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A Novel Front End Converter for Parallel Hybridization of Renewable Energy Sources

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ABSTRACT: This work presents a novel system configuration of the front-end rectifier stage for a hybrid wind/photovoltaic energy system. It is quite evident that as power demand increases, power failure also increases subsequently. Hence, renewable energy sources can be used to drive constant loads. Hybridizing solar and wind power sources provide a realistic form of power generation. In this topology, both wind and solar energy sources are incorporated together using a combination of Cuk and Single-Ended Primary-Inductor Converter (SEPIC) converter. This configuration allows the two sources to supply the load separately or simultaneously, depending on the availability of the energy sources. The fused multi-input rectifier stage also allows Maximum Power Point Tracking (MPPT) to be used to extract maximum power from the sun. An incremental conductance is used for the PV system. The average output voltage produced by the system is the sum of the inputs of these two systems. All these advantages of the hybrid system make it highly efficient and reliable. A MATLAB Simulink model has been developed and compared with the parallel schemes.
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KEY WORDS: SEPIC converter, Cuk converter, PV and wind source, Hybrid system, MPPT.

I.INTRODUCTION

Solar energy and wind energy are the two renewable energy sources most common in use. Wind energy has become the least expensive renewable energy technology in existence. Photovoltaic cells convert the energy from sunlight into DC electricity. PVs offer added advantages over offer renewable energy sources in that they give off no noise and practically require no maintenance.

Hybridizing solar and wind power sources provide a realistic form of power generation. When a source is unavailable or insufficient in meeting the load demands, the other energy source can compensate for the difference. Several hybrid wind/PV power systems with Maximum Power Point Tracking (MPPT) control have been proposed earlier. They used a separate DC/DC buck and buck-boost converter connected in fusion in the rectifier stage to perform the MPPT control for each of the renewable energy power sources. This system requires passive input filters to remove the high frequency current harmonics injected into wind turbine generations. The harmonic content in the generation current decreases its lifespan and increases the power loss due to heating.

In this topology, both wind and solar energy sources are incorporated together using a combination of Cuk and SEPIC converters, so that if one of them is unavailable, then the other source can compensate for it. The Cuk-SEPIC fused converters have the capability to eliminate the HF current harmonics in the wind generator. This eliminates the need of passive input filters in the system. These converters can support step up and step down operations for each renewable energy sources. They can also support individual and simultaneous operations. Solar energy source is the input to the Cuk converter and wind energy source is the input to the SEPIC converter. The average output voltage produced by the system will be the sum of the inputs of these two systems.

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II. LITERATURE SURVEY

The survey of the various classical control methods has been reported to project the proposed method as optimum for improving the dynamic stability of the hybrid system and to improve the performance of the converters. The research aims to implement an intelligently controlled PV and wind source along with THD of the converters.

The following literature review projects the issues connected to the research on intelligently controlled converters, which focuses on various innovative approaches by our frontiers as listed below:

1. DivyaTeja Reddy Challaet al (2012) presented the DC-DC converters are typically used in the applications where the output voltage is considerably higher than the input voltage. Basic objective of this paper is parallel connected SEPIC-Boost converters to share the load current. The approach of varying complexity and current sharing performance has been proposed. The advantage of parallel connected power supply is low component stress, increased reliability, ease of maintenance and repair, thermal management.

2. P. Chidambaram, N. Subramani et al(2012) presented the Hybridizing solar and wind power sources provide a realistic form of power generation. In this topology, both wind and solar energy sources are incorporated together using a combination of Cuk and Single-Ended Primary-Inductor Converter (SEPIC) converter.

3. Carlos A. Canesin et al (2012)presented a evaluations among the most usual maximum power point tracking (MPPT) techniques, doing meaningful comparisons with respect to the amount of energy extracted from the photovoltaic (PV) panel [tracking factor (TF) in relation to the available power, PV voltage ripple, dynamic response, and use of sensors.

4. Bakhshai et al. (2010) presented apower demand increases, power failure also increases. So, renewable energy sources can be used to provide constant loads. A new converter topology for hybrid wind/photovoltaic energy system is proposed. Hybridizing solar and wind power sources provide a realistic form of power generation. The topology uses a fusion of Cuk and SEPIC converters.

5. Chiang.S.J, Hsin-JangShieh et al (2009)presented atwo level SEPIC suffers from higher switching stress due to which the switching losses increase. Because of this increase in switching loss, the efficiency of the power converter decreases. To overcome this disadvantage, this paper proposes a three level SEPIC which has reduced switching losses. Three level SEPIC improves the power efficiency by using a lower rated switch. A control strategy is described to balance the capacitor voltage so that the damage to the power switch is prevented.

