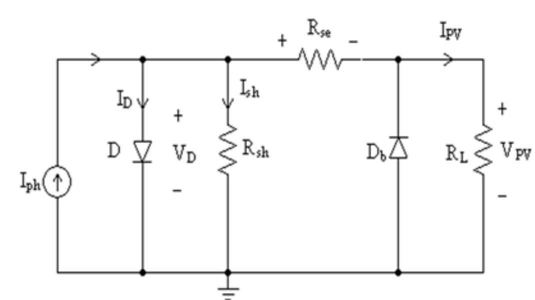

Figure-1. Five parameter model of SPV cell with bypass diode.

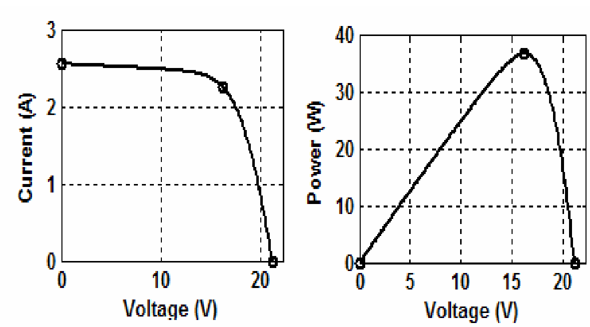

Figure-2. Simulated Characteristics of SPV modules.

VOL. 7, NO. 9, SEPTEMBER 2012 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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MPPT algorithm

MPPT algorithms are necessary in PV applications in order to obtain the maximum power from a solar array because the MPP (Maximum Power Point) of a solar panel varies with the irradiation and temperature. In this paper, Incremental Conductance (INC) algorithm is used for maximum power point tracking. The incremental conductance uses the PV array's incremental conductance dI/dV to compute the sign of dP/dV. It does this using an expression derived from the condition that, at the maximum power point, dP/dV = 0. Beginning with this condition, it is possible to show that, at the MPP dI/dV = -I/V. Thus, incremental conductance can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dI/dV and -I/V. The algorithm is simulated by writing the algorithm in M-file. The flowchart is shown in Figure-3 and the simulated characteristics are shown in Figure-4.

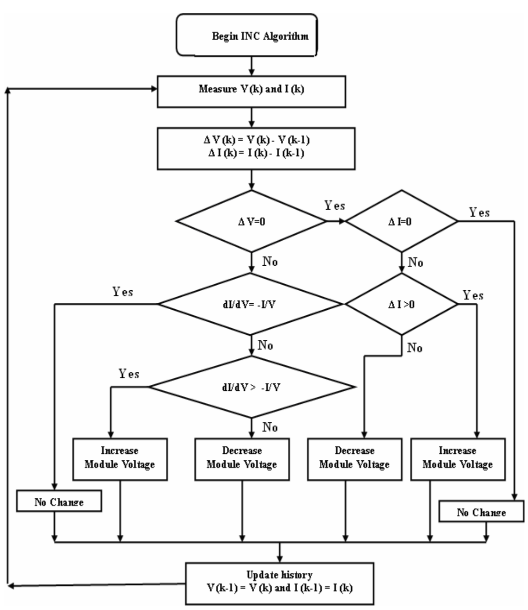

Figure-3. Flowchart for INC algorithm.

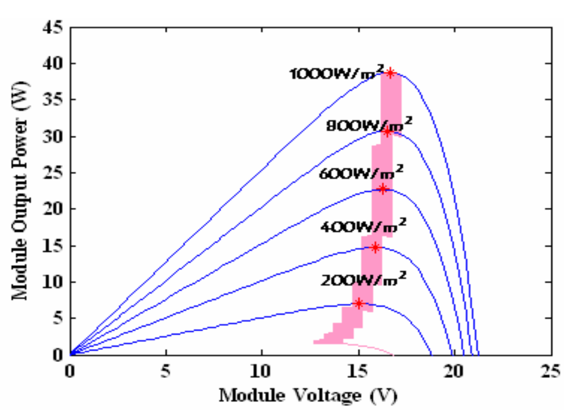

Figure-4. Simulation of INC algorithm.

From Figure-4 it is observed that the INC can track rapidly increasing and decreasing irradiance conditions with higher accuracy than perturb and observe algorithm. With the use of the MPP algorithm V_{mref} has been found.

WIND POWER GENERATION SYSTEM

The wind power generation system is equipped with variable speed generator. Apart from the wind generator, wind power generation system consists of another three parts namely, wind speed, wind turbine and drive train.

