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Integration of CUK and SEPIC Converters for Hybrid Renewable Energy Systems

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Abstract

This paper proposes a modified converter topology for the wind and solar hybrid system. For the hybrid system, extracting as much energy from the wind and solar as possible, and feeding the load with less distorted sine wave are the two main targets. In this topology instead of using separate converters for two sources it uses combined DC-DC converter for wind and solar source i.e. both converters are made to share the single inductor and capacitor on the output side. So those numbers of passive components get reduced. By this configuration two sources can supply the load separately or simultaneously, depending on the availability of the sources. The implicit nature of this converter is that additional input filters are not necessary to filter out high frequency harmonics, as CUK and SEPIC converters can filter out harmonic contents in a better way and can produce efficient outputs. Performance of separate and combined systems is analyzed by using MATLAB /Simulink.

Keywords: Cuk converter, SEPIC converter , Solar- Wind hybrid system,

Reviewed by* **ICETSET'16 *organizing committee*

1. Introduction

II. DC-DC CONVERTERS

A. Cuk Converter

The Cuk converter is a type of DC-DC converter that has an output voltage eminence that is either exceeding or fewer than the input voltage magnitude. It has the capability for both step down and step up operation[1]. This converter consistently works in the continuous conduction mode.

The output polarity of the converter is negative with corresponding to its common terminal. The Ćuk converter Contrive via capacitive energy transfer. When M is turned on, the diode D is reverse biased, the current in both L1 and L2 increases, and the power is delivered to the load.

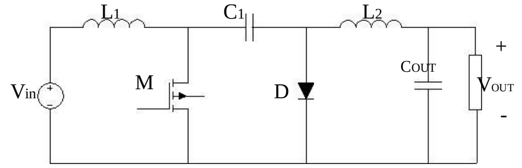

Fig.1.CUKConverter

When M is turned off, D becomes forward biased and the capacitor C1 is recharged. The voltage conversion ratio M_{CUK} of the Cuk converter is given by equation (1):

$$Vo = - Vin[D/(1-D)] \quad (1)$$

B. SEPIC converter

Single Ended Primary Inductor Converter (SEPIC) is a type of converter, performs DC-DC conversion and it makes the voltage magnitude at its output to be exceeding, fewer, or same as its input. Its operation is similar to a buck boost converter. It has the capability to operate in step up and step down modes[12]. The output polarity of the SEPIC converter is positive with respect to its common terminal

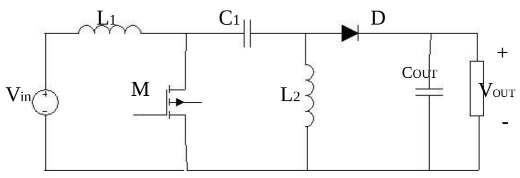

Fig.2.SEPICConverter

The capacitor C1 blocks any DC current path between the input and the output. The anode of the diode D is connected to a described potential[16]. When the switch M is turned on, the input voltage Vin appears across the inductor L1 and the current IL1 across that inductor rises. Energy is also stored in the inductor L2 as soon as the voltage across the capacitor C1 appears across L2. The diode D is reverse biased during this period. But when switch M turns off, D will conduct. The energy stored in L1 and L2 is delivered to the load and C1 is recharged by L1 for the next cycle of operation. The voltage conversion ratio M_{SEPIC} of the SEPIC converter is given by:

$$Vo = Vin[D/(1-D)] \quad (2)$$

III. RENEWABLE ENERGY SOURCES

A. Pv Array

In PV system the output voltage is a constant DC and its magnitude depends on the composition in which the solar cells/modules are coupled. On the same way, the current output of the PV system mainly lean on the available solar irradiance[7]. The main concern of power electronic interfaces for the PV systems is to convert the generated DC voltage into a suitable AC for consumer use and utility connection.

