MATLAB Simulation Model of Hybrid Wind-Solar Energy System using Converter Topology with MPPT Algorithm

Ajeet Khampariya[1], Deepak Agrawal[2]

[1]Research Scholar, Dept. of Electrical & Electronics Engg. TITR Bhopal

[2]Assistant Professor, Dept. of Electrical & Electronics Engg. TITR Bhopal

Abstract-The proposed system in this paper presents power-control strategies for a hybrid power generation system with adaptable power transfer capability. This hybrid system permits maximum utilization of renewable energy sources which are available free of cost in nature like wind and photovoltaic energies. For this, an adaptive MPPT algorithm such as perturbs and observes method will be incorporated with the hybrid system to obtain maximum power. This configuration also maintains the two sources according to the availability of their energy for supplying the load separately or simultaneously. The rotor speed of turbine is the main determining factor of mechanical output from wind energy and solar cell operating voltage in the case of electrical output from solar energy. Permanent Magnet Synchronous Generator is used with wind turbine to get electro-mechanical energy conversion.

Keywords:-Solar energy, Wind energy conversion, Hybrid system, P&O MPPT, DC-DC converter.

I. INTRODUCTION

Recent trends and electric power generation-consumption pattern indicates an increasing use of renewable energy. Almost all regions of the world have renewable resources of some kinds according to the availability. By this perspective the harnessing of maximum power from sustainable energy sources are seeking more attention. Solar energy and wind energy are the two renewable energy sources which is most common in use. Wind energy has turn into the least expensive technology in existence and gaining the interest of scientists and researchers over the world [1]. Photovoltaic (PV) cells convert the radiation from sun into electricity. Additionally, PV offers the advantage that it produces electricity without mechanical link hence no noise and no maintenance [2]. Solar and wind energy source hybridization provides a reliable and sensible form of power generation. Lots of studies have been carried out in last decades on the power generation by renewable energy. The both wind and solar energy systems are highly unreliable due to their uncertainty/unpredictability [3]. In a PV panel was incorporated with a diesel electric power generation system is analyzed and here the result is reduction in the fuel consumption. It was observed that the inclusion of a supplementary renewable source can further cut down the fuel consumption. Several [4-8] wind/PV hybrid systems with Maximum Power Point Tracking (MPPT) technique have been proposed previously. They used a separate DC-DC buck or buck-boost converter to perform the MPPT control for each of the renewable energy sources, but this system has a problem that, due to the environmental influence in the wind turbine-generator set, high frequency (HF) current harmonics are generated. These harmonic contents cause deterioration of electrical output. Buck and buck-boost converters do not have the capability to get rid of these HF harmonics. To eliminate or reduce this HF harmonics contents system requires LC filters, but it makes the system heavier and expensive. A new converter topology for hybridizing the wind and solar energy sources has been proposed in this paper. In this topology, both wind and solar energy sources are integrated together using a combination of Cuk and SEPIC converters, so that in case of absence of one of them the other source can compensate for it. The combined Cuk-SEPIC converters are able to eliminate the HF current harmonics. This eliminates the need of LC filters in the system. These converters can also support the step up and step down operations of voltages for each source. They can also control individual and simultaneous operations of hybrid system [9-12]. Solar energy and wind energy sources output is given to the input to the Cuk converter and the SEPIC converter respectively. The output voltage produced by the system will be the sum of the average outputs of these two sources. All these benefits of the proposed hybrid system make it highly efficient and reliable.

II. COMPONENTS OF THE SYSTEM

- *MPPT ALGORITHM*

Because of the poor efficiency of photovoltaic array most of the solar radiation, reaching over array gets wasted. The algorithm known as maximum power point tracking is implemented to enhance the performance of solar panel [8]. The MPPT algorithm works on principal of Thevenin, according to which the power output of a circuit can be maximize by matching its impedance to the load impedance. This matching of impedance can be achieved by tracking maximum power point.