Wind turbine model

A wind turbine converts kinetic energy in a moving air stream to electric energy. The wind turbine model is implemented depending upon the Tip Speed Ratio (TSR) and C_p coefficient. The tip-speed ratio is defined as:

$$\lambda = \frac{\omega R}{\upsilon} \tag{5}$$

C_p value is calculated by using the following formula:

$$C_p(\lambda, \vartheta) = c_1\left(c_2 \frac{1}{\beta} - c_3\vartheta - c_4\vartheta^x - c_5\right)e^{-c_6\frac{1}{\beta}} \tag{6}$$

Where $\frac{1}{\beta} = \frac{1}{\lambda + 0.08\theta} - \frac{0.035}{\theta^3 + 1}$ and

$c_1 = 0.22$ $c_2 = 116$ $c_3 = 0.4$

$c_4 = 0$ $c_5 = 5$ $c_6 = -12.5$

Drive train model

There are four types of drive train models, usually available in power system analysis. To avoid the complexity in the system, commonly one mass model is considered. In a one-mass drive train model all inertia components are modeled as a single rotating mass. The equation for the one-mass model is based on the second law of Newton, deriving the state equation for the rotor angular speed at the wind turbine, given by:

$$\frac{dw_t}{dt} = \frac{1}{J}(T_t - T_g) \tag{7}$$

where *J* is the moment of inertia for blades, hub and generator, *Tt* is the mechanical torque, *Tg* is the electric torque.

Model of generator associated to the rectifier

Both induction and synchronous generators can be used for wind turbine systems. Mainly, three types of induction generators are used in wind power conversion systems: cage rotor, wound rotor with slip control and

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doubly fed induction rotors. In this paper, gearless multi-pole permanent magnet synchronous generator (PMSG) is chosen and it is attractive because it offers better performance due to higher efficiency and less maintenance since it does not have rotor current and can be used without a gearbox, which also implies the reduction of the weight of the nacelle, and reduction of costs. It produces electricity from the mechanical energy obtained from the wind. The wind turbine controller consists of three- phase diode bridge rectifier which converts the alternating current from wind turbine to direct current. The three phase diode bridge rectifier is comprised of six rectifier diodes. The variable frequency output voltages from wind turbines are rectified to unregulated dc voltages.

Figure-5 shows the input waveform from wind turbine and Figure-6 shows the output waveform of three phase diode bridge rectifier.

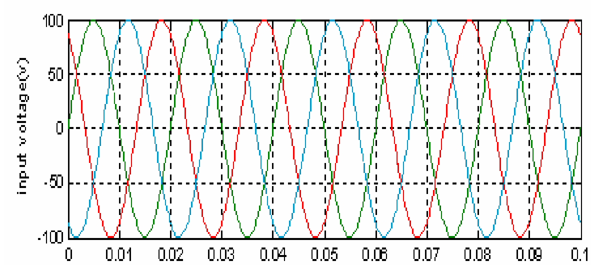

Figure-5. Input waveform from wind turbine.

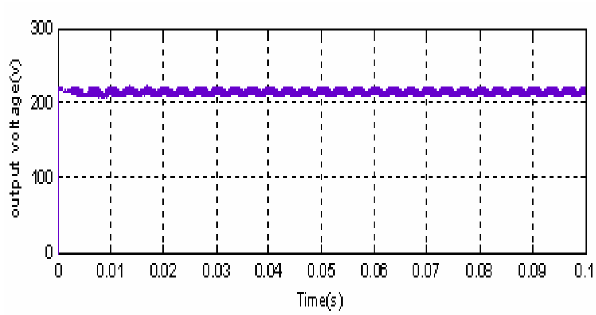

Figure-6. Output waveform of three-phase diode bridge rectifier.

MODEL OF HYBRID WIND/PV SYSTEM CONNECTED WITH GRID

A hybrid energy system usually consists of two or more renewable energy sources used together to provide increased system efficiency as well as greater balance in energy supply. In this project, the hybrid energy system is a photovoltaic array coupled with a wind turbine. Figure-7 shows the schematic diagram of proposed system.

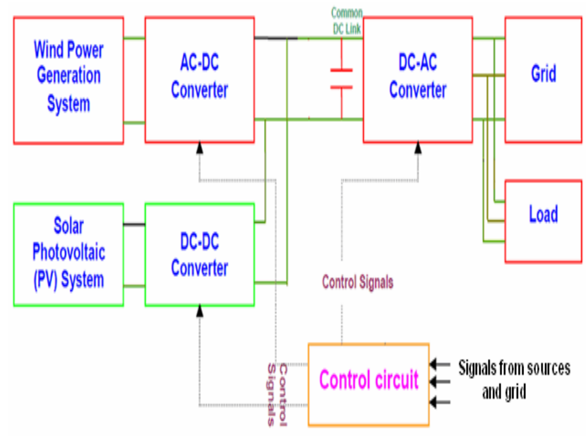

Figure-7. Schematic diagram of proposed system.

The grid interconnection converts the variable frequency and magnitude outputs from the hybrid wind/SPV system to the synchronous frequency of the utility grid. The variable frequency and magnitude output voltages from the hybrid wind/SPV system are converted to DC voltages or so called DC links. The grid side inverter converts the DC link voltages to the synchronous voltages of the grid. A Sinusoidal Pulse Width Modulation (SPWM) is employed for generating gate pulse. Figure-8 shows the MATLAB - Simulink of hybrid wind/SPV system connected with grid.