The characteristic equation of a solar module is relying on the number of cells connected in parallel and number of cells connected in series[6]. It is ascertained from experimental results that the current variation is less subordinate on the shunt resistance and is more relying on the series resistance.

$$I = Iph - Io[\exp\{qV/kT\} - 1] \quad (3)$$

Where,

Iph = photocurrent,

Io = saturation current,

q = electronic charge 1.6x10-9,

KB = Boltzmann’s gas constant (1.38x10-23), T = cell temperature,

I = cell current, V = cell voltage

B. Wind Energy System

Wind turbines novitiate kinetic energy in the wind into mechanical power that can be again converted into electrical energy by using generator. Power is ordinarily generated either with an induction generator or with a synchronous generator [3]. Induction generators are normally employed on standalone systems and Synchronous generators are typically used where grid connection is possible through power electronics converters[11].

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The basic equation for the power of the wind is given by:

P = (ρACpV3)/λ (4)

Where

P is the power,

ρ is the air density,

V is the wind speed and

Cp is the power coefficient, which describes the fraction of the wind captured by a wind turbine.

IV. DESIGN OF PROPOSED SYSTEM

A hybrid wind-solar energy system is shown in Fig.3. The design incorporates two converters at an output side of the sources [15], where one of the converter inputs is connected to the output of the wind generator and the another converter input is connected to the output of a PV array. An unification of the two converters is rendered by reforming the two existing diode from respective converter and the shared utilization of the inductor on the output side[16] of the CUK converter by the SEPIC converter.

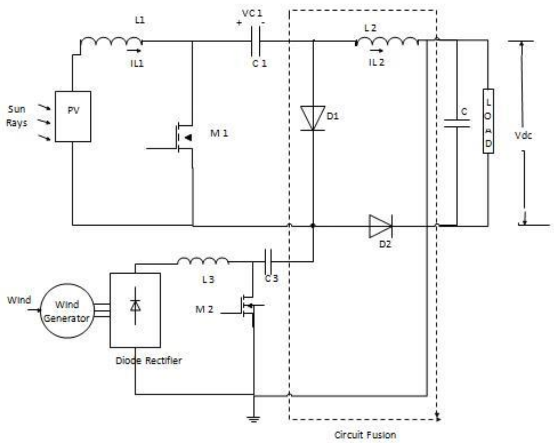


Fig.3. Circuit configuration with integrated converter

When only wind source is available, the circuit works as a SEPIC converter and the voltage conversion relationship is given by:

$$\frac{v_{dc}}{v_w} = \frac{d_2}{1-d_2} \tag{5}$$

When only PV source is available, the circuit acts as a Cuk converter and the voltage conversion is given by:

$$\frac{v_{dc}}{v_{pv}} = \frac{d_1}{1-d_1} \tag{6}$$

A. Operating States- State I (M1 & M2 on)

$IL1 = IPV + VPV/L1\ t, (0 < t < d1\ Ts)$ (7)

$IL2 = Idc + (Vc1+Vc2 /L2)\ t, (0 < t < d1\ TS)$ (8)

$IL3 = IW + Vw /L3\ t, (0 < t < d1\ Ts)$ (9)

B. State II (M1 on, M2 off)

If only the PV source is available, then diode D1 turns off and D2 will be on[16]. In this case the circuit becomes a Cuk converter as shown in Fig. 1. The input to output voltage relationship is given by equation (1). In this case, both step-up/down operations are possible.

C. State III (M1 off, M2 on)

$IL1=IPV+((VPV-Vc1)/L1)\ t\ (d1Ts < t < d2Ts)$ (10)

$IL2 = Idc\ (Vc2/L2)\ t, (d1Ts < t < d2Ts)$ (11)

$IL3= IW+(Vw/L3)\ t, (d1Ts < t < d2Ts)$ (12)

D. State IV (M1 & M2 off): (13)

$IL1 = Ipv+((VPV- Vc1)/L1)\ t, (d2\ Ts < t < Ts)$(14)