There are different techniques [13] used to track the maximum power point. Few of the most popular techniques are:

- ✓ Constant Voltage Method
- ✓ Constant Current Method
- ✓ Perturb and observe (P&O) method
- ✓ Incremental Conductance (IC) method

- *Constant Voltage Method*

Constant voltage method is based on the observation that the maximum power point occurs between 72-78% of the open circuit voltage Voc, for the standard atmospheric condition. The solar PV module always operates at the constant voltage in this range. The duty ratio (δ) of the DC to DC convertor ensures that the PV voltage is equal to:

$$V_{ref} = K_1 V_{oc} \quad (1)$$

Where K_1 = 0.72 to 0.78

- *Constant Current Method*

Constant current method is based on the same phenomenon of the constant voltage method. In the constant voltage method the PV array operates at the constant voltage and in this method PV array operates at the constant current. The maximum power point arrives between 78-92% of the short circuit current Isc thus the sensed parameter is short circuit current.

$$I_{ref} = K_1 I_{sc} \quad (2)$$

Where K_2 = 0.78 to 0.92

- *Perturb and observe*

The P&O algorithm and "hill-climbing", both names refer to the same algorithm depending on how it is implemented. The basic difference among these two is that Hill-climbing involves a deviation of the duty cycle of the DC-DC converter and P&O concern on the operating voltage of the DC link between the PV array and the DC-DC converter takes place. The deviation of duty cycle of the DC-DC converter is the modification of the voltage of DC link refers as Hill-climbing, so both names refer to the same technique. The next perturbation depends on the sign of the last perturbation and the sign of the last increment in the power. The perturbation will continue to the same direction if power is incremented, and if power is decreased then perturbation will be in the reverse direction. The process will be repeated until the point of maximum power (MPP) not reached; hence the operating point oscillates around the MPP.

- *Incremental Conductance*

The slope between power and voltage in P-V curve of PV module is the deciding factor in incremental conductance algorithm, if this slope is zero it shows point of MPP (Pmax).

dI/dV : Incremental conductance,

I/V : Instantaneous conductance.

- Before MPP : slope is positive

$$\frac{dP}{dV} > 0 \quad or \quad \frac{dI}{dV} + \frac{I}{V} > 0$$

- After MPP : slope is negative

$$\frac{dP}{dV} < 0 \quad or \quad \frac{dI}{dV} + \frac{I}{V} < 0$$

- At MPP : slope is zero

$$\frac{dP}{dV} = 0 \quad or \quad \frac{dI}{dV} + \frac{I}{V} = 0$$

MPP can be estimated by comparing instantaneous conductance to the incremental conductance.

There are many more methods of MPPT [13-14] here only some of described. P&O is selected in this paper because this method is easy to implement, shows moderate accuracy, operating point oscillate around MPP, the method is slow and not suitable for fast changing parameters condition, Oscillation can be curtailed by reducing perturbation step size which slow down the MPPT, for this measurement of voltage and current both is required .

- *Photovoltaic Cell*

To convert the radiation supplied by sun a semiconductor device photovoltaic cell is used to converts radiation into electrical energy, this device use photovoltaic effect. PV cells are made by semiconductor materials, such as silicon. For solar PV cells, a thin wafer of semiconductor material is particularly treated to form an electric field, positive on one side of that wafer and negative on the other side. When radiation reaches the solar cell, electrons are dislodged loosely from their atoms in the semiconductor material and become free. If electrical conductors are connected to the positive and negative sides of wafer, this will form an electrical circuit. An electric current is flow due to motion of free electrons (from negative to positive terminal). This electric current can then be used for a power load [2].

- *Cuk Converter*

The Cuk converter is basically a type of DC-DC converter which produces an output voltage magnitude either greater or less than the input voltage magnitude. It is basically a boost converter which is followed by a buck converter. Similar to the buck–boost converter with inversion topology, the voltage output of non-isolated Cuk converter is also inverting, and can be lower or higher than the input voltage. It employs a capacitor as its energy-storage element, unlike other types of converter which uses an inductor as storage element [10].

- *SEPIC Converter*

The SEPIC (single-ended primary-inductor converter) is a type of DC-DC converter that converts the electrical voltage output to more than, less than, or equal to its input. The SEPIC output is controlled by changing the duty cycle of the transistor. A SEPIC is basically a boost converter which is followed by a buck-boost converter, thus it is analogous to a conventional buck-boost converter, but has benefits of having non-inverted output. A series capacitor is used to couple energy from input to output [12].

III. MATLAB MODELLING AND SIMULATION

The proposed system allows power-control strategies of a hybrid generation system with flexible power transfer capability. This hybridization permits maximum utilization of renewable energy sources such as wind and photovoltaic energies. The Permanent Magnet Synchronous Generator is used with wind turbine to get electricity, it gives AC power. The output of solar is DC and an inverter is used to converts the DC output into useful AC power for the connected load. This hybrid system operates during normal conditions which means at normal room temperature in the case of solar energy and at normal wind speed at plain area in the case of wind energy. The simulation results are presented to shows the operating principle, feasibility and reliability of this proposed system.