6. E. Koutroulis and K. Kalaitzakis et al (2006)a wind-generator (WG) maximum-power-point tracking (MPPT) system is presented, consisting of a high efficiency buck-type dc/dc converter and a microcontroller-based control unit running the MPPT function. The advantages of the proposed MPPT method are that no knowledge of the WG optimal power characteristic or measurement of the wind speed is required and the WG operates at a variable speed.

7. D. Das, R. Esmaili, D. Nichols, L. Xu (2005) presenteda harmonic content in the generator current decreases its lifespan and increases the power loss due to heating .In this project, an alternative multi-input rectifier structure is proposed for hybrid wind/solar energy systems. The proposed design is a fusion of the Cuk converter.

8. Shu-Hung et al (2003) The methodology is based on connecting a pulse-width-modulated (PWM) DC/DC SEPIC or Cuk converter between a solar panel and a load or battery bus. The converter operates in discontinuous capacitor voltage mode whilst its input current is continuous. By modulating a small-signal

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sinusoidal perturbation into the duty cycle of the main switch and comparing the maximum variation in the input voltage and the voltage stress of the main switch, the maximum power point (MPP) of the panel can be located. The nominal duty cycle of the main switch in the converter is adjusted to a value, so that the input resistance of the converter is equal to the equivalent output resistance of the solar panel at the MPP.

III. PROPOSED METHODOLOGY AND DISCUSSION

DC-DC CONVERTERS

DC-DC converters can be used as switching mode regulators to convert an unregulated dc voltage to a regulated dc output voltage. The regulation is normally achieved by PWM at a fixed frequency and the switching device is generally BJT, MOSFET or IGBT.

Cuk converter

The Cuk converter is a type of DC-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It provides the negative output voltage. This converter always works in the continuous conduction mode. The Cuk converter operates when M1 is turned on, the diode D1 is reverse biased, the current in both L1 and L2 increases and the power is delivered to the load. When M1 is turned off, D1 becomes forward biased and the capacitor C1 is recharged.

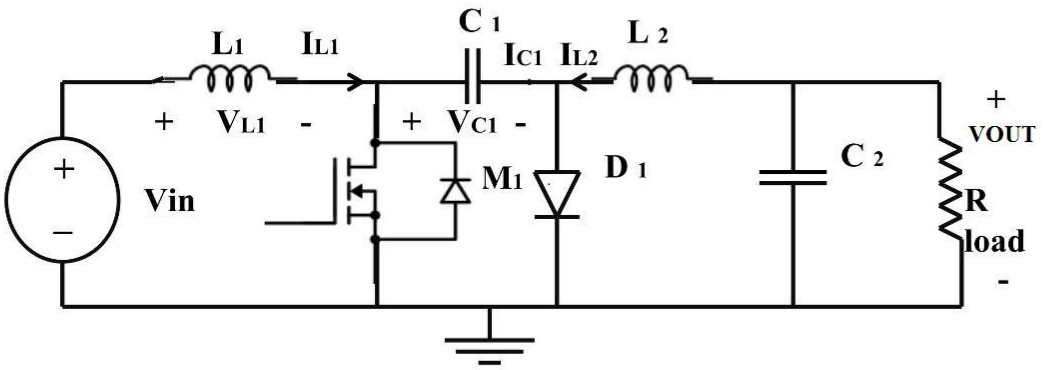

Figure1: Cuk converter

SEPIC converter

Single-ended primary-inductor converter (SEPIC) is a type of DC-DC converter allowing the voltage at its output to be greater than, less than, or equal to that at its input. It is similar to a buck boost converter. It has the capability for bothsteps up and step down operation. The output polarity of the converter is positive with respect to the common terminal. The capacitor C1 blocks any DC current path between the input and the output. The anode of the diode D1 isto a defined potential.