$IL2 = Idc – (Vc2/L2)\ t, (d2\ Ts < t < Ts)$

$IL3 = IW +(Vw-Vc2-Vdc)/L3)t, (d2\ Ts< t< Ts)$

VI. RESULTS

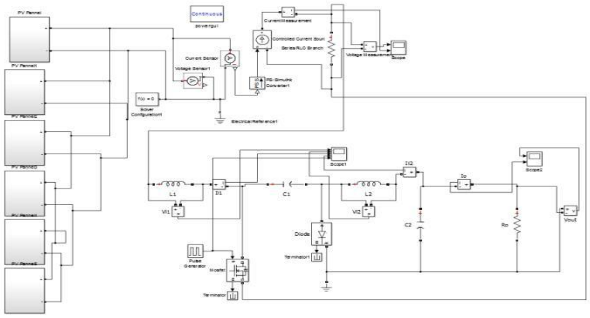
In this section, simulation results from MATLAB is given to verify that the proposed rectifier stage can support standalone as well as integrated operation.

A. Simulation result of PV array with CUK converter

V. SIMULINK MODELS

A. Model of PV array with cuk converter

PV cell is given as the input to the Cuk converter. It is designed for an input voltage of 34V. Fig. 4 shows the Simulink model of PV cell fed Cuk converter[15].



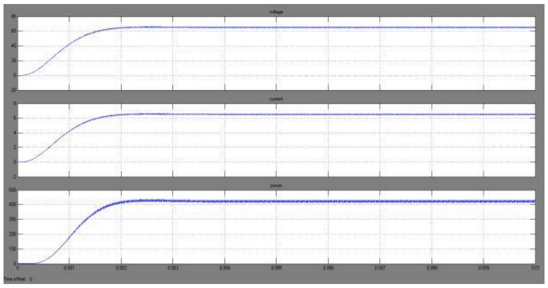


Fig.6.output waveform of PV with CUK converter

Figure 6 manifests the system under the condition where only the PV source (Cuk converter mode) is supplying power to the load and wind source is unavailable. Curve shows the current, voltage and power waveforms corresponding to time and with the input of 34v, Cuk converter gives the output of 60v.

B. Simulation result of wind turbine with SEPIC converter

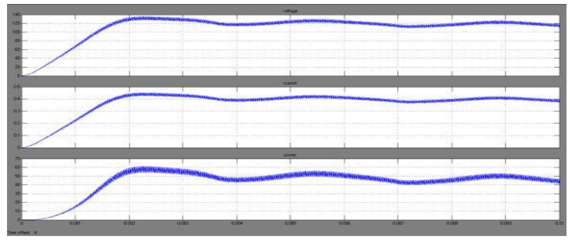
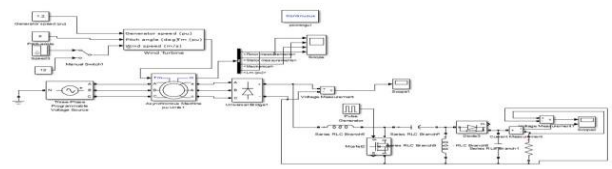


Fig.4. Simulink model of PV array

B. Model of wind turbine with SEPIC converter



C. Simulation result of integrated converters:

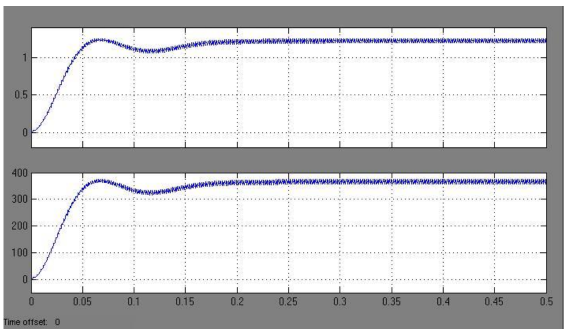


Fig.8.output waveform of integrated converter

Figure.8. manifests the system condition where both sources are available. Here system operates in an integrated mode and both the converter will supply the load[10]. Likewise in standalone mode its output is also high, so that with reduced number of passive elements same output can be obtained.

VII. CONCLUSION

In this paper hybrid system of solar and wind is implemented with a combination of two converters. These converters made the system more reliable and stable, because most of the renewable systems are unstable ones. Results of the systems are analyzed in both standalone and combined manner, so that it provides better results. Here the main aid is that number of passive components needed for this topology is less, compared to the separate converters. This system finds application in electrification of rural areas and variable speed conversion systems.

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