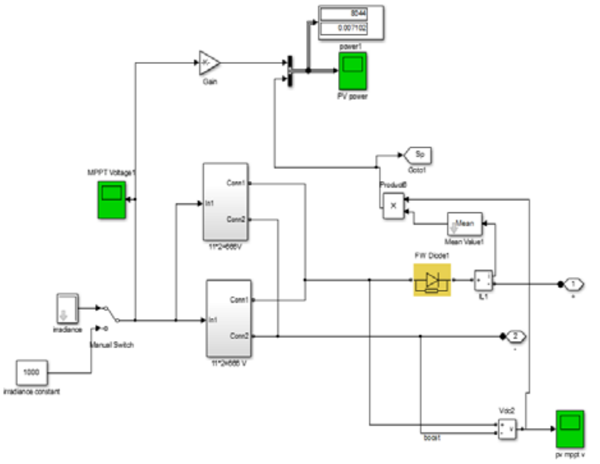

Figure 1: MATLAB Model for PV System

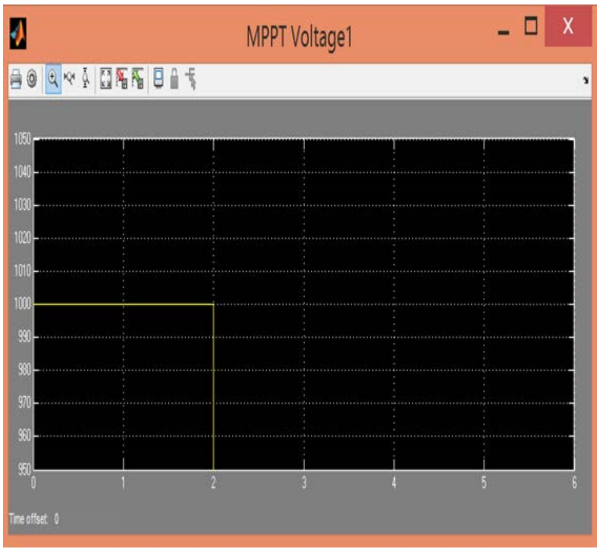

Figure 2: Output Voltage of Maximum Power Point Tracking

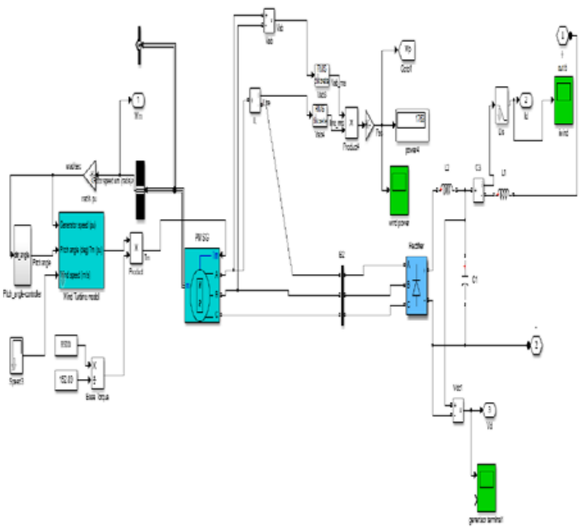

Figure 3: MATLAB Model for Wind System

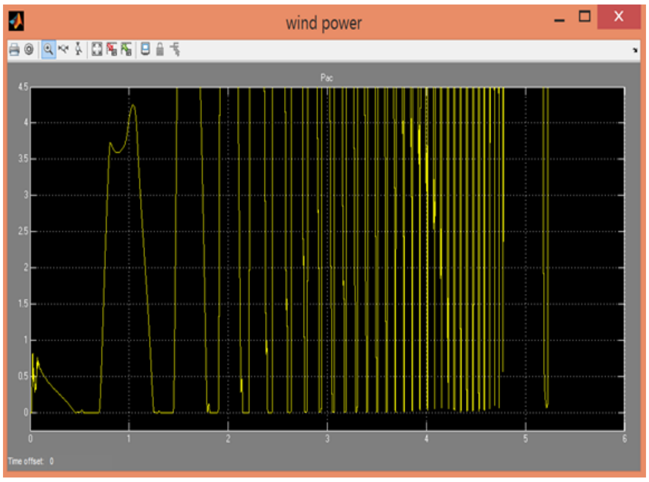

Figure 4: Output Voltage of Wind Power

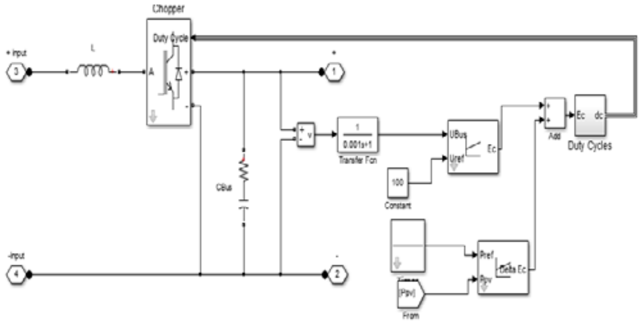

Figure 5: MATLAB Model for DC-DC Converter