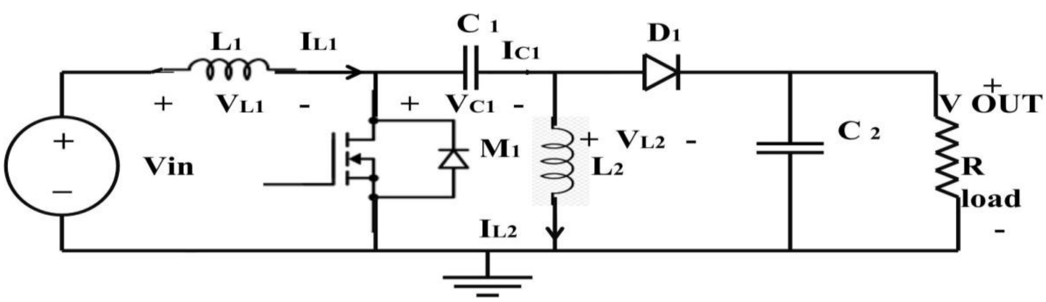

Figure 2: SEPIC Converter

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When the switch M1 is turned on, the input voltage, Vin appears across the inductor L1 and the current IL1 increases. Energy is also stored in the inductor L2 as soon as the voltage across the capacitor C1 appears across L2. The diode D1 is reverse biasedduring this period. But when M1 turns off, D1 conducts. The energy stored in L1 and L2 is delivered to the output, and C1 is recharged by L1 for the next period.

IV. EXPERIMENTAL RESULTS

In order to eliminate the problems in the stand-alone PV and wind system and meeting the load demand, The only solution to combine one or more renewable energy sources to meet the load demand. so the new proposed input side converter topology with maximum power point tracking method to meet the load and opt for grid connected load as well as commercial loads. The implementation of new converter topology will eliminate the lower order harmonics present in the hybrid power system circuit.

BLOCK DIAGRAM

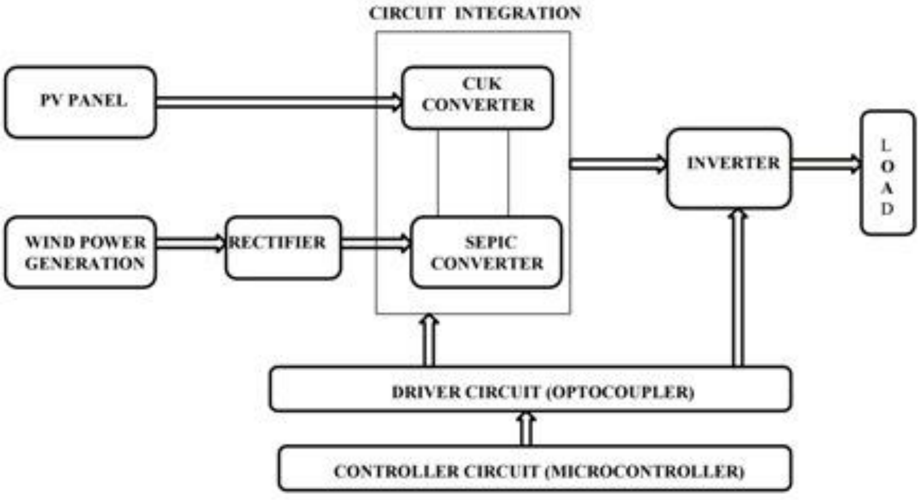

Figure 3: Block diagram of Hybrid system

CIRCUIT DIAGRAM

PV array is the input to the Cuk converter and wind source is the input to the SEPIC converter. The converters are fused together by reconfiguring the two existing diodes from each converter and the sharing the Cuk output inductor by the SEPIC converter. This configuration allows each converter to operate normally individually in the event that one source is unavailable. When only wind source is available, the circuit operates as a SEPIC converter. When only PV source is available, the circuit acts as a Cuk converter.

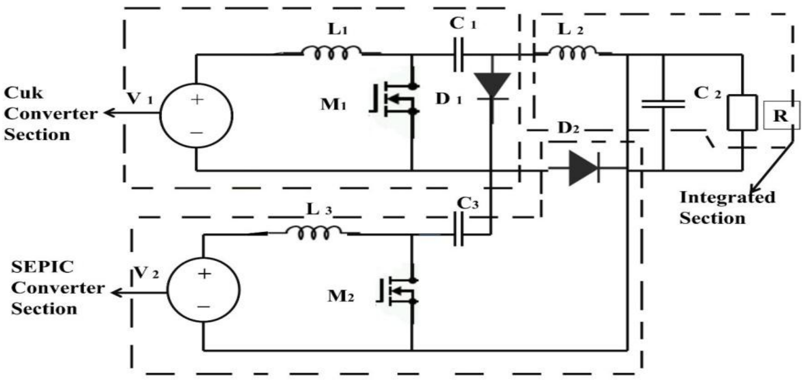

Figure 4: Converter topology for the hybrid system

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MODES OF OPERATION OF THE CONVERTER TOPOLOGY

MODE 1: WHEN M2 IS ON AND M2 IS OFF (SEPIC OPERATION)
When M2 is on condition, in the hybrid system, Wind energy will meet the load by a SEPIC converter operation. The wind energy will produce the Ac power, the Ac power further converted to dc power by using the rectifier. The converted dc power will stored in battery, and feed the load. Normally the SEPIC converter will triggered at 50% of the duty cycle to meet the load demand.

