Single Input DC-DC Converter for Hybrid Distributed Energy Generators with Maximum Utilization using DSP Controller

John Marshal T P*, Deepa K**
*P.G.Scholar, ** Assistant Professor,
Department of EEE, Amrita School of Engineering, Amrita Viswa Vidyapeetham, Bangalore, Karnataka, India.

ABSTRACT

Environmental friendly solutions are becoming more prominent than ever as a result of concern regarding the state of our deteriorating planet. This paper presents a new DSP controller based Switching configuration of hybrid Distributed Energy Generators (DER) with a single input DC-DC Buck-Boost converter, based on their availability . This configuration allows the two sources to supply the load separately or simultaneously depending on their availability. Because of its fast operation and reliability, DSP controller is used to improve the system efficiency at the most. Maximum amount of energy is extracted from the available source based on the control logic proposed in this paper. The system can operate in three different modes to obtain maximum efficiency based on the logic projected. The system is simulated using MATLAB/Simulink 2010a, the obtained results are also analyzed and presented in this paper.

Keywords – **DEG, DSP controller, Single input DC-DC converter.**

I. INTRODUCTION

The energy consumption of the world is increasing dramatically with the rapid increase of population. Renewable energy resources are holding the predominant place for satisfying the future energy demand, but unfortunately their presence is unpredictable. On the basis of understanding this undesirable task, new control logic is proposed in this paper to extract maximum energy from the renewable energy resources based on their availability with the help of a DSP controller.

Among the available renewable sources, wind and solar are predominant ones, since they have more advantages on production, maintenance, etc. when compared with others. But their presence is highly unpredictable due to the natural factors such as trees, buildings, clouds, etc. Many researches are still going on this field to improve the efficiency of this type of systems having wind and solar as resources. Due to the growth of power electronics techniques and digital control methods, in the past so many models are developed to improve the efficiency of hybrid system [1] – [15]. High performance stand alone photovoltaic systems with MPPT technique was developed [1] – [3]. In the same manner wind energy systems are also developed [4] – [5]. Because of the unpredictability of these sources, some systems are developed which contains both wind and solar as sources called as Hybrid systems [6] – [8]. The characteristic features of solar cell and hybrid systems are studied [9] – [11]. Because of intermittent sources, we are trying to store the energy, when it is available. So a new digitally controlled battery storage system was developed [13] and a battery charge control technique is explained in [12]. Use of multi-input converters for hybrid systems and their advantages are listed [14] – [15].

In this paper, a single input buck-boost converter is proposed, which can deal with solar power and wind energy individually or simultaneously based on their availability. The system is designed to extract energy to the maximum level from the renewable sources. At the maximum availability of both sources, system will supply the load directly from the wind and the remaining energy from solar is stored in battery for future use. A dsPIC30F4011 controller is used for the whole system control to obtain maximum efficiency. Thus the volume of the converter is reduced, but the reliability of the system improved considerably.

II. SYSTEM ARCHITECTURE

To the maximum extraction of energy from hybrid renewable energy system, a dc-dc converter with new control logic is derived. Fig. 1 illustrates block diagram of the proposed system. It mainly consists of a PV array, a wind energy generator, a buck-boost converter, DSP controller and a battery with charger. Based on the source availability the controller do all power calculations and generate the required control signal to extract maximum energy.

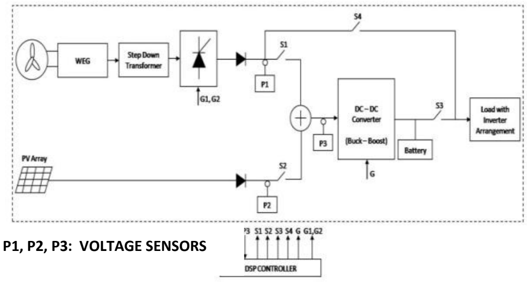


Fig. 1 Block diagram of the proposed system

III. Basic Operation of Proposed System

In Fig. 2 a single input buck-boost converter used for the proposed system is represented. To achieve better performance, the system is designed to operate in three different modes of operation. The dsPIC30F4011 controller which generates all the control signals to select the available source to obtain maximum efficiency as well as to regulate output voltage of dc-dc converter. The three different possible modes of operations are described in the followings.