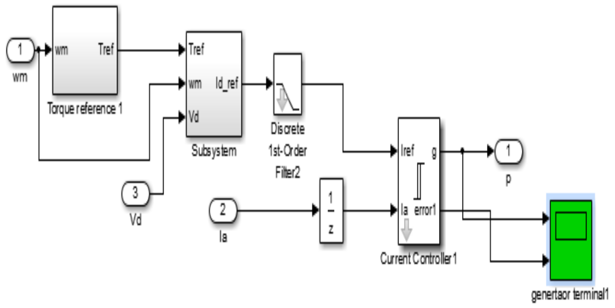

Figure 6: MATLAB Model for wind MPPT

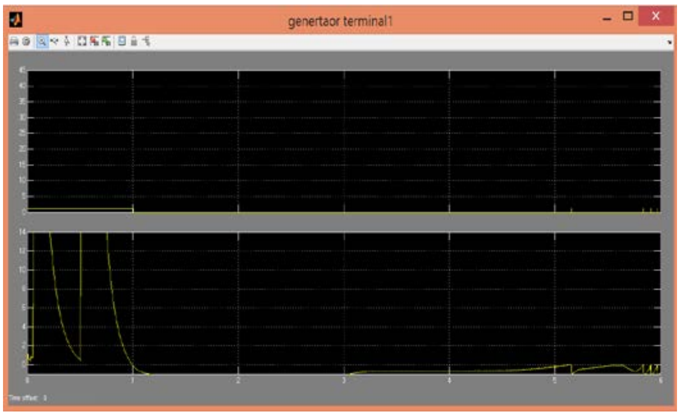

Figure 7: Generator Voltage of wind MPPT

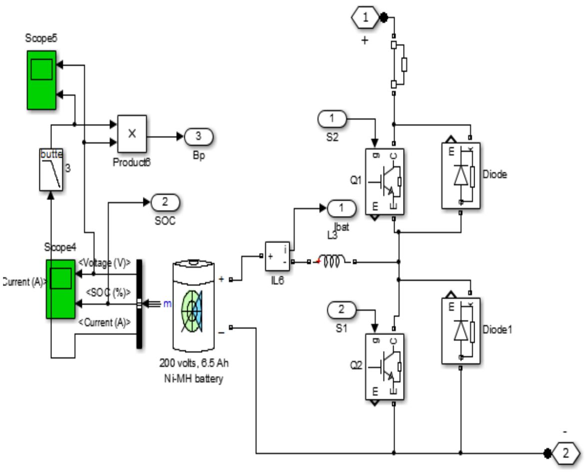

Figure 8: MATLAB Model for Battery and DC-DC Converter

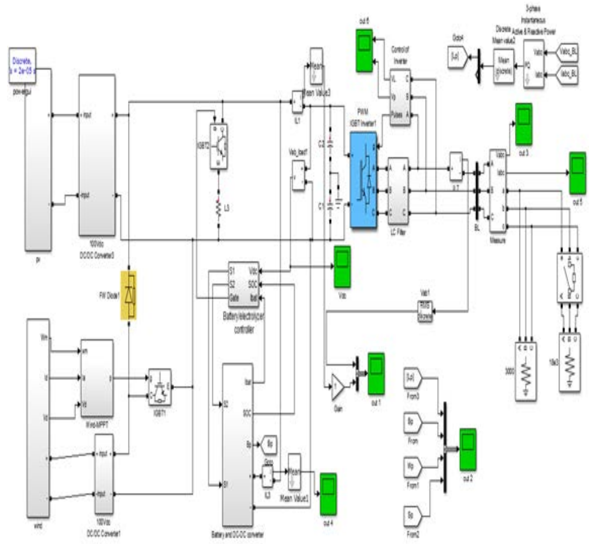

Figure 9: MATLAB Simulink Model of Hybrid Wind-Solar Energy System using MPPT Algorithm