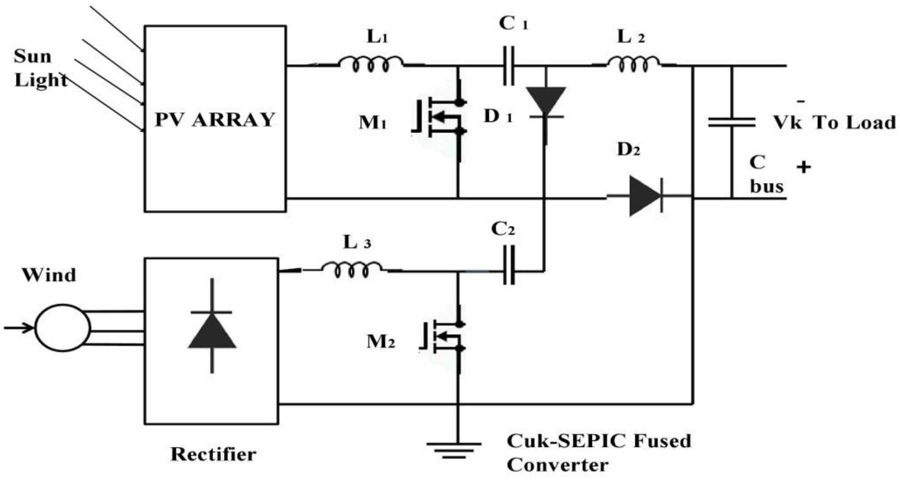

Figure 5: Mode 1-Cuk operation

MODE 2: WHEN M1 IS ON AND M2 IS OFF (CUK OPERATION)
When M1 is on condition, in the hybrid system, solar energy will meet the load by a Cuk converter operation. The solar energy will produce the dc power; the dc power will stored in battery, and feed the load. Normally the SEPIC converter will triggered at 50% of the duty cycle by using the maximum power point tracking controller to meet the load demand.

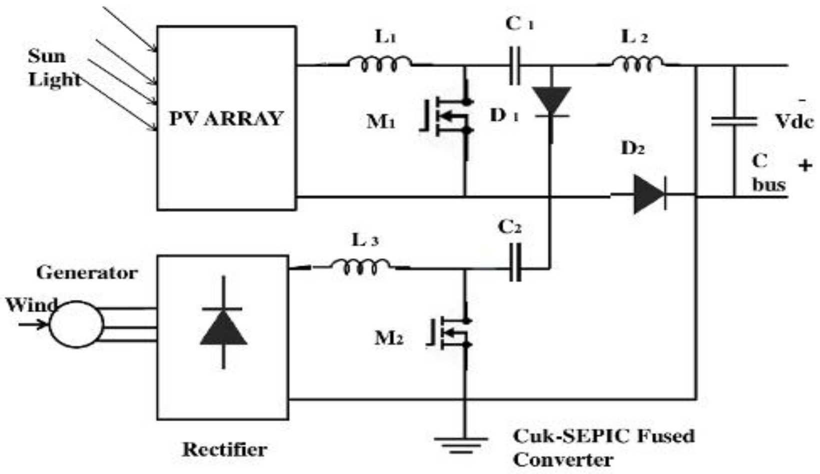

Figure 6: Mode 2-Cuk operation

BOTH WIND AND PV SOURCES
If the turn on duration of M1 is longer than M2, then the converter operates in state I, III and IV and if the turn on duration of M2 is longer than M1, then the converter operates in state I, II and IV. To provide a better explanation, the inductor current waveforms of each switching state are given as follows assuming that d2 >d1; hence only states I, III,

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IV are discussed in this example. In the following, Ii, PV is the average input current from the PV source; Ii, W is the RMS input current after the rectifier (wind case); and Idcis the average system output current. The key waveforms that illustrate the switching states in this example are shown in Figure 6. The mathematical expression that relates the total output voltage and the two input sources will be illustrated in the next section.