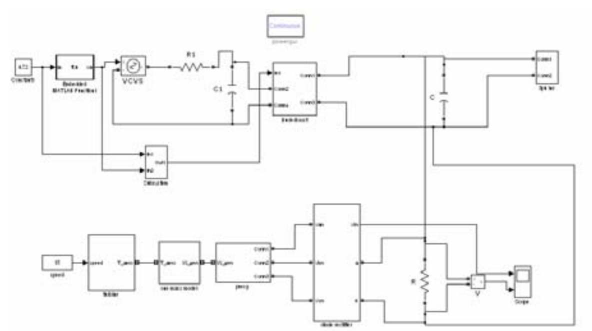

Figure-8. MATLAB-Simulink of hybrid wind/SPV system connected with grid.

The output of grid voltage and grid current are in phase and are expressed in per units (p.u). It is achieved by using Phase Locked Loop (PLL). The PLL consists of comprises of a phase detector (PD), a low-pass filter, voltage controlled oscillator (VCO) and a feedback divider. The three phase PLL converts the abc transformation from grid into dq0 transformation. Figure-9 shows the output waveform of grid voltage and Figure-10 shows the output waveform of grid current.

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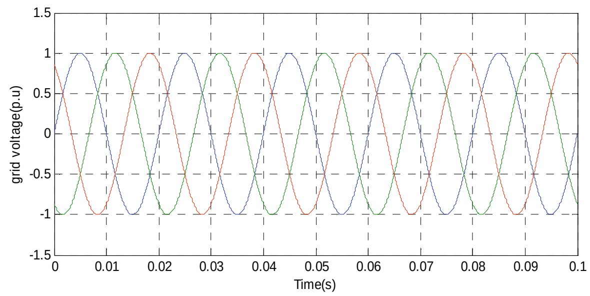

Figure-9. Output waveform of grid voltage.

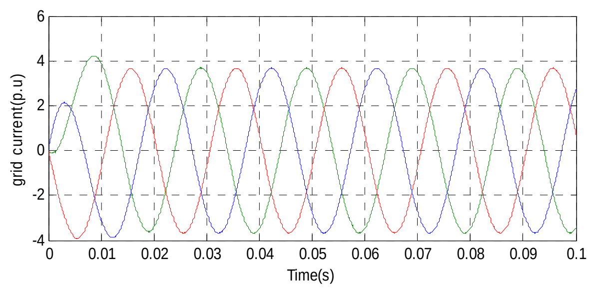

Figure-10. Output waveform of grid current.

HARDWARE IMPLEMENTATION

The hybrid system of wind/PV system connected with single phase inverter is implemented as a hardware setup. Figure-11 shows the hardware setup of single phase inverter interfaced with SPV. The corresponding output voltage and output current are obtained for different load condition.

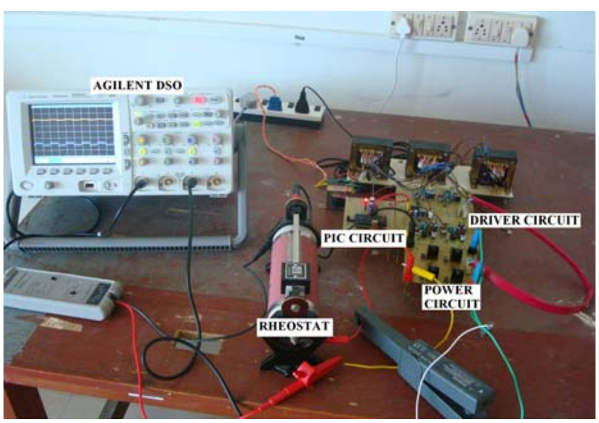

Figure-11. Hardware setup of the single phase inverter.

Figure-12 shows the output voltage and current waveform of inverter at full load condition and Figure-13 shows the output voltage and current waveform of inverter at half load condition.

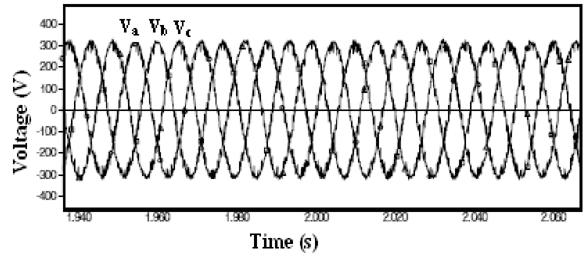

Figure-12. Observed voltage at grid Inverter terminal.

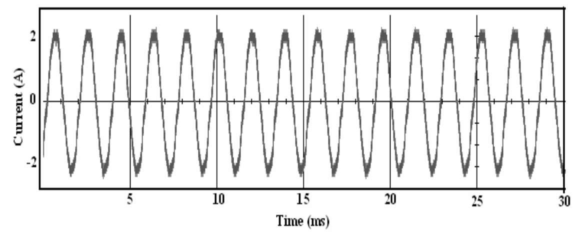

Figure-13. Observed current at grid Inverter side.

CONCLUSIONS

In this paper, grid connected hybrid wind/solar PV generation system has been presented. It is observed that the extraction of the maximum power from SPV array is obtained using MPPT system. The INC MPPT algorithm has been implemented. The proposed system has been simulated in MATLAB-SIMULINK environment. From the simulation results, it is found that, to obtain grid voltage and grid current at unity power factor, the grid side parameters have to be tuned properly by designing the filter and proper modulation scheme for grid inverter interface.

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