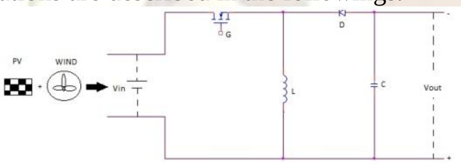


Fig. 2 Single input Buck-Boost converter of the proposed hybrid system

Mode1: Stand alone mode

The controller instantly checks the availability of sources based on the sensor inputs given to it. When any one of the sources is not available, this means less than the minimum rated value of the converter (8V), the controller disconnect that source from the active system to avoid overloading. Any one of the available source (wind or solar) will connect to the active system to satisfy the load demand.

Mode 2: Hybrid mode

At any instant both the sources are available (>8V), but less than the maximum rated voltage of the buck-boost converter (35V), then both the sources are added to the active system by the controller and they together deliver the power to the load. Simultaneously battery will store energy for the future demand (Power shut-down period).

Mode 3: Direct On-Line mode

In any case, both sources are available with their maximum value, then the controller will connect the wind energy to supply the load directly, and the solar power is used to charge the battery bank to satisfy the energy demand in the power off period. The flow of control of this proposed system is described in Table 1.

Table 1. Flow of Control

	Low (< 8V)	**Medium (8<V<35)**	**Maximum (=35V)**
Wind	Not Connected	Connected	Connected (Power directly fed to the Load)
Solar	Not Connected	Connected	Connected
Battery	Discharging	Charging	Charging by using Solar Power

IV. Design of DC-DC Converter

The converter circuit parameters for real time system is designed as follows. The single input dc-dc converter for this proposed hybrid system is designed to operate in a voltage range of 8-35V. Some of the important parameters are listed as follows:

PV panel voltage	: 20V
Wind turbine voltage	: 15V
Battery (as a load)	: 24V
Switching frequency	: 20 kHz

The output of the dc-dc converter is used to charge the battery and supply the load. The duty cycle range is calculated based on the relation shown in equation (1).

$$d = \frac{V_o}{V_d} = \frac{d}{1-d} \qquad (1)$$

From equation (1), the duty cycle range of the proposed buck-boost converter is calculated as 0.44-0.77. The output inductance and capacitance of the converter is calculated from equation (2) & equation (3) respectively. 10% of I_{max} is allowed as ripple current through the inductor and 10% of V_o is taken as ripple voltage across the capacitor.

$$L = \frac{V_o(1-d)}{\Delta I_l * f_s} \qquad (2)$$

$$C = \frac{I_o * d}{\Delta V_o * f_s} \qquad (3)$$

Based on the equations (2) and (3), the values of inductor and capacitor of the dc-dc converter are calculated and their values are expressed below

Output inductance : 7mH

Output capacitance : 72µF

V. FLOWCHART

Flowchart adapted to the proposed system is given in Fig. 3. The DSP controller will generate the control signals to the switches and to the dc-dc converter to extract maximum available energy from the renewable resources thus increase the efficiency of the system. The regulation of output voltage of the buck-boost converter also taken care by the controller.