The experimental set-up shows that, the input voltage of Cuk converter is 12 V and the output voltage is 34 V. The SEPIC converter input voltage is 10 V and the output voltage is 32 V. while combining the Cuk and SEPIC converter, the input voltage is 22 V and the output voltage is 40 V.

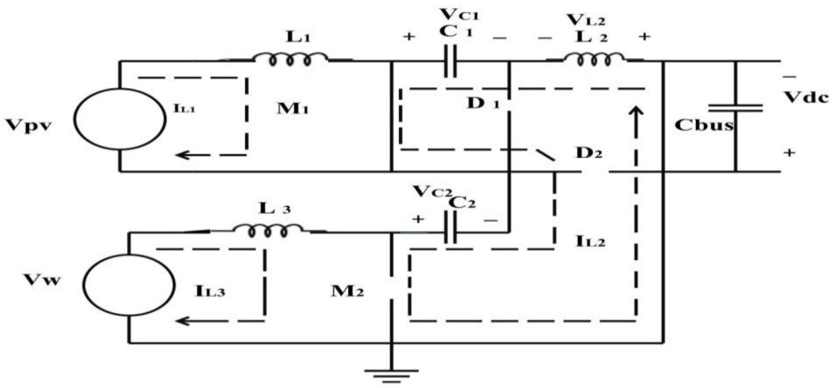

Figure 7(a): M1 ON, M2 ON

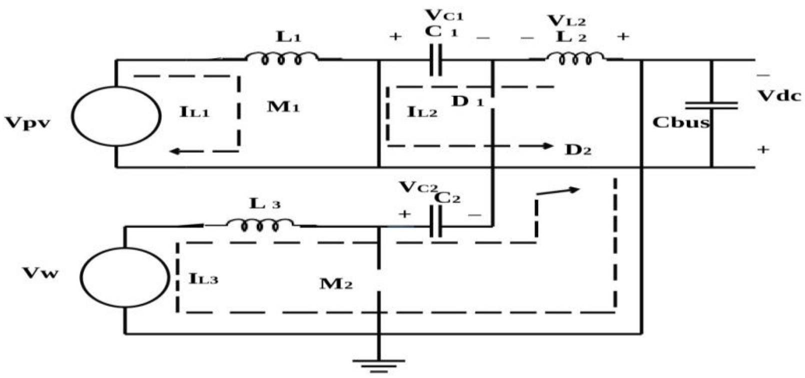

Figure 7(b): M1 ON, M2 OFF

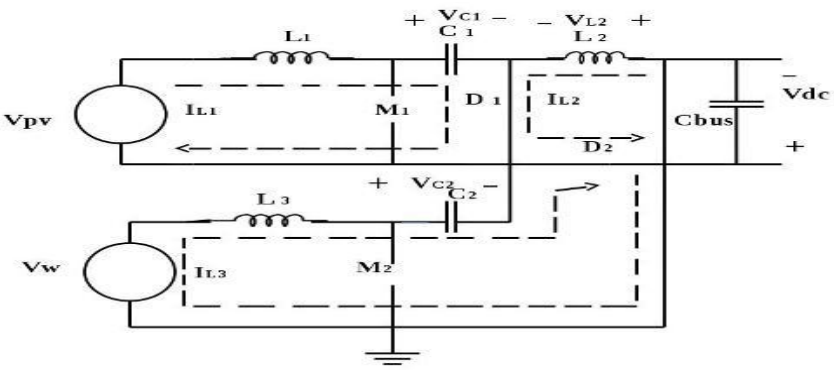

Figure 7(c): M1 OFF, M2 OFF

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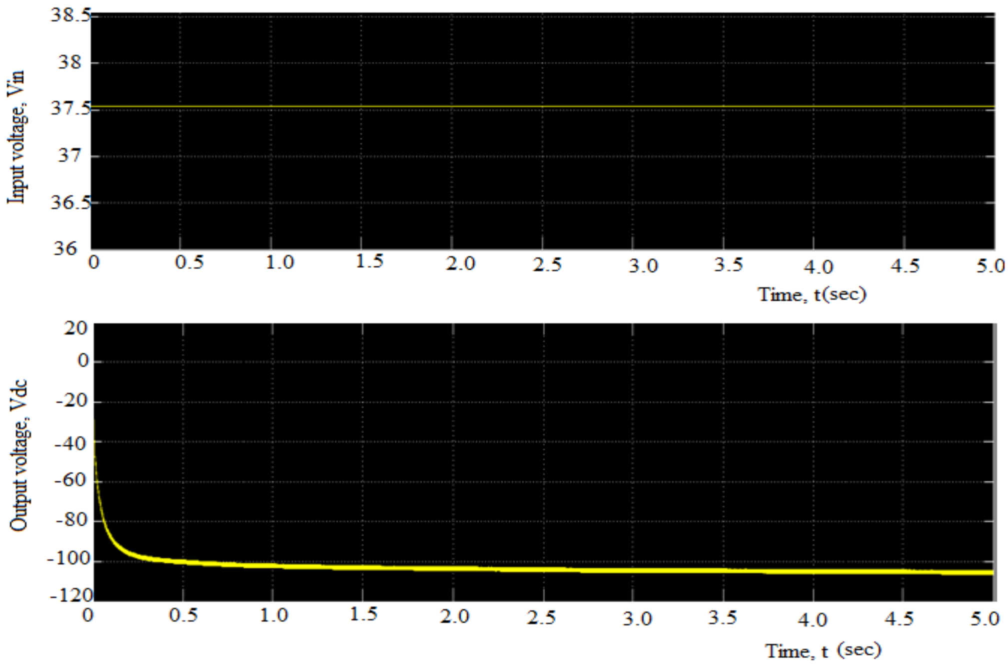

Figure 8 Matlab Simulation results of Hybrid System

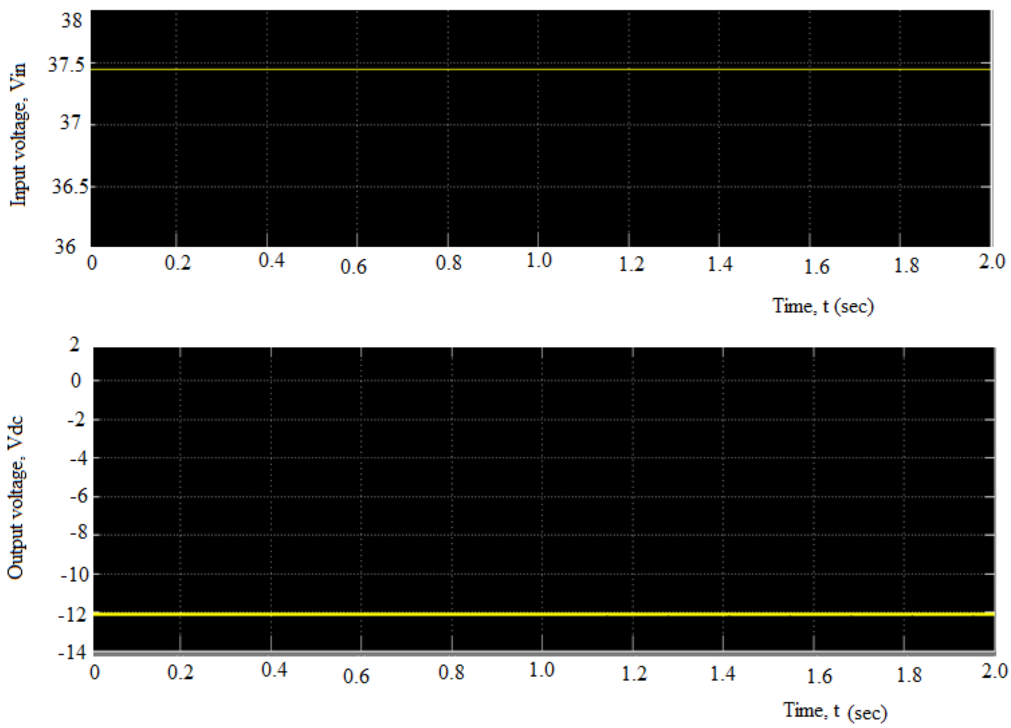

Figure 9: DC Output voltage Waveform of Solar Energy System in Boost mode

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V. CONCLUSIONS

In this work, a new multi-input Cuk-SEPIC rectifier stage for hybrid wind/solar energy systems has been presented. It can support step-up/step down operations for each renewable source. Both converters are efficiently used to improve system efficiency and voltage profile improvement. Additional input filters are not necessary to filter out high-frequency harmonics. Here MPPT can be realized for each source. Individual and simultaneous operation is supported. The approach of varying complexity and current sharing performance has been proposed. The advantage of a parallel-connected power supply is low component stress, increased reliability, ease of maintenance and repair, thermal management. The presence of current sharing loop has been clearly proved for achieving good performance in the paralleling of these converters.

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