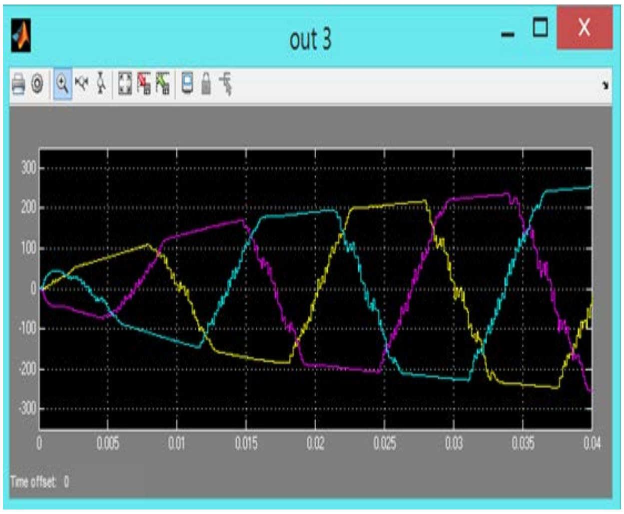

Figure 10: Output Voltage of wind and solar energy hybrid system

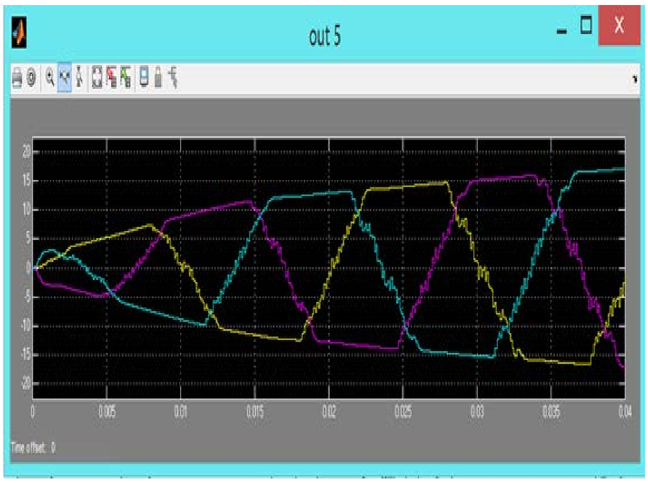

Figure 11: Output Current of wind and solar energy hybrid system

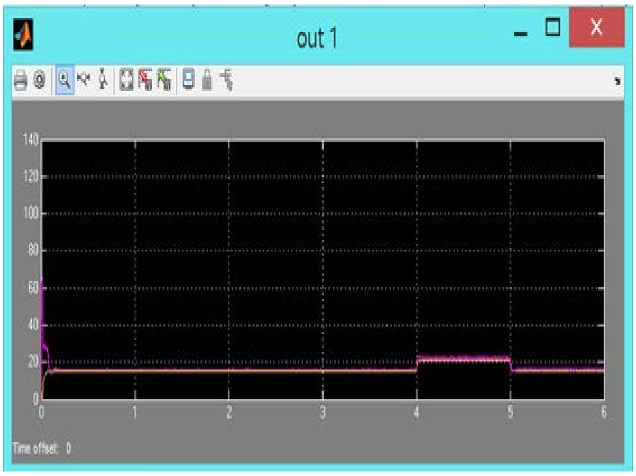

Figure 12: Gain of wind and solar energy hybrid system

IV. CONCLUSION

For integration of hybrid PV and wind sources, the integrated Cuk-SEPIC converter with MPPT has been presented. In this paper two separate DC-DC converters are combined together to minimize the converter components, size and complexity as well as harmonics. The proposed system does not use any additional input filters for the elimination of high frequency (HF) harmonics and to improve the converter efficiency. Since, less number of switching devices and passive components are used in this system it reduces the cost and complexity of the overall system. MPPT has been realized for both PV and wind sources by using perturb and observe method. The developed converters make the use of natural complementary behavior of PV and wind system and maintain constant DC link voltage throughout the day. The simulation results of the proposed model are presented in three operating regions (both PV and wind sources are available, only PV source available and only wind source is available). MATLAB/ SIMULINK software is used to model the PV panel, wind turbine, DC-DC converters, MPPT controller and proposed hybrid system.

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