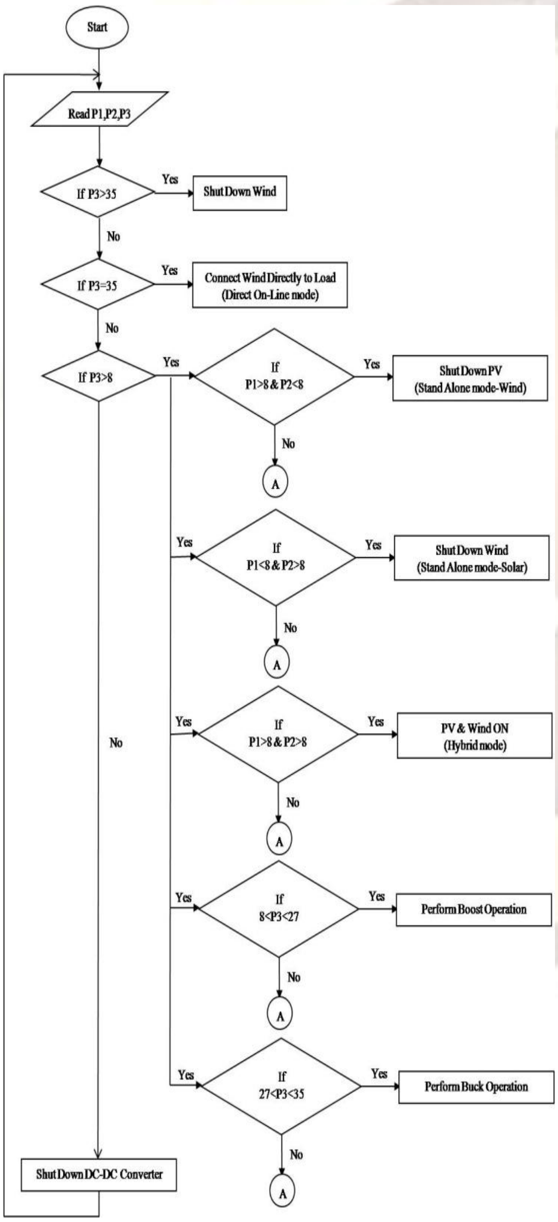
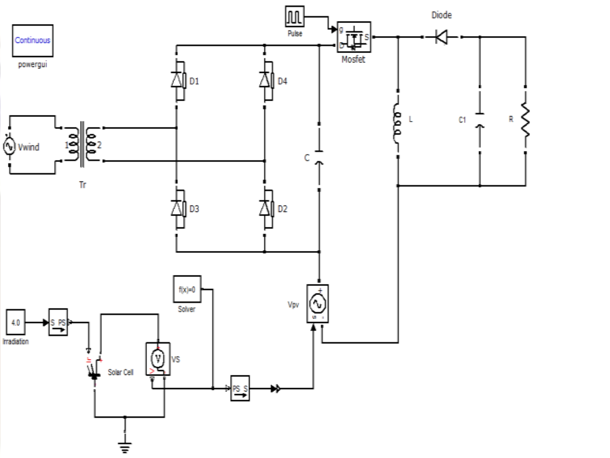


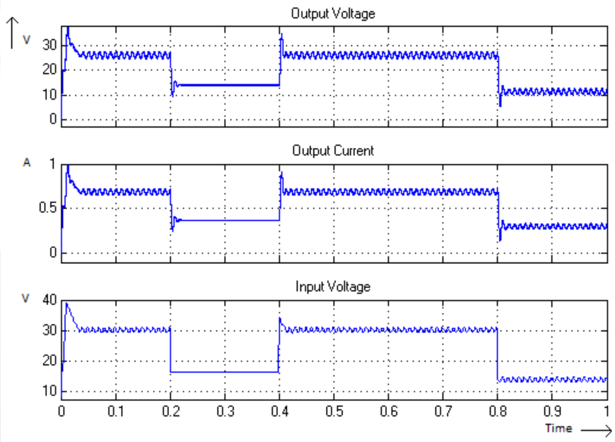
Fig. 3 Flowchart of the hybrid system

VI. SIMULATION RESULTS

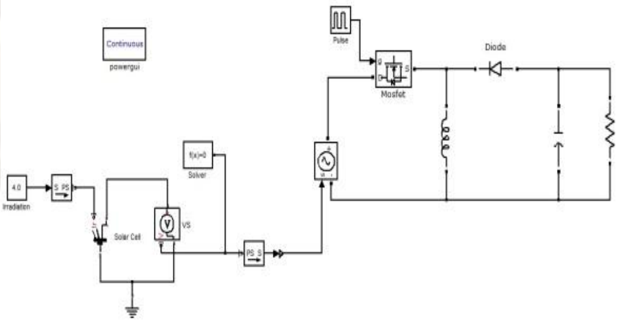
The real time feasibility of the renewable energy system proposed is simulated against the different possible real world conditions using MATLAB/Simulink 2010a. The open loop simulation models of hybrid, stand alone system are given with their respective output waveforms in Fig. 4.



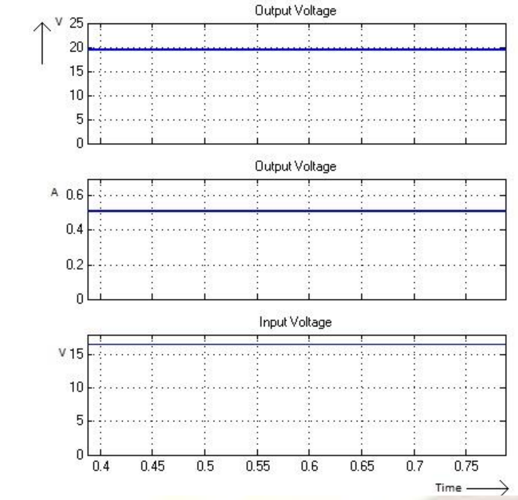
(a) Open loop model of hybrid system



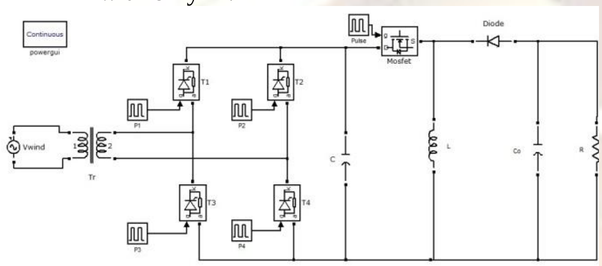
(b) Waveforms of Hybrid system



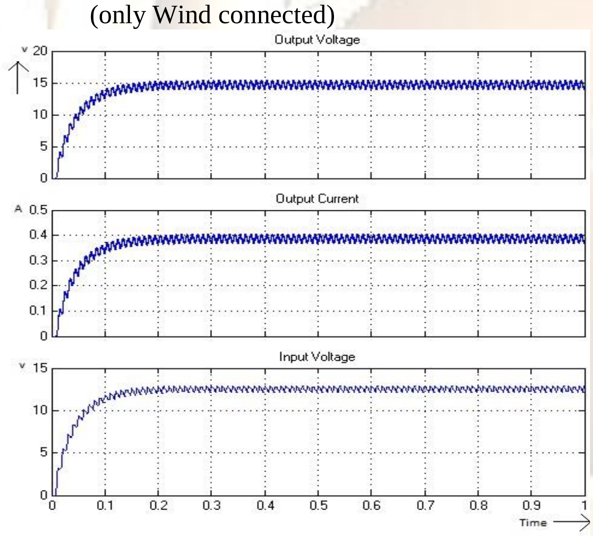
(c) Simulation model of Standalone system (only solar connected)



(d) Output waveforms of standalone system with only PV



(e) Simulation model of Standalone system (only Wind connected)



(f) Output waveforms of standalone system with only wind

Fig. 4. Simulation models and waveforms

Table 2 Analysis of Simulation results

Source	Open Loop				Closed Loop			
	V_{in}	V_o	I_o	d	V_{in}	V_o	I_o	d
Hybrid	22	27	0.7	55	22	27	.7	55
Only Solar	16	20	.55		16	27	.7	63
Only Wind	13	15	0.4		13	27	.7	68

VII. CONCLUSION

This paper proposed a single input buck-boost converter for hybrid renewable energy system with dsPIC30F4011 controller to extract maximum energy from renewable energy resources based on their availability. The system deals with PV power and wind energy individually or simultaneously depend on the various atmospheric conditions. A system which satisfies all the proposed conditions is simulated for different real time possibilities. The generation of control signals to select the available sources and the operation of dc-dc converter will taken care by the controller unit. The reliability of the system also improves to a greater extent with this proposed configuration.

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